Theoretical Contribution towards an Environmental Marker Systemized By a Pressure, State, and Response Model in the Management of Urban Rivers

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Abstract

The way which hydric resources are managed has been degrading water sources to a point it jeopardizes the quality of life of the populations, presenting an impending risk of water shortage even where water abounds. In the present work a proposal of methodological models to guide the assessment and monitoring of revitalization programs of urban rivers through sustainability markers linked to the pressure, state, response (PSR) method is presented. The methodological procedures included literature review and selection/proposal of selected parameters. After thorough analysis of the relevant factors over urban rivers concerning effective environmental management an environmental dimension with three subjects (indicators) fully characterized in name, definition, importance, measurement mechanism, unity of measurement, frequency of data collection and adjustment to the PSR model. The aforementioned models allow the assessment and monitoring of public programs and policies that aim to endorse practical actions towards environmental sustainability in the surface hydric clean urban resources.

Keywords: Environmental indicators, PSR Model, Surface waters

1. Introduction

The term indicator derives from the Latin word *indicare*, a verb that means to point at something. In Portuguese, the researcher's mother tongue, indicator means that which points out, makes something evident, reveals, proposes, suggests, exposes, mentions, counsels, reminds. In the present document, indicator is understood as an instrument that allows one to measure modifications in the characteristics of a system. Sustainability indicators are important and efficacious instruments to environmental management, and in such matter urban rivers, although highly degraded, constitute an essential area to a city, thus making their recovery and preservation paramount. Therefore, the theoretical-methodological proposal of an indicator system should steer towards analytic categories which consider the perspective of the revitalization of the environmental and social role of urban rivers, build from a cooperative and interdisciplinary model (Maia *et al.*, 2001).

According to Nahas (2002) and Jannuzzi (2002), the employment of indicators allows assessing a particular aspect of reality, attributing numerical values to the assessed object. In this perspective, indicators are instruments of quantification of variables, turning them into something measurable and making their understanding easier. Garcias (2001) has contributed to the aforementioned ideas by stressing out that the indicators magnitude variables should be individualized to each case study so as to stablish the degree of significance in their oscillations in each specific context. Methodologic proposals over this subject are not often demanded in national and international level, let alone in local scale, although it is known that they are essential for they require and produce information that allows quality of life management in such scale.

It can be perceived through this initiative, that the most distinct methodological proposal both nationally and internationally is the Pressure-State-Response (PSR) method and its derivations (Quiroga, 2001). This model was originally developed by the Organization for Cooperation and Economic Development – OCDE, in the 90's, which is based on the idea of causality between three kinds of indicators: (a) Pressure indicators which characterize the pressures applied over environmental systems that can be translated into indicators of contaminants' rate of emission, technological efficiency, territorial intervention and environmental impact. The indicators of pressure describe the pressure exerted by the human activities over the environment and natural resources. "Pressures" are here understood as those who are underlying or indirect (in other words, the activity itself and the environmentally relevant trends toward it) as well as the immediate and direct (meaning the employment of resources and the disposal of waste and residues) actions; (b) State indicators which translate into the quality of the environment at a given time/space horizon, i.e. indicators of sensitivity, risk and environmental quality. Such indicators reflect the final objective of environmental policies and aim to provide a global vision over the environment and its evolution throughout time. Indicators that belong in this group are the concentration of pollutants in diverse environments, the excess of citric charges, and population exposure to certain levels of pollution or to a degraded environment, the state of fauna and flora, as well as the amount of natural resources reserve.

In practice, the measurement of environmental conditions can turn out to be either highly difficult or expensive; therefore, the pressures over the environment are often used as substitutes; (c) Response indicators assess the response from the society to changes and environmental concerns as well as adhesion to programs and/or the implementation of measures towards the environment. It can be included in this category the social adhesion indicators, awareness and important social group activities. The indicators of response from the society show to what degree society answer to environmental issues does. They report to individual and collective actions and reactions aiming to mitigate or avoid the negative effects of human activity over the environment, or to adapt to such; to impose limits to the already inflicted degradation to the environment or to lessen their effects; to protect and preserve the nature and its resources. Some of the indicators are: resources applied to the protection of the environment, price setting, market representatives of goods and services which are respectful to the environment, the rates of pollution level reduction and recycling of wastes. Such indicators concern mostly the measures employed to fight pollution for it is hard to obtain indicators over measures of prevention.

While state indicators aim to describe the current situation, either physical or biological, of the natural systems, pressure indicators try to measure/assess the pressures exerted by human activity over the natural systems and response indicators aim to assess the quality of policies and deals made to respond to/minimize human impacts (Herculano, 1998). The PSR model is based on the idea that human activities exert pressure over the environment thus affecting the quality and quantity of natural resources (state); society then responds to such changes, adopting environmental, economic and sectoral policies, increasing awareness of the changes occurred and adapting their behavior (societies' response). Such model has the advantage of evidencing these links and helping the decision makers and the general public to realize the interdependence between the environmental questions and other aspects (not forgetting, however, that there are more complex relationships within ecosystems and the environment-society interface).

The PSR can be easily tailored to requirements of higher precision or particular traits depending on which objective is intended. Among the advantages of PSR are its simplicity, ease of application, the evidence of interdependence, and the categorization of environmental, economic, or social indicators according to their position in the causal chain. This causality refers to the reckoning that (1) human activities linked to the production and consumption pattern, which reflect the intensity of the use of resources, can generate, direct or indirectly, ecological problems; in other words, pressures over the environment and natural resources; (2) the society assess the biophysical phenomena which reflect the environmental conditions, that is, assess the quality or the state of the environment where ecosystem, natural and urban environment, quality of life and human health resulting from the impact of such pressures, including amount and quality of natural resources; (3) as a result of this assessment the decision makers, in several levels of society, develop corrective or preventive actions, under the form of environmental, economic and social policies which include awareness increasing actions towards gradual change of social behaviors, that is, implementing adequate social responses to prevent, mitigate or eliminate the pressures and either control or reverse the current state (Esi, 2002). Such model, however, might lead to a linear logic and the simplification of questions, demanding an analysis process that carries along elements of the underlying complexity.

This model (Fgv, 2000) is already well established and has been used in several countries and different organizations/institutions that work with this subject. It is significant to stress out that it may leave the complexity of the subject at bay, demanding a process that includes such analysis. This systematization outline that allows environmental indicators to be structured in distinct categories, according to their direct or indirect relationship with: (a) the causes or sources of pressure exerted by society (human activities) over the environment; (b) the identification/characterization of the state of the environment due to those pressures or (c) the responses of society to reverse or control the identified environmental issues.

The purpose of this work was proposing a theoretical/methodological model that allows the global comparison of alternatives for urban rivers management with the current intervening indicators, besides the purely technical-hydrologic criteria, which could guide evaluation and monitoring of urban river revitalization programs

1. Theoretical-Methodological Proposal

A consideration must be made over the analytic cohort debated in this work: the superficial urban hydric systems (urban rivers). It is clear that rivers are understood as a part of an extremely complex system that can be defined territorially by the water basin which is completed by the climate elements and underground waters; such complexity is not forfeit, neither is the knowledge that the complete management of hydric systems involves an intrinsic relationship with surface and underground waters. It is also known that the conclusions of this paper will only illustrate a facet of reality, thus justifying a posterior complementation of data. With the purpose of limiting the study subject, the proposed system does not comprehend all the factors and elements that compose a water basin.

The methodological procedures included the steps of literature review and proposition of the parameters related to the sustainability of urban rivers. After weighting the relevant factors concerning the assessment and monitoring of urban rivers revitalization programs, four dimensions were selected and established, with 10 themes and 31 subthemes (indicators) of greater relevance (data not presented) and were characterized in the PSR (pressure, state, response) model. Taking the proposal of sustainability of clean urban rivers into account, a representative of each kind of the PSR model was selected, from those presented in Board 1, setting grounds for the methodological method proposed.

Board 1: Dimensions, Themes, Most Relevant Subthemes, Type (Characterization In The PSR Model) Of the Clean Urban River Indicators – CURI Proposed

Themes	Subthemes	Type
	ENVIRONMENTAL DIMENSION	
WATER	**W**ater **C**onsumption *per capita* **– WC**	Pressure
	Availability of **S**uperficial **W**aters – **ASW**	State
	Investment and **E**xpenses in the environmental **P**reservation of Fresh**w**ater systems – **IEPW**	Response
DRAINAGE	**O**verall **P**ollution – **OP**	Pressure
	Flooding **A**reas **– FA**	State
	Reuse of **P**recipitation **W**ater – **RAP**	Response
SEWAGE	**P**opulation **U**nassisted by the **S**ewage **N**etwork **- PUSN**	Pressure
	River **D**ilution **C**apacity – **RDC**	State
	Population **A**ssisted by waste **W**ater **T**reatment – **PAWT**	Response
SOLID WASTE	**W**aste **P**roduction– **WP**	Pressure
	Incidence of **F**loating **W**aste in **R**ivers–**IFWR**	State
	Quantity of Waste to **R**euse, **R**ecycle e **R**eutilize – **QRRR**	Response
	SOCIAL DIMENSION	
EDUCATION	**I**lliteracy **R**ate – **IR**	Pressure
	Human **D**evelopment **I**ndex – **HDI**	State
	Environmental **E**ducation – **EE**	Response
POPULATION	**S**ociety **E**nvironmental **A**wareness **- PAS**	Pressure
	Demographic **D**ensity – **DD**	State
	Society **O**rganization towards adhesion to River **R**evitalization **P**rograms – **SORV**	Response
HEALTH	**I**ncidence of **W**ater **b**orne **D**iseases –**IWBD**	Pressure
	Incidence of **I**nfectious **D**iseases – **IID**	State
	Disease **E**radication **P**rograms–**DEP**	Response
	ECONOMIC DIMENSION	
ECONOMY	**G**ross **D**omestic **P**roduct – **GDP**	Pressure
	Population **I**ndictment –**PI**	State
	Investment and **E**xpenses related to environmental **P**rotection and **M**anagement– **IEPM**	Response
ENERGY	**E**nergy **C**onsumption – **EC**	Pressure
	Vehicle **C**irculation – **VC**	State
	Incentive **P**rograms toward consumption of **A**lternative **E**nergy sources–**IPAE**	Response
	INSTITUTIONAL DIMENSION	
INSTITUTION	**U**rban **D**rainage **M**anagement **S**trategy – **UDMS**	Response
	Solid **W**aste **M**anagement **S**trategy – **SWMS**	Response
	City **S**trategy on **U**rban **D**evelopment– **CSUD**	Response
	City **S**trategy on **B**asic **S**anitation– **CSBS**	Response

Source: Own authorship (2016)

And so, based on Board 1, the proposed methodological method is presented as it follows, in Equation 1:

$$CURI = \sum_{i=1}^{n} (fiDi)$$

(Eq. 1)

Where:

CURI = Clean Urban Rivers Indicators
D = dimension
f = weight of the dimensions
i = number of stipulated variables

Considering i = 4 dimensions, the equation expands as it follows in Equation 2:

$$\mathbf{CURI = f_1D_1 + f_2D_2 + f_3D_3 + f_4D_4} \qquad \textbf{(Eq. 2)}$$

Replacing the four dimensions with their respective weights Equation 3 is achieved:

$$\mathbf{CURI = 0{,}40D_{Env} + 0{,}30D_{Soc} + 0{,}20D_{Econ} + 0{,}1D_{Inst}} \qquad \textbf{(Eq. 3)}$$

Where:

CURI =Clean Urban Rivers Indicators
D_{Env} = Environmental Dimension
D_{Soc} = Social Dimension
D_{Econ} = Economic Dimension
D_{Inst} = Institutional Dimension
f = weight of the dimensions, taking into account the amount of themes (Board 1) in each dimension (4, 3, 2 and 1, respectively).

Presenting the Environmental Dimension (Board 1) themes as an example, Equation 4 is achieved as it follows:

$$\mathbf{D_{Env} = f_1t_{water} + f_2t_{drainage} + f_3t_{sewage} + f_4t_{waste}} \qquad \textbf{(Eq. 4)}$$

Substituting in Equation 3 the Equation 4 with the respective factors (weights), Equation 5 is obtained:

$$\mathbf{CURI = 0,\ 40[0{,}10t_{water} + 0{,}10t_{drainage} + 0{,}10t_{sewage} + 0{,}10t_{waste}]} \qquad \textbf{(Eq. 5)}$$

Each theme represented in Equation 5 possesses subthemes (indicators) which are in presented in Board 1. Water was selected as theme in our example, which leads to:

$$\mathbf{t_{water} = (0{,}04P_{WC} + 0{,}02S_{ASW} + 0{,}04R_{IEPW})}$$

Thus, making the corresponding substitution in Equation 5, Equation 6 is achieved:

$$\mathbf{CURI = 0,\ 40[0,\ 10(0{,}04P_{WC} + 0{,}02S_{ASW} + 0{,}04R_{IEPW})]} \qquad \textbf{(Eq. 6)}$$

2. Detailiing the Water Dimension and the Water theme

The environmental dimension of the clean urban rivers indicators comprehends the usage of natural resources and environmental dilapidation and its related to environmental preservation and conservation goals, considered fundamental to the benefit of future generations. The detailing (name, purpose, responsible for the information, calculi, unity of measurement, update schedule, relationship with other indicators and adjustment to PSR model) of the subthemes (indicators) chosen for the given theme, Water, according to Board 1 and Equation 6 are as it follows:

2.1. Water Consumption per capita – WC

Purpose: amount of water which is consumed by each inhabitant of a given area, whenever feasible divided into the main types of user, namely domestic, industry, and farming. The existence of adequate amounts of water to a human daily needs is one of the prerequisites to existence, health and human development. It has been verified that when progress happens on development levels the water consumption is also increased. Therefore, this indicator can act as an indirect measure of socioeconomic development levels.

Institutions responsible for the information: system operators (city hall, third party companies). National Water Department, Local Environmental Directories, Ministries of Agriculture, Rural Development, and Fishing, National Statistics Institute.

Calculation: It is defined as the consumption which is categorized according to the specificities of each enterprise. Its importance resides within the fact that it allows adequate planning over the usage of surface waters available in the rivers. Its measuring takes into account the estimate water consumption using parameters of consumption targeting specific activities. Direct determination from the domestic consumption from the supply networks is also employed.

A gross estimate can also be done based on the total amount of water which is supplied to a given population agglomerate divided by the number of inhabitants of given area or even through local sampling.

Unity of measurement: liters/inhab/day

Frequency of data update: annual

Relationship with other indicators: Availability of Surface Waters – ASW

Category in the PSR model: pressure

2.2. Availability of Surface Waters – ASW

Purpose: Annual volume of water which circles in the hydric network that can be employed in human activities and diverse ecologic functions. The existence of amounts of adequate water to human necessities is one of the prerequisites for human existence, health, and development.

Institutions responsible for the information: National Water Agency

Calculation: This parameter is defined as the individualized flow rates of the river springs, of utter importance to understand the dynamic of water availability related to the rainfall rates across the year. The measurement mechanic consists in measuring each spring's flow rate through a direct method. The United Nations have proposed a method that aims to assess the availability of water resources based on the gross water volume (underground and surface) which was extracted and comparing it with the average yearly value of available water for specific uses (domestic, industrial and agriculture)

Unity of measurement: m^3/s

Frequency of data update: annual

Relationship with other indicators: Human Development Index

Category in the PSR model: state

2.3. Investment and Expenses in the environmental Preservation of Freshwater systems – IEPW

Purpose: To assess the expenses and investments of public and private sectors in environmental preservation of urban rivers. This indicator provides a generic indication of the financial efforts towards environmental preservation and in defense of rivers a country makes. This assessment's efficacy is increased when related to other environmental variables, for high figures depicted in this indicator can reveal a trend towards fading quality in this section or a quality improvement.

Institutions responsible for the information: National Water Agency; Nature Conservation Institute; National Statistics Institute

Calculation: Should be divided in three categories whenever feasible, namely: i) infrastructure investments; ii) exploration and maintenance expenses; iii) investigation expenses. One of the limitations associated with this indicator resides within the comprehension limits, that is, the calculation processes is subject to either including only the activities of more direct character towards river quality preservation or including also more indirect activities such as the investigation programs, among others. Therefore, it is often hard to perform credible comparisons of this indicator if the calculation database is unknown.

Frequency of data update: annual

Relationship with other indicators: Gross Domestic Product

Category in the PSR model: response

3. Considerations

Using the three items of the Water theme as an example, replacing the items for their numerical value, we achieve:

a) Average consumption, lowest rate admitted = 200 liters/inhab/day
b) Availability of water during the drought season = $32m^3/s$
c) Annual Investment = USD $500x10^6$

$$\textbf{CURI = 0, 4 [0, 10 (0,04}P_{WC} + 0{,}02S_{ASW} + 0{,}04R_{IEPW})] \qquad \textbf{(Eq. 6)}$$

CURI = 0, 40 [0, 10 (0, 04 x 200 liters/inhab/day + 0, 02 x 32 m3/s + 0, 04 x USD 500 x 106/year)]
CURI = 0, 40[0, 10 (0, 04 x 200 liters/inhab/day + 0, 02 x 2.764.800 m^3/day + 0, 04 xUSD 1.369.863/day)]
CURI = 0, 40[0, 8 liters/inhab/day + 5.529,6 m3/day + USD 136.986, 3/day]
CURI = 0, 32 liters/inhab/day + 2.211,84 m3/day + USD 54.794, 52/day

The model proposes that the pathway to the sustainability of water bodies, especially the surface ones, lays heavily on dimensions and principles that guide the management through indicators with urban specificity and related to the role of rivers. In this case, it indicates that for an availability of 2,211.84 m^3 of surface water/day a sum of USD 54,794.52/day is required, plus each inhabitant should consume 0, 32 liters of water in order to maintain urban rivers clean.

Urban water bodies monitoring through time is one of the goals, as well as the comparative analysis with other areas so that sustainability routes may come out and thus help in environment management without spoiling it in order to maintain it for the generations to come: harmonizing the actual usage, the maintenance of its functions for the future, improvement of quality where the usage has impaired it and the protection of such water. The existing indicators comprehend short/mid-term events in general, and the national scale is generally preferred whereas data obtaining proves difficult most of the time. The lacking of systematic data and the difficulty to compare the ones produced from different sources/methodologies are an everlasting problem to those who work with environmental indicators. Therefore, the proposed system focuses on the surface urban rivers, but takes into account the context of the water basin. This methodological option carries with it some research limitations, which, on the other hand, are not considered to invalidate the proposal, mainly because the complementation of the data could come in the near future.

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