Construction of indicators systems tool for making decision to related stormwater management problems

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ABSTRACT: Large part of volume of water that reaches the river and drainage systems comes from runoff due to the waterproofing process of urban space and paving the riverbeds and streams. The management of cities should take into account the sustainability and for this, the indicators are important tools to aid decision making, use and land occupation, and thus avoid risk situations related to urban water. For selection of appropriate indicators was used multicriteria methods, based on the principles of sustainability and more sustainable urban drainage processes, such as urban low impact development. These indicators were used for the scenario development, through specific tool for monitoring and decision making of managers and responsible for the management of stormwater. This is the purpose of the design of the Support System for the Sustainable Management of Stormwater - SAMSAP, it is to generate a monitoring tool and decision support. With the use of software can be further expanded the scope of the models to include more variables and test alternatives, can simplify complex phenomena by eliminating everything that can be foreign to what needs to be studied. This tool will be applied experimentally in São Carlos / SP, because it is a city in which problems related to the management of rain waters are recurrent and have several data sources on the topic.

Keywords *Stormwater management, Urban Planning, Indicators of Sustainability, Decision-making tool.*

1. INTRODUCTION

Waters plays an important part in the urban areas, with the needs of service to different demands, questions concerning the quality, availability and flow of stormwater. The vulnerability to storm events in some cities is high, which aggravates poverty in the periphery. The biggest losses are not necessarily material, but social.

The urban water systems are characterized by complex environmental, economic and social interactions, forming delicate structures which are not always adequately assessed in urban developments in its implementation process. Faced with these problems, new approaches to treat urban development have been developed, as widely reported in the technical literature, integrating the principles of sustainability.

The sustainable management of stormwater is rapidly gaining acceptance. The increased interest is a response to the increasing development costs of new projects and infrastructure reconstruction, more stringent environmental regulations and to concerns about the impact of growth on natural resources. The strategy recognizes the relationship between the natural and the built environment, and seeks to manage the components in an integrated manner. The transition to more sustainable stormwater management is a slow process and each country must find its place in this process (Barbosa *et al*, 2012).

Major instruments related to sustainability are the indicators. The main pertinent characteristics to indicators are the ability to assess existing conditions and trends; the possibility of making comparisons in the temporal and spatial scales; the ability to assess conditions and trends in relation to the goals and objectives, the ability to provide warning information and to anticipate conditions and trends.

A Support System Decision -DSS, is an organized set of procedures, software, databases and devices used for support the decision-making related to a specific problem. The objective of most decision support systems is to assist on the topics analyzed in the stages of decision-making process.

The purpose of the design of the Support System for the Sustainable Management of Stormwater - SAMSAP, is to generate a monitoring tool and decision support. Based on sustainability indicators for monitoring issues related to the management of stormwater.

2. BACKGROUND

Even if unconsciously, the act of planning is old, especially the daily activities related to a life in society. According to (Souza, 2006, p21) "The act of planning refers to future actions, trying to predict a certain phenomenon and simulating the evolution of the process in an attempt to prevent the possible problems and difficulties, or enjoy best possible benefits."

From this premise, the emphasis of planning, ceases to be the search for the ideal city for a search for concrete and practical problem solving, establishing control instruments of urban processes over time.

The urbanization process in Brazil printed on regional development a mark characterized by peripheral expansion, the socio-spatial segregation and social and environmental inequality, resulting from the forms of precarious inclusion which were submitted broad layers of society (Maricato, 2001).

Because of erroneous planning methods, the cities of developing countries have a vast range of problems present throughout the urban network. With uncontrolled growth of urban centers, social problems and environmental imbalances increase, pointing to a future with low quality of life and severe environmental degradation (Rossetto, 2003).

The planning is a constant process that must be oriented vision for the future, taking into account the limits, restrictions and potential, and the ability to change direction when necessary and constant evaluation.

The urban water-related activities should be integrated into the own urban planning, including here the design of the urban fabric and its expansion, zoning activities, road and transport network, information flows, landscape features.

Shares located, carried out somewhere along the basin, can be felt kilometers away. All components of river basins are interconnected and rivers are the vectors of this integration. Because of this natural interconnection, watersheds are excellent planning and management units (Tucci *et al*, 2001).

2.1. Stormwater in urban areas

According to Pompeo (2000), in a general way, the floods are natural phenomena that occur periodically in watercourses due to high magnitude rainfall. The floods in urban areas can be caused by these intense rains wide payback period; or due to overflowing water courses caused by changes in the balance in the hydrological cycle in regions upstream of urban areas; or because of the very urbanization.

The impacts caused by floods are growing much due to anthropogenic changes in river basins and the progressive occupation of the natural flood areas. Urbanization changes the hydrologic cycle, changing their plots and the water balance of the basin. The chaotic urbanization associated with inappropriate land use, decreases the natural storage capacity of the run-offs. The solution adopted traditionally aimed at increasing the speed of flow with plumbing works and rectification of water courses (Canholi, 2005).

To Mascarenhas and Miguez (2007) the design of urban drainage should consider some local aspects, becoming only solution, and the replication of some successful experiences in countries, can lead to waste of money, social conflicts and environmental impacts, and solutions do not become effective. Thus, it is necessary to understand the growth and patterns of land use change, with the purpose of defining urban plans and flood controls that consider the environmental, cultural, social economically. Some urban issues and urban flooding common to developing countries are listed below:

• Large population growth in a short period of time;

• urbanization without planning and management;

• Disability in spatial coverage drainage, water supply, sanitation, and infrastructure wastewater treatment;

• Removal and disposal of inadequate solid waste;

• Lack of capacity for investment;

• Plans definition of need and guidelines for the management of urban drainage and qualification of municipal technical staff;

• Conflicts with respect to liabilities;

• legal and illegal occupations of risk areas of floods and landslides;

• Large number of occurrences water related diseases;

• Lack of public education and awareness programs, which often cause damage to flood control structures and have household waste in the streets and river banks.

To Tucci & Porto (2005) urban flooding is a chronic problem in Brazil, mainly due to inadequate project planning and management of drainage. The mistaken thinking reflects the preconceived idea that good drainage is one that allows you to quickly drain the precipitated water. The consequences of these misconceptions is an extremely high impact on society the environment. Thus, better drainage is one that manages the flow, in order to not produce impacts on site or downstream, using methods retention and infiltration of rainwater through more sustainable management techniques.

2.2. Sustainability Assessment

According Ness (2007) sustainable development has been incorporated into various levels of society in recent years. The US National Research Council (NCR, 1999) argues that there are three important components of sustainable development: what is to be sustained, what is to develop, and the inter-generational component. They identified three areas to be sustained: nature, support systems of life and the community. For what needs to be developed bring: people, society and the economy. The inter-generational component is critical because the specific objectives of sustainability must explicitly express the time horizon so that the objectives are achieved.

According Kasemir *et al* (2003) in the transition to a more sustainable situation, the objectives should be evaluated. Research evaluation methods, tools, indicators have shown that the approach can be based on numerous factors or categorized dimensions and thus, the following factors were considered (Ness, 2007):

• **Features of temporality**, that is, the tool evaluates the past development, or if it is used to predict future outcomes (oriented to change): as a policy change or an improvement in a production process.

• **Focus** (coverage areas), for example, if your focus is on the product level, or on the proposed change in policy.

• **Integration of nature-society systems**, i.e. to what extent the merger of environmental, social and economic aspects.

Sustainability is a process which involves the combination of three aspects of development of a country for the benefit of generations present and future: economic development, improving environmental quality and social equity, so the indicators are selected parameters and considered in isolation or combined, being especially useful to reflect on certain conditions of sustainability.

3. METODOLOGY

3.1 Indicators Selection

With interest in selecting indicators was applied multicriteria analysis methodology, which is the main feature of adding diverse and divergent criteria, and varying weights depending on the observed importance of each aspect in the overall analysis. The choice of indicators was performed using the Analytic Hierarchy Process (AHP), used as a technique for decision making structured in complex environments with using variables or criteria used for prioritizing and selecting alternatives.

The process is performed by decomposition of the problem using criteria that are compared and analyzed independently. After this hierarchical decomposition is built, it is the systematic comparative evaluation of alternatives by decision makers, two by two, to each of the criteria (Saaty, 2008).

For comparison is used to pair the relative importance scale between two alternatives proposed by Saaty (Saaty, 2005). Assigning values ranging from 1 to 9, the scale determines the relative importance of alternative with respect to each other, as shown in **Table 1**.

Table 1. Saaty.Scale

Numerical scale	Nominal scale	Justification
9	absolute importance	An indicator has absolute superiority over other indicator. That is, 9 times more important.
7	strong importance	One of the indicators has strong superiority compared to other indicator. Which was 7 times more important.
5	great importance	One of the indicators has great importance when compared to other indicator. That is, 5 times more important.
3	minor importance	One of the indicators is slightly more important than others in the criterion. That is 3 times more important.
1	Equally important	The two indicators are also relevant for the criterion

Source: Saaty, 2005

The multicriteria analysis through the Analytic Hierarchy Process was utilized as a method for structured decision making in complex environments using variables or criteria considered in the prioritization and selection of alternatives. This conversion capability of empirical data into mathematical models is the main difference from the AHP compared to other techniques (Vargas, 2010).

In this study, a prioritization of indicators for each of the problems related to the management of stormwater found in the literature was conducted. Initially, decomposition of the problems using the criteria to which they were compared was performed and analyzed independently. Therefore, the problem was used as the criteria for the comparison of indicators with the purpose to find the most appropriate indicator for monitoring each problem.

The priority was conducted by three evaluators, university professors and researchers that manage research in the areas of water management, stormwater and sustainability in the departments of environmental sciences, urban engineering and civil engineering of Federal University of Sao Carlos. To support the decision of the experts who participated in the choice, four criteria were used: 1 - Relevance - The indicator should be relevant with respect to what one wants to observe, i.e. in relation to the problem to be monitored; 2 - Comparability - the indicator should be sensitive to observe changes and be comparable with respect to variations in time and space; 3 - Cost and Reliability - the indicator must have a reasonable cost of obtaining data, without losing reliability; 4 - Accessibility - the indicator should have an ease of communication and interpretation regarding the results. After this hierarchical decomposition was carried out a comparative systematic evaluation of alternatives by decision makers of two for each of the evaluated problems. This process was conducted by online questionnaire so that no response was influenced by the responses of the other experts. After obtaining the responses of experts was held an arithmetic average of the results and then held for the method.

3.2 System of drafting support for decision

A Decision Support System -SSD is an organized set of procedures, software, databases and devices used to support making specific decisions of a problem. The goal of most decision support systems is to watch on the topics analyzed in phases of decision-making.

Using software, you can expand the scope of the models to include more variables and test alternatives, can simplify complex phenomena by eliminating everything that can be foreign to what needs to be studied.

The purpose of the design of the Support System for the Sustainable Management of Stormwater - SAMSAP, is to generate a monitoring tool and decision support. Based the decision indicators will be used for monitoring of the problems related to the management of rainwater. Monitoring problems through indicators, we will have the opportunity to present trends and the possibility of assessing the situation over time. The logical sequence tool operation, initially, the user selects the priorities of the problems, this way you can know if the problems are relevant. In listing the problems will be separated by color, according to the priority: High (red), medium (yellow) or low (green) priority, as if the problem is not relevant to the municipality or study basin: no applies (gray). Then select the indicators for each related problem. At this point, the user will enter with the data / parameters available to analyze the evolution of the problem over time and if there is need for action or if the conditions are under control. This information will be saved so you can follow the evolution of the indicator and determine actions to solve expansion problems. You can print partial and full reports for study and presentation in team meetings.

For construction of the tool was used Visual Basic.NET, a programming object-oriented language, created by Microsoft and distributed with Visual Studio.NET. One of the advantages of this program is the tool developed can be applied in a Windows environment, making it easy to install and use.

The use of Visual Basic allows the assembly of the application modules; it facilitates the structuring tool. After this assembly requires the drafting of codes. The implementation of these codes is that they will carry out the activities necessary for the operation of the tool. In Visual Basic writing and implementation of these codes are simplified.

4. RESULTS

With the support of multi-criteria tool, it was possible to select 54 sustainability indicators, which in turn, were divided with regard to the problems directly related to the management of stormwater. The distribution was not equal, and some problems more indicators than others, but the minimum amount was two indicators for a particular problem. As the research core is in a search for more sustainable solutions for the stormwater management, the problems were divided according to the five dimensions of sustainability: environmental, social, political, economic, cultural and technological or management.

Whereas the level of local development and its sustainability in a territory assumes a dynamic balance between the various dimensions that cross the lives of people, if you have here dimensions: **economic dimension -** involves the ability to articulate different actions that go beyond conventional relationships ; **social dimension -** respect the existing level of social cohesion in the community; **cultural dimension -** the knowledge and the identification of the community of their own history; **political dimension -** is related to the degree of autonomy of local groups in the management process and decision-making; **environmental dimension -** is the linking of experiences with respect to environmental characteristics of the territory.

Sustainability indicators were then used to build a decision support tool, SAMSAP - Support System for the Sustainable Management of Stormwater (**Table 2**). This tool will be able to monitor the problems based on information provided by the indicators over time. Data can be collected in the field or secondarily obtained through database of municipal, state or federal governments, academic publications, among others.

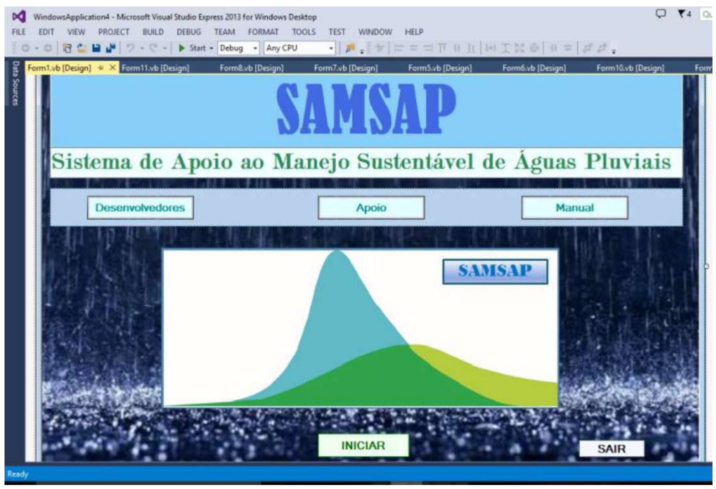

Figure 1. SAMSAP .homepage

Table 2. Indicators for the problems related to stormwater management.

Dimensions	Stormwater Management Related Problems	Indicators
Environmental	Increased soil waterproofing	Variation of peak flows due to rain
		Percentage of urban area built or waterproofed
		Percentage of increase of peak flows
		Existence of legislation to charge or subsidize for permeable area reservation in lots or allotments
	Decreased soil protection	Percentage of urban sprawl over time
		Percentage of urban areas with vegetation
		Percentage of urban occupations in protected area
		Percentage of vegetation cover use in stormwater system
	Physical interference in flow channels	Sedimentation rate of channels by dragged sediment
		Extraction of sand and gravel installed in the basin (regular and irregular)
		Percentage length of restructured channels coated, buffered, rectificated and expansion of channel
	Impact on quality of water resources	Overtaking of frequency limits of quality standards
		Fish fauna diversity
		Single species indicator
Social	Deficit in services to the population	Percentage of area covered by the system
		Coverage of the management of stormwater systems
		Service percentage of urban stormwater systems
	Occupation of areas with risk of flooding or landslides	Municipal plan existence of emergency response to problems caused by rain
		Extension of the areas affected by floods and landslides that occur in the city
		Extension of the occupied area with risk register of floods and landslides in the city
		Percentage of affected families (displaced / injured / dead) by floods and landslides that occur in the city
Economic	Inadequacy budget	Own budget of existence (self-sufficiency financial)
		Effectiveness of the budget used in the stormwater system
		Investment per capita in urban drainage
	Cost generated by deficiencies in the management of stormwater	Reduction in revenues due to interruption of services and freight flow
		Investment value for recovery of material losses from floods and landslides
		Estimated monthly production loss due to rain
Politic	Deficiency in public participation	Existence of mechanisms for systematic evaluation by the user of the quality of the stormwater system services
		Existence of regular meetings between managers and the public to discuss problems related to the stormwater system
		Existence of municipal councils with public participation related to the management of stormwater
		Existence of public involvement in monitoring
	Normative deficiency	Existence of municipal legislation with the requirement of controlling the final destination of stormwater
		Existence of Master Plan management of regulated urban stormwater
	Deficiency in internal	Existence of periodic integration activities between sectors of urban management and maintenance teams and monitoring

	integration for management stormwater system	Existence of instruments for standardization of road projects to reduce interferences in the management of stormwater (Standards for paving, manuals with requirements for management of stormwater)
	Deficiency in intermunicipal articulation	Existence of inter-municipal programs for stormwater management
		Existence of periodic inter-municipal meetings related to the stormwater management
Cultural	Conceptions of stormwater systems that change the original water cycle	Percentage of area served by more sustainable techniques (Best Management Practice, Low Impact Development, others)
		Disconnected area percentage of conventional drainage systems.
	Disabilities in society education for the management of stormwater	Existence of projects / programs of awareness in schools, public and private institutions, and communities.
		Evaluation of the society perception of stormwater management
	Inadequate discharge and control of solid waste	Percentage of waste that is not destined for final disposal with the possibility of canals and pipelines silting
		Amount of releases of solid waste near canals and streams
		Volumes of solid waste causing obstruction of channels and ducts
Technical or management	Deficiency in technical qualification	Existence of specialized courses, training, and the qualification of technicians.
		Percentage of professionals periodically sent for professional qualifications
	Deficiencies in development of stormwater systems project	Existence of skilled workers with expertise in stormwater system projects
		Existence of flaws and inaccuracies in basic projects
	Deficiencies in the implementation of the stormwater system projects	Extended channels and galleries with interference from other systems of urban infrastructure
		Existence of skilled workers with expertise in the management of stormwater
	Deficiency in maintenance of the stormwater system.	Annual frequency of channels and pipe disruptions and clogging streams due to lack of maintenance
		Existence of preventive maintenance plans for channels
		Frequency of preventive maintenance plan execution
		Frequency of flow reduction by clogging of the channel due to lack of maintenance

5. CONCLUSIONS

Problems related to the management of storm water should be monitored to avoid disastrous consequences. The thought of merely drain the water to other locations is no longer viable, this will only transfer the problem to another area, it is necessary to rethink the mechanisms and propose more sustainable possibilities. It is also important to think about staff training to work in management. As well as the participation of the affected population is critical in decision making. The service should be universalized and preferably use techniques with less structural impacts. This tool can be useful in monitoring the problems related to the management of stormwater over time and with the management units watershed

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