Multifunctional landscapes for urban flood control in developing countries

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Abstract

The urbanising process usually changes the patterns of land use and aggravates urban flood problems. Developing countries do not always have the basic infrastructure implemented to follow the increasing urbanization and this lack of planning makes the situation even worse. Traditional approaches to urban flood problems basically modify the drainage net in order to suite them to receive discharges of the urbanized areas. This approach is being complemented or replaced by newer concepts, that tend to consider the basin as a system, using distributed interventions, focusing on infiltration and storage measures, trying to restore pre-urbanization flow patterns. These measures integrate the stormwater management in terms of quantity and quality control. In highly urbanized environments, however, it is not always simple to find free adequate areas to settle hydraulic engineering structures. In this situation, there is an interesting option related to the use of multifunctional landscapes, where urban solutions receive additional hydraulic functions, bringing urban planning closer to hydraulic engineering. In this context, this article presents a case study, in which is shown Joana river basin that drains the centre-north region of Rio de Janeiro City, in Brazil. The flooding patterns of the basin and the introduction of traditional engineering measures by the City Hall are studied here, and a set of alternative interventions is presented, pointing to multifunctional landscapes and articulating Architecture, Urbanism and Engineering to aid in the solution of urban flood control problems, especially in a developing country reality. A mathematical model is used to aid the simulation of these different scenarios.

Keywords: multifunctional landscapes, urban flood control, mathematical modelling of future scenery.
1 Introduction

The present urban conception has appeared in the second half of 19th century in Europe, introducing the concept of “functional city” with large urbanised spaces (squares, avenues, gardens, wide streets) allowing a better flux of people and commerce and either the conforming of districts with better integration between men and urban environment. The modern structure also influenced the fields of transportation, communications, and many kinds of services. However, the urbanisation is surely the man-made action that generates one of the greatest environmental impacts. Some of them, especially those related to occupation and soil use changes, generate direct consequences on the drainage system, and may be felt by flood aggravation, decreasing of dry seasons discharges, water quality deterioration and therefore of the fluvial, estuarine and lake ecosystems.

The understanding of the ways by which the urbanisation act on floods is very important for the adequate planning and control of urban flooding. Generally one can say that the urban flood control encompasses the adoption of structural measures, modifying the basin landscape, introducing different interventions inside and outside the drainage net to decrease the problem, associated to non-structural measures, as environmental education and other measures allowing a more harmonic co-existence with the flooding phenomenon.

The combination of structural and non-structural measures, in an integrated planning with the urban growth, and the use of urban landscape structures with hydraulic functions, allows a composition able to model the urban flood problem in a harmonic and sustainable way. Regarding the problem, it must be stressed that the solution is closely related to the understanding that the basin works as a system, in which single actions may only change problems in space, and therefore there are needed combined solutions that treat the system as a whole.

2 Brief review of historical growth of the cities

Benevolo [1] shows in a wide way the history of the cities and is the basis for the discussion presented here.

The Industrial Revolution marks a deep change in the societies, promoting the increasing of goods and services generated by agriculture, industry and commercial activities, as effects of technological progress and economical development. The decreasing of death rates leads to a consequent increasing population, which together with a production increasing, picture a growth pattern. In such a moment there is a rupture in a secular equilibrium between generations, where each of them has occupied the place of the preceding ones and followed the same destiny. In this way the cities become to grow quickly, encompassing the natural population increasing and the migration trends, in a new situation with new problems to solve.

In the field of thought, liberal economists teach how to limit the public intervention in all sectors of social life, including urbanistic terms. The consequences are critical to city functioning. In the first half of the 19th century, the industrial city faults appear to be too numerous to be completely eliminated. The cities original nucleus does not support adequately the need of increasing
habitation and the streets are too narrow for the traffic. This nucleus starts emptying and turning poorer, the peripheral area becomes to be occupied by districts of different characteristics that combine them in a compact urban tissue.

As an answer to the industrial city it appears the post-liberal city in which the complete freedom given to the private enterprise is limited by the intervention of the public management, which establishes limits in regulations and makes public works for the population welfare. In this context, the public administration manages a minimum space in order to put in work the city as a whole (ways, squares, waterways, sewers, electricity net, etc). Still yet, there continue to exist many different problems. Technical and artistic aspects are considered in a not dissociated way. The commerce and circulation of goods are privileged in detriment of the remaining productive functions.

On the other hand, the modern architecture search for a new city model, alternative to the traditional one, and starts when “artists” and “technicians” work jointly in order to try to reach the equilibrium of the built environment. Modern architects criticise the contrast between public interest and private property and indicate as alternative the re-conquering of the public control over all the city space. In the modern city the productive activities are put in the same level of importance, the residence becomes to be valued as a very important element for the city, the recreation activities are re-evaluated and free green areas are proposed as a great single space, in such a way as the city would be a park with all built ins necessary to the different functions of the urban life, the ways need to be re-thought to separate and optimise different kinds of traffic.

However, in the Third World countries, with late industrial process, the development and population increasing have becoming faster, concentrating from the second half of the 20th century. In this way, the situation of buildings adequately designed, in a context of a city instructed by urbanistic plans and having public services, is related only to a part of the population. The other part is not in conditions to take services from the formal city and organises by itself in poor and irregular conditions. This was a secondary fringe of the post-liberal city and in many countries shows increasing of irregular settlements with greater speed than the regular ones. The poorness and lack of infrastructure lead to urban chaos. The formation of an irregular city aside to a regular one forces to consider the modern architecture development in another manner. Here it appears a paradox: the modern architecture has born with a program to overcome the social discrimination of the post-liberal society, giving an environment studied scientifically to all citizens, however the regular city is not yet available to all – and the majority of the world population already agglomerate in the irregular city. The modern architecture, as well as the engineering, are then located at the crossroad created and need to find solutions to rescue the irregular city, providing the needed infra-structure and developing urbanistic plans that correspond to the real needs of the communities.

3 The urbanising process and the urban floods

Natural floods are phenomena caused by exceeding surface flow generated from an intense rainfall. The urbanisation of a basin generally tends to aggravate the
floods as it promotes original vegetation covering removal, imperviousness increasing, canalisation and occupation of the near river zones. Therefore greater water volumes flow more rapidly over the basin, carrying sediments and accumulating at lower areas, frequently already occupied. When the urbanisation is not adequately planned the consequences of that process are more severe and critical and may cause strong material losses as well as social problems with different magnitude levels.

In developing countries, like Brazil, it is generally observed the disordered city growth, without the adequate control over the soil use and without an entailment to an Urban Master Plan. The city as an attraction point, favouring the migration in searching for better life conditions, suffers a not programmed population intake and the poorer inhabitants occupy critical zones in a disordered way, in sub-residences, without the necessary accomplishing of infrastructure that would be needed. The result, regarding the urban drainage question, pictures a portrait with cities without drainage systems and adequate sanitation, with high population density and a great social pressure.

In some cases, the urbanising process progresses until a level in which there are achieved high imperviousness and demographic density rates, with the generalised occupation of the basin, including areas naturally subjected to floods. In such cases the flooding result is critical. At this level, the urbanised city is known as an ultra-urban environment, where the high value of the urban soil is stressed, as well as the complete lack of free inbuilt areas. In such situation, the range of structural measures for flood control becomes more limited, as the lack of free areas, and the cost associated to liberate them, act restraining the intervention possibilities. In this context, traditional solutions not only may just transfer the problem to downstream, but they are also difficult to implement, as function of the sizes of the resulting works, turning important the option of distributed flow control, acting at the source of the problems with smaller interventions spread over the basin and integrated to the urban life.

4 Flood control measures and urbanistic solutions

Traditional urban drainage practices tend to focuses the problem of the waterway conveyance, trying to adequate it to the flow, generally involving major works, high costs and possibility of great environmental impact. This traditional methodology treats therefore the problem as it is posed, or, in other words, attacks its consequence, which in this case is the concentration of exceeding waters at the waterways or main channels. One can notice that this conception acts directly on the concentrated flows, differently of the concept of distributed solutions. However, more recent practices involve the use of the so-called Best Management Practices (BMP) and the concept of low impact development. It is defined as BMP the set of planned actions implemented in a watershed that present the goal of promoting the attenuation of the urbanising impacts considering not only the water quantity aspects but also the quality aspect of the water that flows over the basin (AMEC [2]). Coffman et al [3] recommend the use of low impact projects, that are those using procedures of hydrological
analysis aiming to understand the functioning of the basin prior to the development as well as in post development, in order to take strategies in a way where the implementation of any project incorporates the functions of storing and infiltration of the basin prior to the urbanisation.

Figure 1: (a) on site seeping pavement; (b) retention reservoir; (c) schematic chart of a retention reservoir; (AMEC [2]).

Therefore, the urban flood problem is being considered under a new point of view in the scientific and technical discussions. It is assumed to be more important to treat the problem in its source or cause, in a systemic way, with distributed actions over the urban landscape, to decrease and delay flood peaks, allowing also the recharge of the groundwater level, searching for rescuing the
approximate conditions of the natural flow. So seeping pavements, on-site
detention reservoirs, infiltration measures, temporary storage reservoirs, re-
forestation, green areas preservation, sidewalk gardens and arbored lanes, among
others, can be good solutions to achieve the proposed goals, and can also
integrate the urban environment harmonically as they can be designed as
recreation areas at dry seasons, therefore presenting multifunctional landscape
characteristics. Many European cities have been working to minimise the
presence of concrete surfaces. The city of Saarbrücken, in Germany, for instance,
has developed a program of subsidies for projects that allow water conservation
and surface flow decreasing. Some detached actions are related to projects for
collecting and use of rainfall water, projects of substituting impervious
pavements by vegetation or seeping pavements and projects for green roofs
installing (Beatley [4]).

Hall and Porterfield [5], searching to find solutions to rescue the harmonic
design of communities, arranging their growth in a sustainable way, while
preserving the landscape characteristic, stress the importance of treating the
surface water question. These authors state that detention or retention basins,
used for flood control, can be also used as amenities, when projected with
imagination, helping to create healthy and functional environments, favouring
the development of a diversity of vegetable and animal species, as well as
aggregating esthetical aspects that value the built environment. The integration
of drainage solutions with revitalising and valuing of urban space can be an
important way for the flood problem solution, either by the possibility of
projecting distributed actions over all the urbanised basin, running away from the
traditional focus that put efforts in the direction of the drainage net adaptation, or
by the possibility of public financing, by public authorities, of works with
multiple purposes, or even by the better accepting of these works by the
population that has in this conception the possibility of improving the
environment where it is established. Fig. 1 shows some flood control measures
integrated to urbanistic solutions.

5 Case study: Joana River basin, City of Rio de
Janeiro/Brazil

The city of Rio de Janeiro, in the southwest of Brazil, presents a highly
urbanised environment, with many irregular occupations in slope areas, and
suffers regularly from urban flood problems. In this town, the City Hall has been
developing, since 1993, a revitalising program of the urban space, acting on
public squares, re-defining streets alignment, parking areas creation, sidewalks
reformation, and mainly reformulating the drainage net at the places of action.
This program is known as “Rio-Cidade”. In the most part of time, however, this
municipal program focuses the use of procedures of the traditional drainage
school, with actions on galleries and channel enlargements. This treatment given
to the drainage system, sometimes transfers the flooding problem in the region of
acting to areas located downstream, degrading this other region. In this work a
critic evaluation of the Rio-Cidade program is done, for the districts of Vila
Isabel, Andarai and Grajau, in the Joana River basin.
Figure 2: Flooding aggravation in a downstream area after a traditional canalisation intervention, for a 10-year recurrence time rainfall.

Figure 3: Profile of Edmundo Rego Square in the alternative conception, with delimitation of areas in different levels, acting as temporary reservoirs.

With the aid of a mathematical model capable to represent the diversity of flows occurring in an urbanised basin, integrating the drainage net with typical structures of urban landscape (Miguez [6], Mascarenhas and Miguez [7]), based on the concept of flow cells (Zanobetti et al. [8]), there were constructed
different and alternative project scenery in order to verify the effectiveness of the implemented or proposed projects, under a 10 years of recurrence and critical duration design rainfall for the basin.

The enlargement of the gallery containing the Joana River, implemented by the City Hall, in the middle reach of the basin, shows potential to minimise problems in that region; however, a simulation done through the mathematical model shows the transfer of flooding to a critical traffic area downstream, where originally the river did not spilled out the watercourse (fig. 2). This is an example of the consequence of not planning integrated actions for the whole basin.

From the analysis of the implemented projects there are proposed alternative actions, in the context of multifunctional landscapes, avoiding actions on the existing drainage net and controlling generated flows in a distributed way. Among these actions there are detached the possibility of re-urbanisation of the squares to work as temporary detention reservoirs, the use of seeping pavements in sidewalks, the proposition of stone-cutters with capacity of retaining part of water flowed, the disconnection of some drainage system areas, among others.

Figure 4: Damping result in the square compared to the inflow discharge.

As an illustration of the developed discussion, fig. 3 shows a profile view of the proposed project for Edmundo Rego square, in the Grajau district, with an alternative conception, lowered at different levels, for acting as a detention reservoir. Fig. 4 shows the hydrograph with the damping result over the Edmundo Rego Square. Fig. 5, considering the extensive application of the concept of transforming public squares into functional landscapes aiming flow
detention, shows the result of damping for the whole basin, in zone marginal to its outlet, from the implementation of detention reservoirs in 11 squares of the basin, also considering the dissemination of the on site reservoirs concept and making re-foresting actions, rescuing slope areas presently occupied irregularly.

Figure 5: Result of decreasing of flooding over streets, computed near the basin outlet, in function of the action of a set of square detention reservoirs, of a set of on-site detention tanks and of actions of re-forestments of degraded slopes.

6 Conclusions

Developing countries suffer with the growth of the so-called irregular city. The lack of basic necessary infrastructure to accomplish the urban growth in those cities is generally critical. One of the major problems that appear, due either to the occurrence of material losses, aggravation of habitation deficit, consequent public health problems or loss of human life, is that related to urban floods. Traditional engineering solutions show to poorly comprise, where canalising presents the trend to transfer problems downstream. Historical urbanistic solutions not always have solved the surface water problem. However one can notice that the combination of knowledge of Hydraulic Engineering with those of Architecture and Urbanism, with integrated actions aiming the urban space revitalizing, the natural environment recovery and the incorporation of hydraulic functions to urban structures landscapes, in order to allow a systemic action over the basin, rescuing when possible flow patterns close to the natural ones, can be an important alliance in the search for the construction of an equilibrate, harmonic and sustainable environment in long term. These alternative proposals,
as illustrated in the presented case study of this paper, have potential to generate very positive results, jointing multidisciplinary efforts and allowing the optimisation of the available resources application.

References


