A Multi-functional Design Approach to Deal with New Urban Challenges

M. Pereira Guimarães and V. Dessì

Abstract The chapter addresses the urban regeneration of an area starting from multi-step interventions in a small square. These interventions consider a multi-faceted point of view which respects local ecological processes while ensuring that transit and other economic and social functions take place. This approach encompasses solutions that respond to city scale needs in terms of stormwater management and the local conditions of thermal comfort and livability at the neighborhood scale. The benefits of urban liveability are now well recognized internationally, and among them increased city attractiveness to avoid abandonment is at the table of several local governments. Municipalities worldwide have pushed for the development of new pedestrian spaces or the regeneration of existing ones to foster liveability through a strategy known as Tactical Urbanism. The paper focuses on the first square in the south part of Milan-Italy to receive such intervention. Beyond Tactical Urbanism, but starting from it, this proposal is a preliminary assessment that aims to evaluate permanent and structural interventions in a square that can also contribute to the environmental resilience of the city. Two different software were used to estimate the environmental benefits of the proposal. The software SWMM (US-EPA) was used to evaluate strategies that guarantee the hydraulic invariance of the intervention area. Second, RayMan Pro was used to assess the contribution of the proposed solution to the microclimate by comparing scenarios in terms of the UTCI index, taking as input local climatic data and data present in the literature.

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1 Introduction

As we enter the post pandemic period, climate change impacts such as extreme urban heat was already starting to be felt in urban areas. Cities were at the forefront of the Covid-19 crisis and experienced the worst effects concerning the health of citizens, that led to reductions in urban liveability levels [1]. Many local administrators have since then embraced the goal to "build back better" by redefining the role and quality of urban spaces as well as encouraging forms of coexistence that reinforce the environmental and social resilience of the city [2].

The management of material (such as is water) and immaterial flows (such as is energy) within the city, constitutes only part of the solution for the urban complexity equation [3]. Urban flows also vary periodically: episodic intense events require corrective and sometimes extraordinary actions. Among the material flows we have, for example, transportation of goods and people, and regular or excessive stormwater runoff. Intangible flows, such as solar radiation that generates shaded and sunny areas or air temperature, usually receive less attention from city officials.

Nevertheless, some of these flows often intercept the daily life of city inhabitants, and can imprint, consciously or not, a sense of belonging or discomfort towards the spaces they frequent. One of the most successful strategies to improve the urban livability is to modify the setting of the open spaces by increasing pedestrian areas to the detriment of roads and car parking lots often by visual low-cost interventions.

On the other hand, individual municipalities have already identified more concrete and long-term actions to adapt the urban environment that must be implemented now to cope with the negative impacts of climate change in a timely manner. Whether it is about reducing the summer heat island or managing excess rainwater, the post-pandemic planning scenario offers an opportunity to rethink city spaces. The regenerative design approach offers possible solutions for both the mitigation and adaptation to the effects of climate change. Particularly in the short-term planning spectrum, such approach can enhance the capacity of local urban areas to buffer seasonal flooding and extreme heat events [4].

Inspired by the many opportunities to recover and rebuilt greener and livable cities, this paper focuses on an Italian case study in Lombardy Region (Milan City). The Lombardy Region Administration counts on policy instruments to impose limits of rainwater discharge to the sewer system. Specific permeability percentages are set for lots that undergo new interventions, using the principles of hydraulic and hydrological invariance. These limits have a legal binding and mitigate the phenomena of flooding caused by the increase of impervious surfaces, and contribute to ensuring high levels of aquifer recharge and environmental protection. The reduction of soil permeability is calculated in relation to the original natural permeability of the site, before urbanization, and not the urban condition prior to the intervention. Although restrictive, the concept of hydraulic and hydrological invariance is usually not sufficient to address situations in which the risk is posed by rivers in densely built and impervious river plain areas. In these cases, a threshold can be used when defining and dimensioning a series of interventions [5]. Thus, the impositions of this law direct new interventions to apply sustainable water solutions to the site.

Sustainable urban drainage solutions (SUDs) have several co-benefits [6]. Therefore, we observe that in trying to integrate design processes through different approaches—always respecting the local environmental resources—some of the strategies used for sustainable rainwater management can be reinterpreted to respond to extreme heat and reduce air and surface temperatures in summertime. Such measures are especially important in the onset of more intense, frequent, and prolonged heat waves. Rain gardens with shading trees, located near rest areas along urban equipment that favor seated activities, or cisterns for collecting rainwater that can be stored and purified to be reused as a water-based cooling strategy in squares, are just some of the possibilities.

The approach proposed feeds from different design perspectives and is not often reflected in the existing strategic tools. For example, in Milan, the Territorial Government Plan (PGT), through the "Neighborhood Plan", guides interventions targeted at the redevelopment of public spaces, while strategies for climate adaptation are advised in other plans (such as the ARERA's "Resiliency of the Energy Networks") [7] and seem to respond with specific requirements for particular issues. The Milan Metropolitan Area's Resilient Territories sector present strategies that try to combine social and ecological aspects, but without defining a clear methodological structure.

2 Tactical Urbanism

In the last ten years, the international movement called Tactical Urbanism has become an easy low-cost and temporary scheme for redesigning public spaces. It usually also includes community engagement and participation in the project and implementation of new uses in urban spaces [8]. Since 2018, numerous small projects were implemented in Milan based on the tactical urbanism strategies adopted previously by other cities around the world, such as New York and Dallas in the United States. These projects aimed at "testing" alternatives of public space reconfiguration selected by the public administration and, so far, amount to around thirty initiatives throughout the city [9].

The main goal was to reverse the current cycling-pedestrian-private car use trends in the street space and, ultimately, trigger mechanisms that attract people to public spaces (using, for example, ping pong tables, as seen in Fig. 1). The Municipality

Fig. 1 Aerial view of Angilberto II Square in Milan, before and after the tactical urbanism intervention (left and central pictures) and an element that invite people to visit and spend time in the renewed square (picture on the right)

of Milan started the program "Open Squares", (Piazze Aperte—Comune di Milano) with five strategic goals:

- To strengthen local identities of de-characterized neighborhoods.
- To foster pedestrian walkability and slow traffic.
- To increase city attractiveness, beauty, and livability.
- To encourage local economy and tourism.
- To promote safety, social cohesion, and inclusion.

Recent surveys observed that the behavior of users has changed positively, and the population has been given the opportunity to make suggestions to improve the proposal. The Angilberto II Square in Milan was the first space to receive such treatment and was very well received by the population.

The tactical urbanism interventions through the city accelerated in the lockdown months during the Covid-19 pandemic, in Spring 2020. By taking advantage of the limited number of cars and crowds, many kilometers of cycle paths were traced on the streets; and some interventions were expanded to incorporate whole squares and part of streets. Most important to note, with the need to activate social distancing, the public space was also substantially occupied by bars and restaurants. The goal of the current public administration is to intervene permanently in these spaces once its uses have been consolidated, considering that some minor changes are still taking place (e.g., realocation of benches or the redesign of pedestrian walkways). Among the most common elements used in these interventions there are pavement painting, trees, shading systems, and benches: a simple intervention that positively impacts the city but could benefit from more design.

3 Management of Excess Stormwater in a Regenerative Design Approach

Taking as a starting point the tactical urbanism experience carried out in Piazza Angilberto II in Milan, a regenerative design approach for stormwater management is proposed for the area. Located in a densely built and mostly soil-sealed neighborhood, the current tactical intervention did not contribute to change the permeability of the existing impervious surfaces.

The proposal's step two goal is to intercept excessive rainwater (for design storms of 10-years and 100-years intensity, respectively, see hyetographs in Fig. 2), store and infiltrate part of it. Lastly, send the remaining (or at least part of it) water volumes to the sewer system once the worst of the storm event has passed. It initially involved only the public space, concerning interventions in the pavement of the square.

The square and adjacent sidewalks were considered a separate stormwater catchment area: runoff water that flows into the driveway would go directly to the sewer, while the runoff water from the square surface would be collected in an alternative system that can at the same time improve the square's appearance and attractiveness [10, 11].

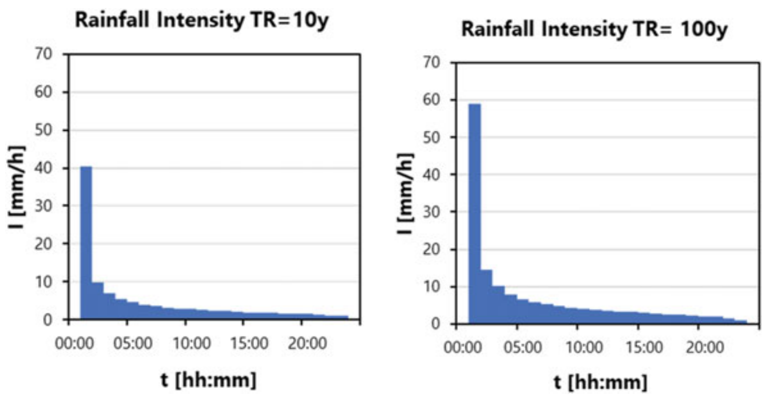

Fig. 2 Design storm intensities for TR = 10 years and TR = 100 years using data provided by ARPA-Lombardia

Therefore, the new design alternative considers a rain garden with trees, permeable pavements in the area occupied by restaurants. Additionally, a water collection system consisting of a small water-square (a paved retention basin) adapted with water splashes or a water misting system provides extra cooling. It is partly fed by the rainwater that is collected is this portion of the square—a system designed to store, clean, and reuse water. The preliminary hydrological and hydraulic modelling and assessments were produced using the Storm Water Management Model (SWMM), developed by the US Environmental Protection Agency (USEPA) [12]. The SWMM software has an in-built stormwater management catalogue of solutions that can be applied to a catchment area. In SWMM they are defined as Low Impact Development (LID) control practices designed to capture surface runoff and provide some combination of detention, infiltration, and evapotranspiration.

Three from the eight possible simulation strategies were chosen to carry-out the analysis: bioretention cells (vegetated rain gardens), pervious pavement, and rain barrel or cisterns (for the water-square). SWMM "LID Controls" are considered as properties of a given sub-catchment. Bioretention cells and permeable pavement systems can contain optional drain systems in their gravel storage beds to convey excess captured runoff off the site and prevent the unit from flooding. Rain Barrels are containers that collect roof runoff during storm events and can either release or re-use the rainwater during dry periods.

In the case study, the adopted bioretention used mostly SWMM default values with exception of the cell berm value of 200 mm, surface roughness of 0.2 (Manning n), suction head of 50, storage thickness of 45 mm and drain offset of 6 mm. Permeable pavement had a berm height of 50 mm, surface roughness of 0.1, pavement thickness of 100 mm and storage thickness of 300 mm.

For the rain barrel, the adopted barrel height was 3 m. This first analysis allows to evaluate the run-off amortization of the proposed solutions in terms of their areas within the main catchment and compare the proposed systems for TR = 10 and TR = 100 years. The catchment areas were estimated using Google Earth pro measurement tool.

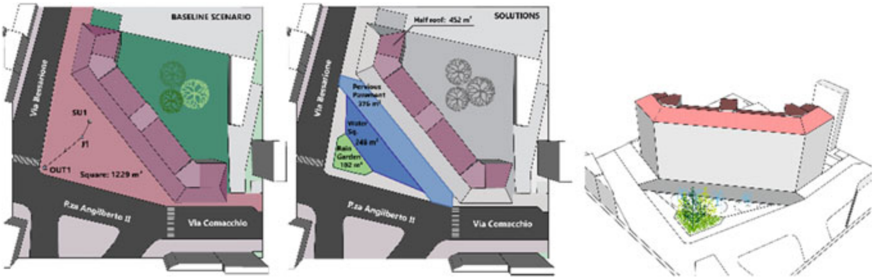

Fig. 3 The existing drainage condition (left image) compared to the LID (Low Impact Development) strategies implemented in the Angilberto II Square (central and right images)

The Baseline Scenario (a 100% impervious square catchment with an area of 1229 m^2) is seen in Fig. 3 and the proposed solutions have the following dimensions: rain garden (102 m^2 equal to 8.3% of sub-catchment), water square (248 m^2 equal to 20.2%) and permeable pavement (376 m^2 equal to 30.6%).

Because the solutions applied to the square would not meet the hydrologic and hydraulic invariance law, it was proposed to capture the rainwater of 452 m^2 of roof in the adjacent building, what accounts for roughly half of the roof area (second image in Fig. 3). The amortization capacity of each solution can be seen in Fig. 4. Their combination was then analyzed for the two design storms (TR = 10 and 100).

First, from Fig. 5, in the left, it is possible to observe that the proposed LIDs are not enough to capture and amortize the runoff from the horizontal surfaces (in the public space). And even more, these solutions are not sufficient to manage the volume of water that also comes from the existing (private) buildings. Generally, the stormwater from the roofs is collected and directed to the sewer system.

It is therefore also necessary to involve the surrounding buildings in the alternative drainage system to avoid extra criticalities in the collection system (Fig. 5, right, shows the solutions applied to the square in combination with rainwater collected from half of the building roof). Only by involving the adjacent buildings is it possible

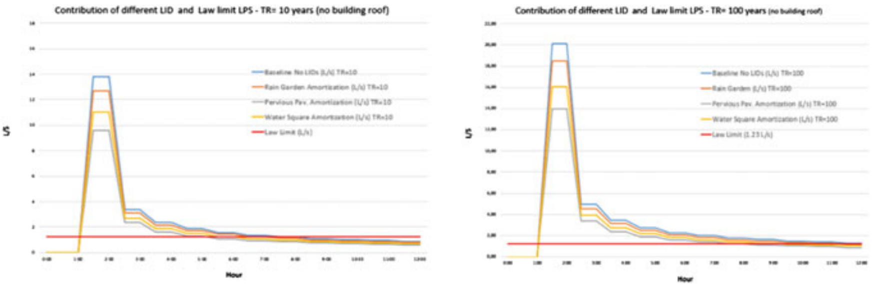

Fig. 4 The comparison of the contribution from different strategies implemented in the public area, considering a return time storm of a 10 (left) and 100 (right) years

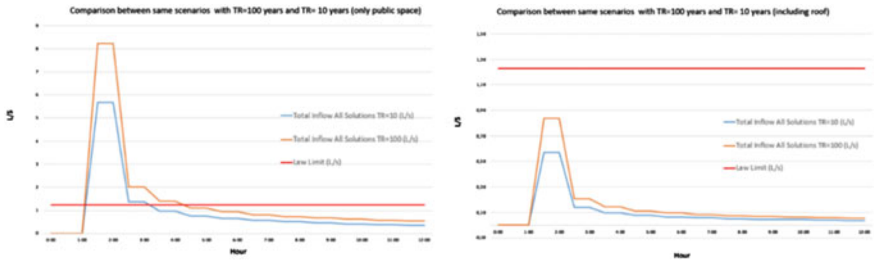

Fig. 5 Comparison of the scenario that combine all the strategies implemented in the public area in the left versus all strategies implemented combined with stormwater captured from the facing building's roof (right), considering a return time of 10 and 100 years

to meet the restricted limit imposed by the hydrologic and hydraulic invariance law for Milan, i.e., 1.23 L per second.

4 Thermal Comfort in an Environmental Design Approach

If the configuration of a square is transformed as so to function as both an attractive public space (with the intervention of tactical urbanism) and as a key site to manage excess rainwater (according to a regenerative design approach), it is also true that the environmental thermal quality of the space must also be acceptable. Therefore, the thermal comfort must be appropriate for the rest of the year in which people use public spaces to carry out social, recreational, leisure and sport activities [13, 14]. The strategies identified for the management of excess water are in fact compatible with strategies that contribute for improving thermal comfort due to reduction of air and surface temperature. Notably, two elements can work to satisfy both requirements: rain gardens that have soil and plants to drain rainwater can host trees capable of providing shade; while harvesting stormwater (with a cistern) in a water square can supply recycled water to fountains and nebulized water systems during the summer for part of the square space. Simulations of energy performance of the urban space coupled with models in dynamic regime allow to evaluate thermal comfort improvement given by the proposed solutions. The software Envi-met 4 [15] can be used to support such evaluation of comparative scenarios and is intended to be used in a later stage of the research project. However, since there is an exhaustive literature that highlights the contribution of both vegetation and water on the amelioration of uncomfortable microclimate, this second method was used instead of a simulation tool, as a preliminary study in this paper (Fig. 6).

According to [16, 17] and to several of field surveys carried out during the research or didactic activities at the School of Architecture of the Politecnico di Milano [18], we can consider a reduction of air temperature and solar radiation due to the presence of trees of about 0.5–1 °C and an increase of relative humidity of about 1–3%.

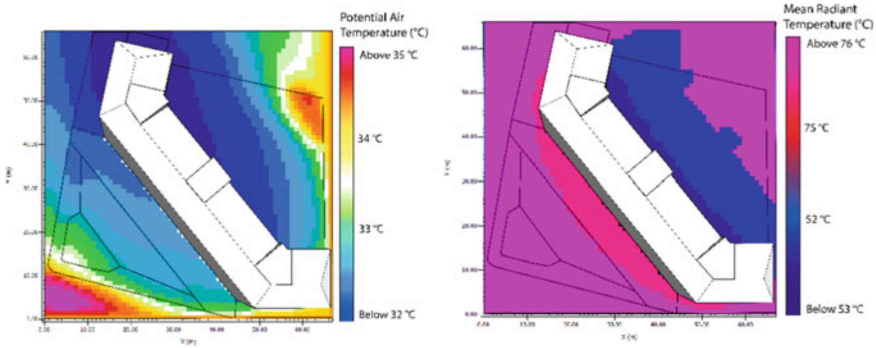

Fig. 6 Potential air temperature (left) and mean radiant temperature (right) of the Angilberto II Sq., in Milan, for July 12th, 2019, at 16.00 for the baseline scenario, generated using Envi-met 4

It is well known that the most important effect on thermal comfort is due to the decrease of solar radiation in the central and hottest hours of the day—that means less incident solar radiation on the person and on the building facades and pavement surfaces shaded by the trees (about the 90% of direct solar radiation decrease), with an important decrease also in terms of Mean Radiant Temperature.

In this paper, two conditions have been considered. The first one, using data for a very hot day in the middle of an intense heat wave that overlap with the existing urban heat island of Milan (June 27th of 2019) and a warm day of the same year (July 12th of 2019). By observing the results of the comfort condition for these two days without and with vegetation and the water-based solutions to cool the environment it is possible to devise some considerations regarding the applicability of the proposed design alternatives to alleviate extreme heat.

The indicator used is the UTCI, an internationally recognized index of thermal comfort, result of the EU COST 7302 research [19]. By using the UTCI, the comfort condition ranges between 9 and 26 °C and it is calculated in this study through the software Rayman Pro.

The existing condition at 3 p.m. of June 27th, 2019, is very unpleasant, reaching values of UTCI of 43 °C (Table 1), i.e., 17 °C over the comfort limit. Considering a decreasing of 1 °C in temperature and the 90% of solar radiation, the situation would pass from UTCI 43 °C to around 36 °C, only considering the trees' shade. It represents a dramatic improvement, but still not sufficient to reach a comfort condition in the hottest day of the year during an intense heat wave.

Considering the water-based solutions (fountains and nebulizers), air temperature and relative humidity would change, and probably also solar radiation being partly reflected by the water droplets. According to [20–23], air temperature can decrease of 7.5–10 °C as the relative humidity can increase up to 20–30%. During the heat wave on June 27th in Milan, if we consider a misting water system in the water square with air temperature of 28 °C (10 °C less) and relative humidity of 56% (20% more), we can approach a comfort condition, but we cannot reach it (29.7 °C), despite an improvement of about 13 °C.

Table 1 Data form ARPA, the Protection Agency of Lombardy Region, during one the hottest summer day in Milan, June 27th, 2019 (during the heat wave) and a warm day, July 12th (no heat wave), at 3 p.m., and for both days two different proposals to cool the environments, shadows provided by the trees and misting water

Date/Condition	Air temperature (°C)	Relative humidity (%)	Global solar radiation (w/sqm)	Wind velocity (m/s)	UTCI (°C)
June 27th (heat wave)	**37.8**	**36.3**	**806**	**2.9**	**42.8**
Under a tree (Hypothesis)	36.8	38.0	80	2.9	36.2
Under jets/mists (Hypothesis)	28.0	56.0	750	2.9	29.7
July 12th (no heat wave)	**30.0**	**35.6**	**827**	**3.2**	**33.0**
Under a tree (Hypothesis)	29.0	37.0	82	3.2	25.2
Under jets/mists (Hypothesis)	23.0	60.0	770	3.2	25.9

During a warm summer day, 12th July 2019, in the afternoon after a heat wave period, the UTCI is about 33 °C, i.e., out of the range of the comfort condition. A comfort condition is reached (respectively 25.2 °C and 25.9 °C) when considering the alleviation given by the vegetation or the water-based solution to cool the area of the square.

5 Conclusions

Three different ways to design urban spaces have been considered in the study: tactical urbanism, regenerative design, and environmental performance. These approaches involve the quality of public space from different points of view. At first sight, these three approaches are not compatible with each other. They are in fact, complementary, and when taken into consideration at the same time, can contribute to further enhancing the urban space and reinforcing the environmental and social resilience of the urban area.

There are two considerations to highlight. The first one concerns the participation of citizens, evident in the tactical planning process, which requires a different strategy when it comes to managing excess rainwater and extreme heat.

Citizen participation in the case of ecological adaptation, refers to the role of private building owners in creating more sustainable and livable cities. Without making available the surfaces and areas pertaining to private residences (for example, the roofs), for the collection and possibly also for the storage—even if temporary—of rainwater, as highlighted by the results of simulations with SWMM, the values imposed by law are not satisfied.

It is necessary to involve the facades of the buildings as well as roofs also for the construction of green and/or blue infrastructure (green facades and green roofs) that guarantee acceptable comfort conditions to people who walk or spend time in an urban space. It was verified using RayMan Pro using data from the literature for the proposed vegetation and water-based solutions applied to square. If implemented widely in the city, these solutions also contribute to reduce the urban heat island (UHI).

The second consideration concerns the climate adaptation strategies considered in the study: stormwater management and passive outdoor cooling. These solutions are certainly effective and manageable for harsh but not extreme conditions (heavy storms and intense heatwaves). Climate adaptation measures can contribute to the enhancement of urban space from the point of view of aesthetics and psychological aspects (for example, by increasing biophilia and safety), but they have a limit beyond which they are no longer sufficient to improve the overall outdoor environment.

In other words, the ability to adapt the urban environment is not infinite and it is essential that these actions are always accompanied by mitigation measures that limit the causes of climate change in the city-region and in the global scale.

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