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WATER SENSITIVE URBAN DESIGN: A SUSTAINABLE DESIGN APPROACH TO REFORM OPEN SPACES IN LOW-INCOME RESIDENTIAL REHABILITATION PROJECTS IN EGYPT

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HIGHLIGHTS

- WSUD approach and storm water management must be economically and socially sustainable.
- The new incentives for urban rehabilitation are trying to reverse the town planning model.
- The low annual rainfall average causes limitation of WSUD solutions.
- WSUD can participate in three items of the six items of rehabilitation standards.

ABSTRACT

Urban communities and cities often evolved alongside the rivers or coasts of the sea, the water element was always important and influential in shaping the visual and urban character. Neglecting such natural resource in urban development has a bad impact on city's economic, ecological and visual values and subsequently, on the rights of next generations. Moreover, programs of urban transformation and development in low-level residential projects suffer from random policies and blurred strategies which ignore natural and social opportunities. This requires new approaches which in turn comes out of an integrated strategy based on a multi-dimensional approach to solve the problem. Among them is Water Sensitive Urban Design (WSUD). which is a methodology that depends on respecting an important environmental natural resource "Water" and is oriented to use water more effectively and integrating water cycle with built environment.
The research will examine practically the efficiency of WSUD in reforming governmental rehabilitation housing projects, alongside with the urban rehabilitation standards. An urban residential area in Port Said coastal city will be selected for implementing this study. A proposed framework –from WSUD with urban rehabilitation standards– will be extracted to improve the quality of this area with its built context in order to alter water from being a potential nuisance into a valuable resource. Through Developing Design guidelines for WSUD implementation potentials, the study will reach developing actions on the urban and built level, to help assessing the validity of the proposed design guidelines in the light of WSUD contributions with rehabilitation process.

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1. INTRODUCTION

Nowadays, not only do we rely on water supply for our daily needs, but we also depend on it for our food and produce resources, to transport our goods and waste, beautify our urban spaces and provide recreation and pleasure. Water is often vital to the identity of our places.
This paper will investigate low-income residential public open spaces and the way in which WSUD techniques can enhance their sense of place for the community. The aims of this paper are:

- Investigate what has been done in the area of sustainable stormwater handling and Water Sensitive Urban Design approach.
- Conduct an extended framework and form a guideline with techniques and solutions that can be used to plan or evaluate low-income housing open spaces.
- Finally, apply it on an ongoing case of residential projects. The location chosen is Port Said.

The structure of this paper is outlined and illustrated below in Figure 1.

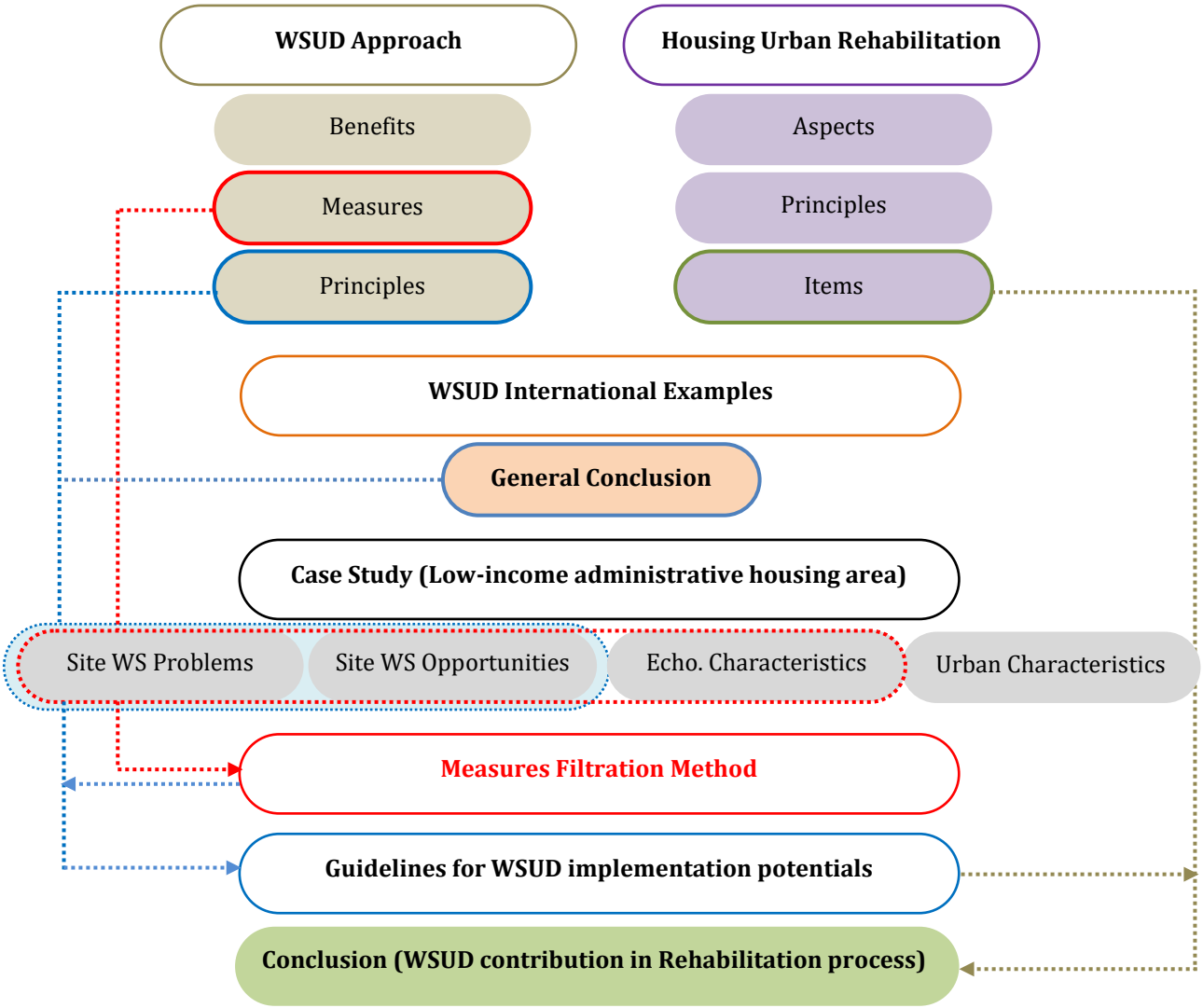


Figure 1: The research contents. *Source: The researchers*

2. WATER SENSITIVE URBAN DESIGN APPROACH

2.1 What is Water Sensitive Urban Design (WSUD)

The definition of WSUD varies among practitioners across the world; the definition provided by the National Water Initiative – 'the integration of urban planning with the management, protection and conservation of the urban water cycle, that ensures urban water management is sensitive to natural hydrological and ecological processes' (National Water Commission, 2004). WSUD is also commonly known as Low Impact Development (LID) in the USA or Sustainable Urban Drainage Systems (SUDS) in the UK (Morison et al., 2010).

The integration of urban water cycle management with urban planning and design is referred to as 'Water Sensitive Urban Design' or 'WSUD' in Australia (Melbourne Water, 2005; Wong, 2006a). This approach is aiming to minimize the hydrological environmental impacts of urban development on the surrounding context (Lloyd et al., 2002). There are few similar approaches have been developed and applied in other countries (Van Roon, 2007), which include "Urban Drainage Sustainable Systems" in the UK (Butler & Parkinson, 1997; Interim Code of Practice for Sustainable Drainage Systems, 2004) and "Low Impact Development" in North America (Elliott & Trowsdale, 2007).

The current driving force of WSUD techniques is the ability to contribute to water conservation. By incorporating water sensitive urban design initiatives into residential areas, such as streets, open spaces and other facets of the urban environment, water sensitive urban design can contribute to place-making, a sense of place and local identity.

2.2 Benefits of WSUD

To understand the climate benefits of WSUD is very important, WSUD commonly integrates vegetation into its design, or provides an alternative water source (e.g. rainwater tank) for irrigation of vegetation. There are few studies that consider the climatic effects of WSUD itself, but insights can be drawn from studies of vegetation and green space. At the micro-scale, trees have been shown to be particularly beneficial in lowering urban temperatures (Tsiros, 2010) and improving HTC (Georgi and Dimitriou, 2010) due to both transpiration and shading. Figure 2 shows the process that WSUD support to form the urban micro-climate.

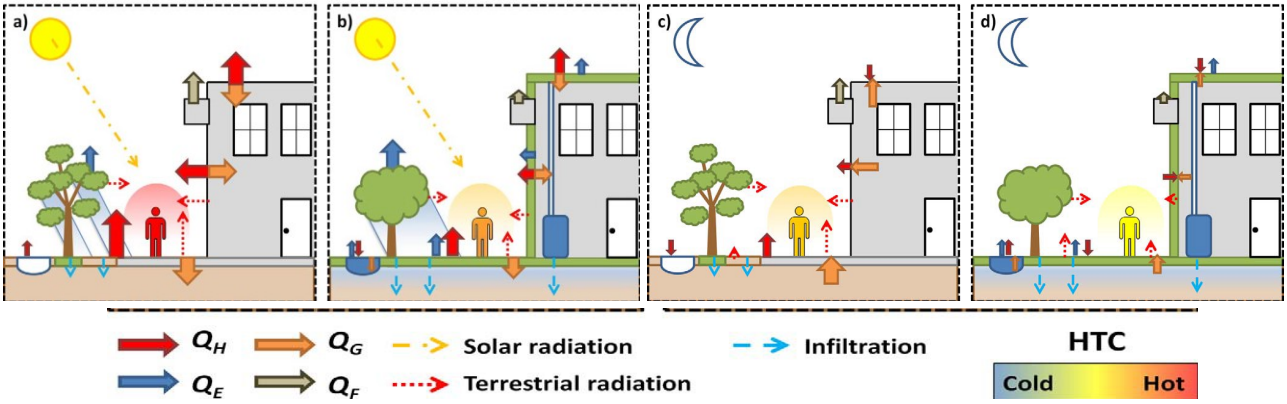


Figure 2: The formation of urban micro-climates during summer for convential water limited urban landscape (a,c) and water senstive urban landscape (b,d). *Source: Oke (2009), Adapted by the researchers*

2.3 WSUD measures/solutions

Objectives and benefits of WSUD can't be achieved simply by constructing a lake or wetland structure. WSUD integrates water cycle management and sustainable solutions/measures in the process of urban development (BMT WBM Pty Ltd. 2009). These solutions/measures were developed to adapt with specific stormwater management needs and site opportunities (Hoyer et al., 2011).
For optimal application of WSUD, is the integrated adoption of appropriate Best Planning Practices (BPPs) and Best Management Practices (BMPs) (BMT WBM Pty Ltd. 2009).
Figure 3 illustrates the general frame that brings together a range of measures, solutions and techniques of WSUD categorized according to former levels of practicing.

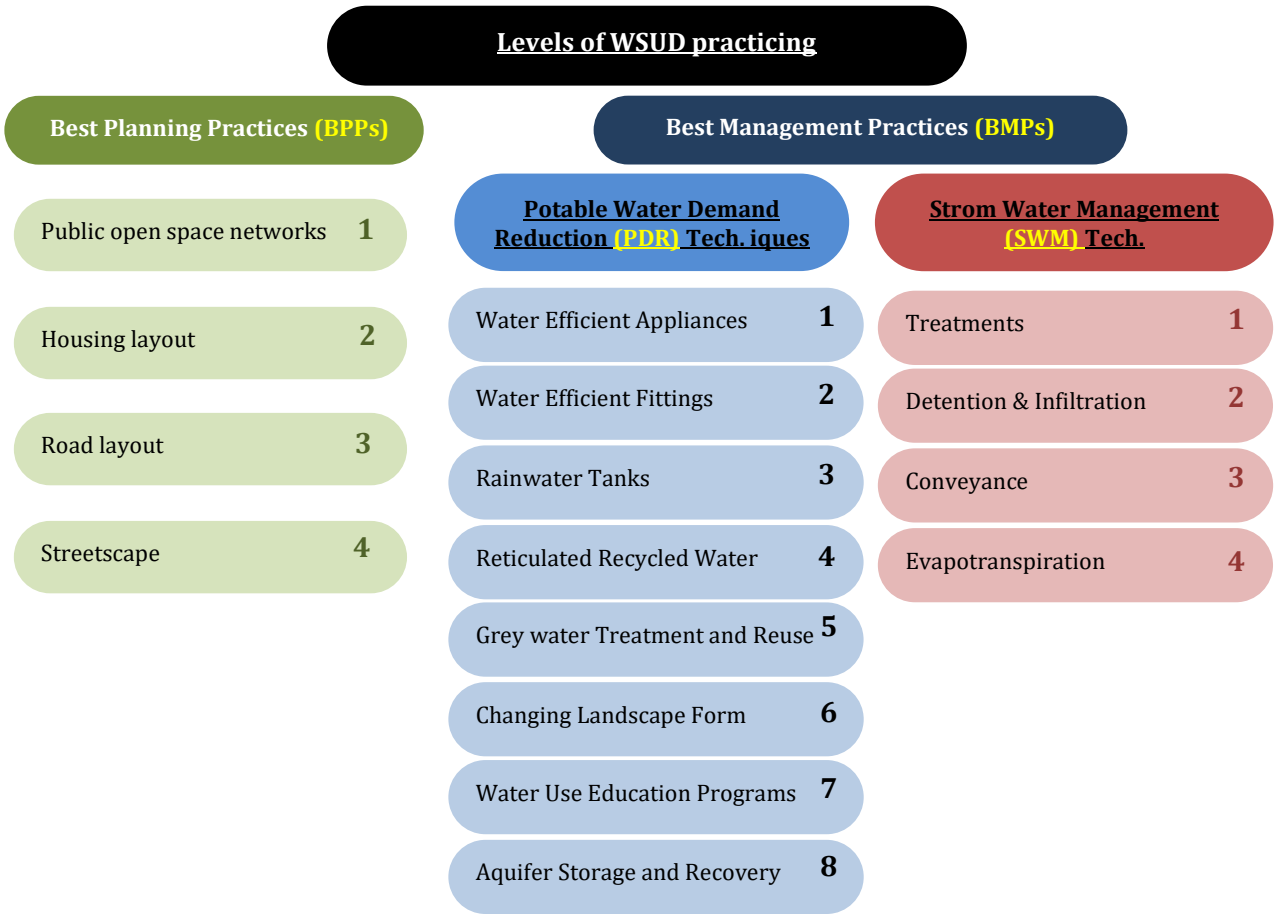


Figure 3: Categories of WSUD measures, practices & techniques, *Source: Hoyer et al. (2011); BMT WBM Pty Ltd. (2009), Adapted by the researchers*

Table 1 states brief definitions for WSUD measures/solutions, it will be encoded according to the levels mentioned above. Implications of these measures/solutions will be concluded to help in selecting the most appropriate and efficient measures for the case study.

Table 1: Definitions and implications of WSUD measures/solutions

Measure	Code	Definition	Implication
Best Planning Practices (BPPs)			
Public open space networks	**BPP1**	Integration of public open space with stormwater management systems and recreation amenities, promotes social and economic benefits	U. Design
Housing layout	**BPP2**	Residential blocks with more compact form integrated with drainage system and open spaces.	U. Design
Road layout	**BPP3**	Topographic characteristics of site affected water sensitive road layout	U. Design
Streetscape	**BPP4**	By integrating social needs & road layout with stormwater management	U. Design
Potable Water Demand Reduction (PDR) Techniques			
Water Efficient Appliances	**PDR1**	Helps in reducing demand on potable water supplies and wastewater generation.	Furniture - Appliances
Water Efficient Fittings	**PDR2**	as showerheads, sprinklers and taps for reducing water consumption	Furniture - Appliances
Rainwater Tanks	**PDR3**	Can be a house integrated element used for toilet flushing and washing machine supply. Outer elements can be used through landscape design.	Sewage
Reticulated Recycled Water	**PDR4**	An advanced sewage line, supplied through several sources related to stormwater management and reticulation systems.	Sewage
Grey water Treatment & Reuse	**PDR5**	Recycling and reuse of greywater reduce demand of potable water on the blocks, cluster and suburb scale.	Sewage
Changing Landscape Form	**PDR6**	By reforming landscape cover in parks and open spaces to more water efficient planting varieties.	Landscape
Water Use Education Programs	**PDR7**	Education campaigns are important component for achieving a site's WSUD objectives besides other measures.	Culture
Aquifer Storage	**PDR8**	Storage of stormwater or wastewater in aquifers and reusing it	Sewage
Strom Water Management (SWM) Techniques			
Bio-retention	**SWM1a**	Shallow areas of vegetation cover based on an engineering soil dedicated to filtration processes for reducing downstream runoff.	Landscape
Biotopes	**SWM1b**	Areas of green cover and animals give aesthetic appearance and promote environmental stability	Landscape
Gravel or sand filters	**SWM1c**	Above or below ground Filtering systems with gravel or sand, designed to treat surface water runoff.	Landscape
Rooftop retention & Green roofs & walls	**SWM2a**	Horizontal or inclined multi-layered structure roof system, implanted as green roofs, either extensive or intensive.	Architecture
Permeable paving	**SWM2b**	Concrete, asphalt & interlocking porous paving is useful for reducing stormwater runoff. It facilitates permeation of surface runoff water into the underlying subsoil.	Landscape
Infiltration zones and trenches	**SWM2c**	Concentrated planted spaces consisted of multi layers of sand, gravels and metals, can be integrated with private and public parks and streets.	Landscape
Swales	**SWM2d**	A vegetated channel that facilitates stormwater filtering and enables infiltration into the soil or the stormwater system.	Landscape
Geo-cellular systems	**SWM2e**	Underground prefabricated structures installed for stormwater storage.	Infrast.
Detention pond - dry	**SWM2f**	are mostly dry, but used to collect rainwater for filtration or evaporation	Landscape
Detention pond- wet	**SWM2g**	Water storage basins, used for recycling and reuse in irrigation or supply.	Landscape
Open stormwater canals/ drains	**SWM3**	Canals can convey stormwater from into underground sewer systems.	Landscape
Passive evapotranspiration	**SWM4a**	All vegetated orders can be considered as passive evapotranspiration.	Landscape
Active evapotranspiration	**SWM4b**	Active methods rainwater walls, fountains, and pools. Used for improving air quality of public open spaces or inside built areas.	Landscape - Architecture

Source: Hoyer et al. (2011); BMT WBM Pty Ltd. (2009), adapted by the researchers

2.3 WSUD Principles

WSUD approach and storm water management for future cities must be ecologically, economically and socially sustainable. Successful stormwater management should addresses these concerns, stormwater management has already contributed to increasing sustainability in water management. Nevertheless, there is some challenges for this approach such as (Shutes & Raggatt, 2010):

- Lack of Implementation:
- Missing or Lacking Integrated Approaches:
- Lack of Knowledge, Acceptance and Awareness

In order to deal with these challenges, many studies have come with a group of design principles for a successful WSUD and storm water management approach, Table 2 shows a brief summary of these five design guideline principles.

Table 2: WSUD Principles/solutions

Topic	Symbol	Principle	Short Form
Water Sensitivity	**P1**	should use decentralised methods to bring urban water management closer to the natural water cycle.	Water Sensitivity
Aethetics	**P2**	should be used to provide an aesthetic benefit where possible.	Aethetics benefits
		should be adapted to the design of the surrounding area.	Integration in surrounding area
Functionality	**P3**	should be used in an appropriate way, adapted to the local basic conditions and the intended use	Appropriate design
		should consider the corresponding maintenance requirements.	Appropriate maintenance
		should consider possibilities for adaptation to uncertain and changing basic conditions.	Adaptability
Usability	**P4**	should be used to create places that are usable for recreation and/or nature conservation purposes.	Appropriate usability
Public Perception and Acceptance	**P5**	should consider the demands of all stakeholders and involve them in the planning process	Public involvement
		costs should be comparable to the costs of conventional solutions	Acceptable costs

Source: Shutes & Raggatt. (2010), adapted by the researchers

3. HOUSING URBAN REHABILITATION

Urban rehabilitation can be defined as a system of actions focusing to solve a certain urban problem within the local environment. The main purpose for urban rehabilitation is to modify or correct the negative effects of spontaneous urban development processes and aim to establish a good balance between the economical-social and environmental aspects of it (SOÓKI-TÓTH, 2005).
According to Patsy Healey, the main role of local government has changed, it's not the key-player any more rather to coordinate collaborative governance as the city is a multi-level complex structure in terms of sustainable development and other different complicated processes (NYSTRÖM, 1999).
Ewa Kipta argue that urban rehabilitation is more cultural than only in physical aspects. It affects the daily life-styles of local people, some of the important aspects in rehabilitation can be listed as follows:

- ***Political Aspects***

Political support is very important and crucial for urban rehabilitation, unfortunately, in many housing cases it lacked the political acceptance for the effort. Many years ago, UNSCO and Aga Khan Foundation of architecture started to work in Cairo, national authority didn't support to take up a World Bank loan (Steinberg, 1996).

- ***Cultural Aspects***

Local culture has been always a way to promote tourism, and create the unique ambience of the city (Burgess, 1988). In a lot of historical cities, local agencies play an important role to promote the old towns as tourist centers, but it loses out to rapid decay and destruction, and the non-availability of governmental support and funding (Bromley and Jones, 1995).
Nowadays, Rehabilitation has become a leverage to establish the cultural corridor which succeeded to revitalize the city center with all its cultural and economic activities.

- ***Social Aspects***

The social aspects rise strongly especially in low-income projects rehabilitation, most of poor and low income crowded housing stocks suffers from the impact of subdivision and over utilization of outdated services. In some of the rehabilitation projects for poor and low-income areas, the local residents have been relocated elsewhere in a modern housing with better environment, and all the existing area were redesigned totally (Pinheiro and Del Rio, 1995).

- ***Economic Aspects***

The economic aspects is always control the overall process of urban rehabilitation. The economic and financing problems have simulated a good chance for doing rehabilitation process through the approach of adaptive reuse and invite the private sector (Nongovernmental organizations) to participate and invest in such type of projects.
As conservation and rehabilitation are going forwards, not only the land values of these areas increase, but also local revenues. Such increase can have an additional stimulating impact for the rehabilitation of infrastructure and other services in high value areas (Lichfield, 1990)

- ***Urban Aspects***

In conservation and rehabilitation projects, it is important to preserve the existing urban fabric, which is one of the most important goals of urban planners and designers. The more carefully dealing with the existing architecture and the nature of building heights and ratios, the more successful the rehabilitation projects are. Some rehabilitation processes and experiences – as in the case of Cairo, Singapore – have emphasis on the importance of preservation of existing urban pattern and tissues, in some case they even developed detailed design guidelines to be applied later by the private investors (Steinberg, 1996).

3.1 Urban rehabilitation principles

The new incentives for urban rehabilitation are trying to reverse the town planning model, based on urban expansion areas whose negative consequences are well known to all (Bigio & Licciardi, 2010):

- The waste of over-sized infrastructures.
- The spread of urbanization within the urban perimeters, with no continuity of urban fabric.
- The urbanized ruins of new neighborhoods which are still waiting for buyers. For the first time urban rehabilitation action is required for new buildings and new neighborhoods that became old without ever having been inhabited. The empty spaces require special strategies of urban rehabilitation.

In the case of the detailed local plan of urban rehabilitation, it states that urban rehabilitation is today an indispensable component in city politics and of rehabilitation. The regime of urban rehabilitation establishes two modalities for which the urban rehabilitation actions can be performed:

- Simple urban rehabilitation, where responsibility and expenses are on the building owners.
- Systematic urban rehabilitation, defined by the head office of the detailed local plan of urban rehabilitation where the responsibility is with the municipal authorities

The six new principles of urban rehabilitation regime can be listed as shown in Figure 4. In summary, the detailed principles of urban rehabilitation include the task of identifying the necessities of rehabilitation cities, modernization or demolition of buildings (, rehabilitation of urban infra-structures, equipment and green spaces of collective utility (Razzu, 2005).
For the first time, the meaning of urban rehabilitation exceeds the actions in buildings and includes the actions in public spaces of the city such as streets, infra-structures or green areas (Rojas, 2002).

Principles of Responsibility	**Principle of Subsidiarity**	**Principle of Inter-generation Solidarity**
Understanding the urban rehabilitation actions as a private sector responsibility, at the expense of the building owners.	Recognizing the general interest of urban rehabilitation actions, but which should be financed by free market rules and not by public funds, in which the unilateral solutions should be the final ratio.	Which transfers the financial bill of the urban rehabilitation to the following generation.
Principle of Sustainability	**Principle of Contracting**	**Principle of Protecting of what Exist**
In terms of financial, sociocultural and environmental issues, in which each of the agents which participates contributes with their resources towards the urban rehabilitation in a process of what amounts to self-financing.	As a form of streamlining the executions of the operations of urban rehabilitation.	Principle of integration, principle of co-ordination, principle of a just consideration and, finally, the principle of equality.

Figure 4: Urban Rehabilitation Principles, *Source: Razzu (2002); Rojas (2005), Adapted by the researchers*

3.2 Items of residential rehabilitation sta ndards

For most of the residential projects, there is a lot of studies propose some standards for optimal rehabilitation process (De Chiara et al, 1995; Roos et al, 1980; Wardani, 2011). These standards consist of the following items:

- Building Structure
- Heating, Ventilation and Air Conditioning Systems
- Electrical System
- Plumbing
- Environment
- Elimination of Lead-Based Paint Hazards

Figure 5 describes the main subdivision points for all the standards, while Figure 6 shows general requirements for each of the six items.

Figure 5: Main Subdivision of residential Rehabilitation standards, *Source: Wardani (2011); De Chiara et al (2005), Adapted by the researchers*

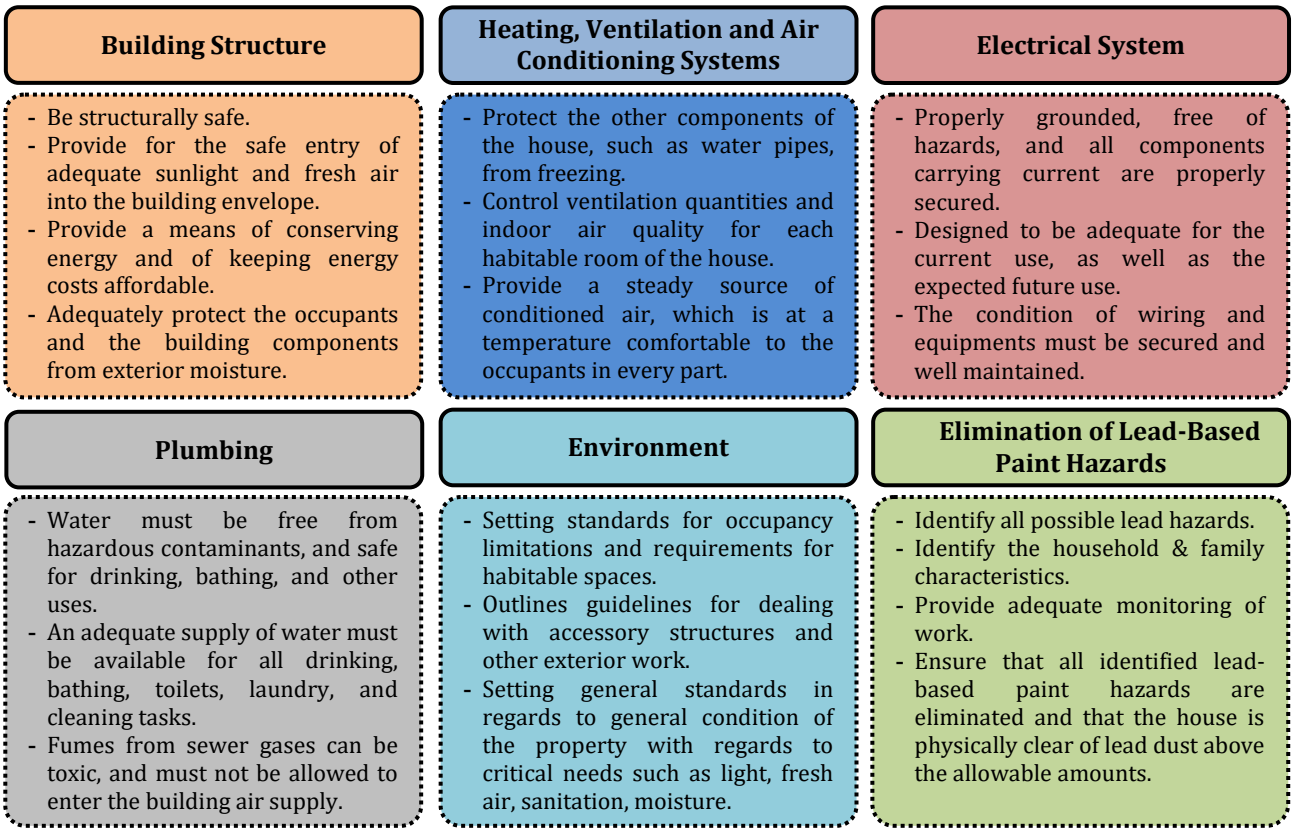


Figure 6: General requirement of residential Rehabilitation standards, *Source: Wardani (2011); De Chiara et al (2005), Adapted by the researchers*

4. WSUD INTERNATIONAL EXAMPLES

This part introduces three projects that successfully applied the principles of Water Sensitive Urban Design. In addition, the selected projects reflect various scales to which WSUD can be applied (site level "small scale" and district level "medium scale"). These projects scales and types are consistent with the chosen case study at the last part of this paper. Table 3 shows the selected projects titles, scales, locations and main objectives.

Table 3: Selected projects titles, types and locations

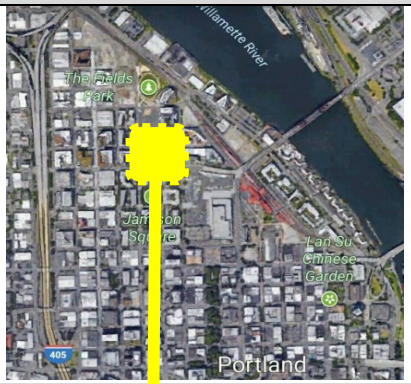
No.	Project title	Location	Type	Main objective
1	Tanner Springs Park	Portland, Oregon, USA	public park – urban – residential/commercial	Use decentralized stormwater management to re-establish natural wetland in a dense urban area that can also be used for recreation.
2	Hohlgrabenäcker	Stuttgart, Germany	new development district – suburban – residential	save costs for stormwater management through green roofs, cisterns and pervious pavement instead of enlarging sewer system for rainwater drainage
3	10th@Hoyt Apartments	Portland, Oregon, USA	housing block – urban – residential	turn rainwater into art to contribute to the quality of life in the apartment complex

Source: Hoyer et al. (2011), Adapted by the researchers

Each project will be presented by giving a short brief about the basic information for the project followed by a description for the WSUD principles achieved and measures applied in the project. Finally, a conclusion is stated at the end of the projects presentation addressing which measures have been applied the most in each case? And why? Table 4, 5 and 6 present the three selected international examples.

Table 4: Tanner Springs Park project, Portland, Oregon, USA

Project Definition	
Type of project	Public park
Time frame	Planning: 2002-2004 Construction: 2004-2005
Project Scale	District level (medium scale)
Main concept	Create a functional, beautiful park in a dense urban area.
Context	**Park size:** 4,800 m^2, Surrounded by a dense urban area Residential use (mixed with some commercial facilities)

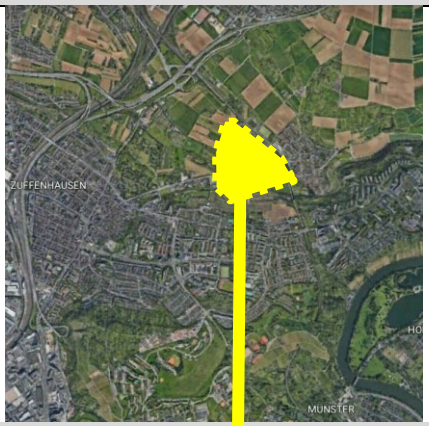


Project Description	
Water sensitivity	**Borders:** • Three sides of the park are lined with steps allowing a terraced, permeable edge for visitors to enter, exit, and sit. • The east side of the park is lined with an art installation (Art Wall) and a boardwalk. **The pond:** • The park is characterized by irregularly shaped open water area. **The Art Wall:** • It is a reminder of the Pearl District's industrial origins as a marshland. • It is comprised of railroad tracks at different lengths and leaning at slightly different angles to create a wave-like effect. Panels of blue glass were installed between the railroad tracks and painted with wetland themes. • Rainwater flows from adjacent sidewalks that slope toward the landscape, thus contributing to the redevelopment of the water cycle. • Narrow channels and a leaf-shaped glass roof (rainwater pavilion) collect the water and lead it to the lower pond, where water is captured and pumped back up to a spring. • Part of the park paths is raised boardwalks jutting through a pond leading to cobble paths into the planted wetland grasses.
Integration with surroundings	Through the use of urban materials such as concrete, metal, and glass The designers succeeded in fitting the park into the surrounding context through the use of urban materials such as concrete, metal, and glass.
Appropriate usability	• The Park was successful in creating a thriving urban space. • The residents use the park for relaxing, sunbathing, reading, and more. • The bridge acts as a meeting space and streams encourage exploration. • The new marsh, pond, and meadowland form a diverse habitat for some of the original inhabitants (animals/plants of the marshes).
Public involvement	Local residents were actively involved in the design and planning process.

Source: (Hoyer et al., 2011; Dreiseitl and Grau, 2006; Google Earth Images), Adapted by the researchers

Table 5: Hohlgrabenäcker, Stuttgart, Germany

Project Definition	
Type of project	Residential use
Time frame	Planning: 2003-2007 Construction: 2007-2010
Project Scale	District level "medium scale"
Main concept	Save costs of stormwater management through the application of green roofs, cisterns and pervious pavement.
Context	**Area:** 167000 m²; **Green roof area:** 18300 m² Semi dense site (265 private homes - 9 apartment buildings)



Project Description

Soil analysis:
- Steep hillsides and cohesive homogenous soils are unsuitable for stormwater infiltration.
- Hence, a combination of different measures for stormwater management was initiated; Green roofs, cisterns and pervious pavement.

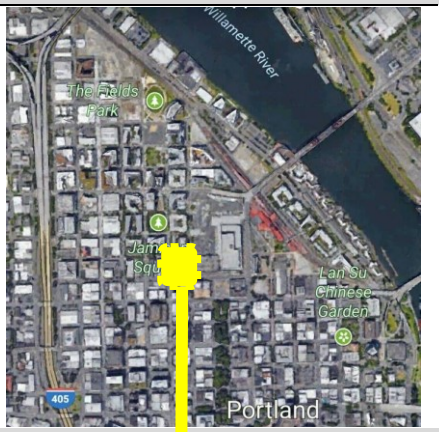
Used measures benefits:
- Imperviousness was reduced to a total of 20%.
- Contribution in the sustainable development of the City while saving immense cost savings for residents.

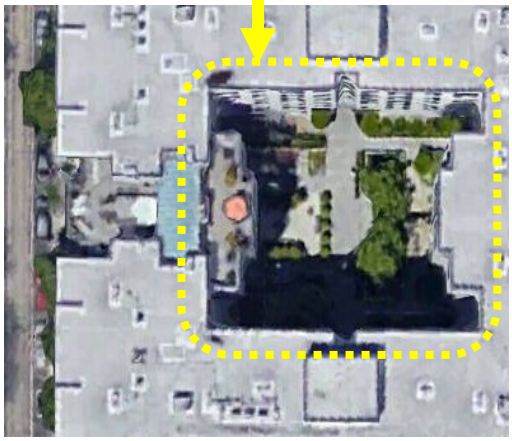
Water sensitivity	• 18,300 m² green roofs, 56 cisterns, and pervious pavements managed almost all stormwater on site. • Paved roads were reduced to minimum. Thus, only a small amount of stormwater needs to be drained to a separate stormwater sewer. • The rainwater collected in cisterns is used for irrigation and other domestic purposes. • Green roofs serve as local rainwater storage and detention measure.
Integration with surroundings	• Green roofs are well integrated in the surrounding environment. • Underground cisterns are not visible. • Pervious paving almost looks the same as standard paving. **However, the choice of plants used for the green roofs could have been more diverse to allow a variety in shape and appearance (e.g. to create different characters for different streets).**
Appropriate usability	• All measures used are integrated in the settlement in such a way that there are no restrictions on use. • Cisterns are located below ground and greenery on roofs utilizes space that is normally not used. • Planners succeeded in finding a system that did not take up much space in public areas to preserve space for real estate.
Public involvement	Homeowners decided major components: plants for green roofs and cisterns capacity for private usage.

Source: (Hoyer et al., 2011; Diem and Ansel, 2009; Google Earth Images), Adapted by the researchers

Table 6: 10th@Hoyt Apartments complex, Portland, Oregon, USA

Project Definition	
Type of project	Urban apartment courtyard
Time frame	**Planning:** 2003 **Construction:** 2003
Project Scale	Site level (small scale)
Main concept	Using stormwater management as an on-site design feature that contributes to the amenity of the site.
Context	**Courtyard size:** 790 m^2, **Whole site size:** 4,800 m^2 **Density:** densely built site.



Project Description	
The courtyard: • An underground garage and a courtyard which acts as a green roof over the garage, captures, conveys and displays all rainwater shed from the roofs. • Concrete channels and cascades directs the rainwater into the courtyard, where it visibly flows over back lit and colored glass dotted Cor-Ten steel weirs into rectangular river stone filled detention basins and a 4,000 gallon-cistern underneath the surface. • Water is stored for up to 30 hours and then is gradually discharged to the public stormwater system. • Ornamental plantings grace the arrangement and create a connection between the building's hard materials and the technical elements necessary for managing the rainwater.	
Water sensitivity	• The stormwater management – through detention - reduces the excess runoff rate, suspend solids and pollutants. **However, the courtyards' rainwater management system could have been made more comprehensive by also using the rainwater not only for just detention, but also for irrigating plants in the yards.**
Integration with surroundings	• The courtyard uses materials which match the design objectives of the building complex. • The courtyard's elements orthogonal arrangement matches the orthogonal structures of the surroundings. • By using rainwater for art, the courtyard has become an oasis in the dense urban area.
Appropriate usability	**Through a combination of natural and urban structures, the courtyard serves several uses;** • Enjoyment for the residents to enjoy. • Providing space for nature (planters with perennial and ornamental shrubs planted in black pots). • Serving the demands of rainwater management by giving space to and emphasizing the water running from the roof to the ground.
Public involvement	The involvement of the future users did not play a role in the planning of this project.

Source: (Hoyer et al., 2011; Rodes, 2006; Echols and Pennypacker, 2008; Google Earth Images), Adapted by the researchers

The analysis and results for these three international examples for WSUD applications are presented in the following table (e.g. Table 7).

Table 7: Analysis and results for WSUD international examples

Measure code	Project		
	Tanner Springs Park	**Hohlgrabenäcker**	**Hoyt Apart. complex**
BPP1			
BPP2			
BPP3			
BPP4			
PDR1			
PDR2			
PDR3			
PDR4			
PDR5			
PDR6			
PDR7			
PDR8			
SWM1a			
SWM1b			
SWM1c			
SWM2a			
SWM2b			
SWM2c			
SWM2d			
SWM2e			
SWM2f			
SWM2g			
SWM3			
SWM4a			
SWM4b			
General comment	This project is a prime example of how stormwater management can be realized in a public park setting, and how its measures can lead to an attractive design.	Urban planning and water management Cooperation to find the right combination of measures can lead for better stormwater management and with decreasing costs.	This project is one of the top examples of artful rainwater design in the United States. The rainwater was creatively displayed and treated in the courtyard.
Most Used measures	• The park has successfully applied several measures from the two levels of WSUD practicing.	• The project has used several measures from the two levels of WSUD practicing.	• The project has used several measures from the two levels of WSUD practicing.
	• Potable water measures were of limit usage in the project.	• From best planning practices, the park applied all measures.	• From best planning practices, the park applied only one measure (BPP2).
	• It is obvious from the nature and scale of the project as a public park that it focused mainly on landscaping measures as well as urban design measures.	• It is obvious from the nature and scale of the project as a residential community that it focused mainly on urban design measures, besides some of the best management ones.	• It is obvious from the nature and scale of the project as a public park that it focused mainly on architectural and landscaping measures rather than urban design ones.
Public involvement	Existed	Existed	Not existed

Source: The researchers

5. CASE STUDY

5.1 Brief on selected area

The following maps show the selected area for case study (e.g. Fig. 7), it's a (low-income) administrative housing area for technicians working in the Suez Canal Authority - Port Said – Port Fouad. This area was created in the sixties & seventies of last century.

Figure 7: Location of prject site, *Source: The researchers*

5.2 Urban characteristics and functions

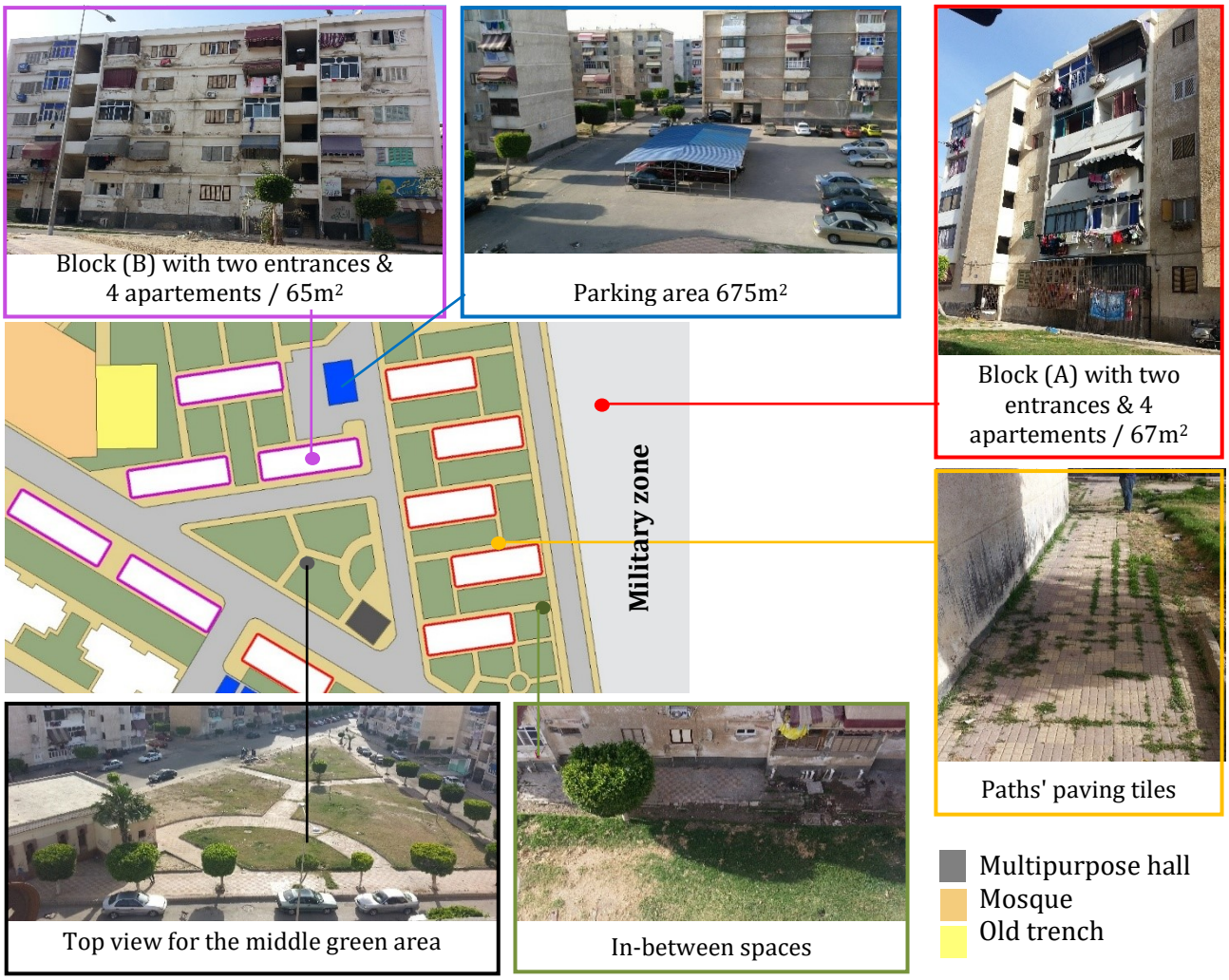


Figure 8: Urban characteristics & functions , *Source: The researchers*

5.3 Drainage system

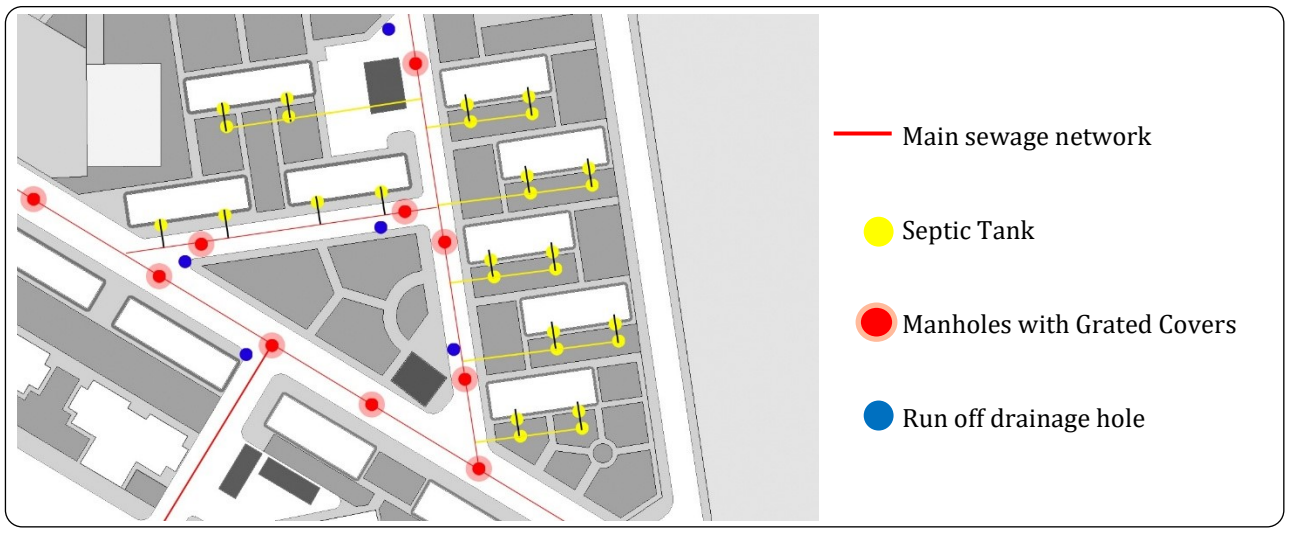


Figure 9: Drainage system, *Source: The researchers*

5.4 Climatic conditions (Rainfall rate/Humidity)

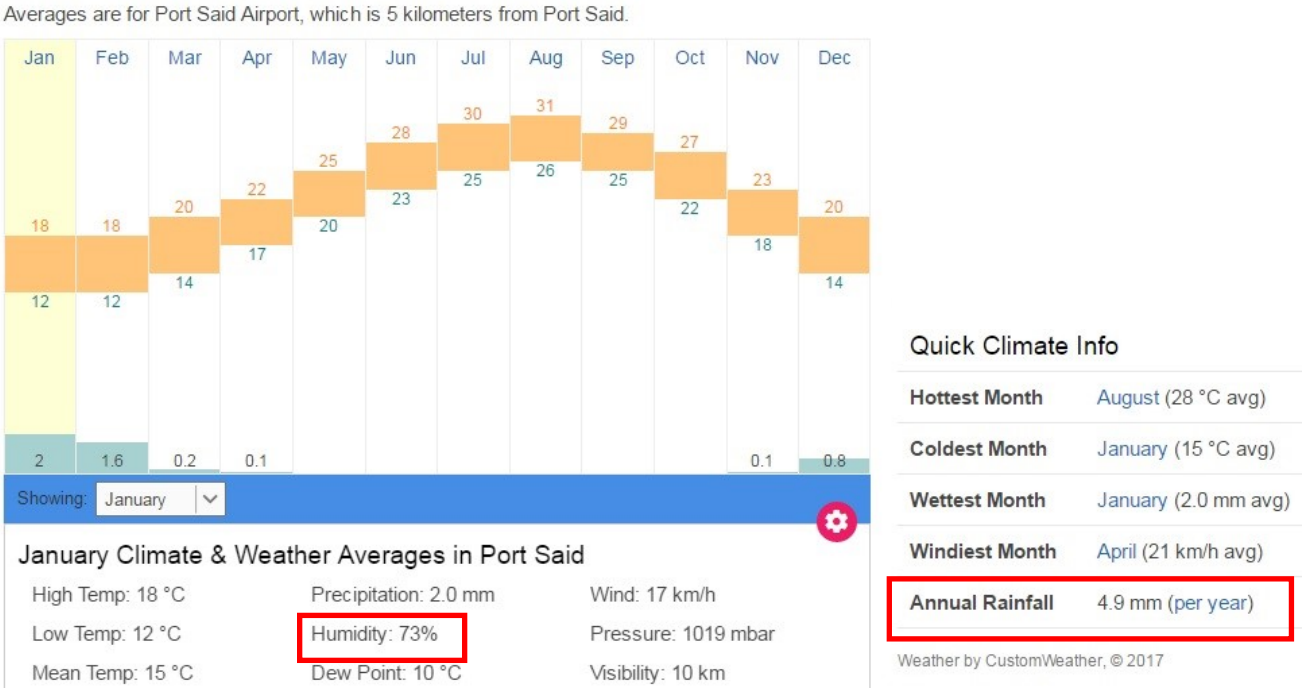


Figure 10: Climatic datat of Port Said, *Source:* https://www.timeanddate.com/weather/egypt/port-said/climate

The above graph reveals the following (e.g. Fig. 10):

- The driest months are May, June, July, August, and September with 0 mm of rainfall. In January, the precipitation reaches its peak, with an average of 20 mm.
- **Annual Rainfall** is 4.9 mm (Per year) >>> **Very Low Range**
- Additionally, the figure shows a high value of humidity 73% according to January average, which increases in summer months.

5.5 *Site (Water Sensitive) Opportunities*

Table 8: Site (Water Sensitive) Opportunities

Block	Roof	• Regular • Spacious: 265m² • Good overlooking	
	Facade	• Almost flat • Regular forming • Two empty/ free sides. • Low heights: **5 fl. = 14m**	
	View	• Every residential unit has at least two sides for outer view	
Urban Spaces	Open spaces	• Large percentage of greens: 33% • Only 16 % built. • Wide in-between spaces • Wide open spaces as parking & trench	
	Paths	• Regular network and well distributed / Diversity of use for vehicles and pedestrian	
Sewage	• Existing of rainwater drainage network / Regular lines for Sewage network		

5.6 *Site (Water Sensitive) Problems*

Table 9: Site (Water Sensitive) problems

OF Residential Block		
• Installation of sewage pipes on the external facade	• Drainage of rain water on the outer skin of facades	• Permeability of rain water to the stairwell through top holes
		
• Roof is utilized with random installations of satellites	• Nondurable roofs tiling - rainwater accumulation	• Poor aesthetic image
		

OF Sewage System

- Frequent overflow of sewage water on paths and streets


- Prominence of Septic Tanks through green yards

- Overflow of sewage through rain water drainage sinks


- No use of grey water

OF Open Urban Spaces

- Dredged Grasses

- One kind of grasses used in green areas

- Random distribution of neglected L.S. elements

- Low maintenance for L.S. elements

- Impermeable paving used for pedestrian paths

- Lack of rain water streams and fountains

- Waste of clean water in the irrigation process

- using greens as parking causes degradation of grasses

- Lack of Knowledge, Acceptance and Awareness of inhabitants about water resources.
- Low involvement of inhabitants in the process of conservation.
- Poor procedures are taken by the authority for maintenance

Source: The researchers

5.7 Measures Filtration Method

Site & climatic conditions, project type, water resources and implementation scale, should be considered as key factors influencing effectively in selecting the appropriate and effective WSUD measures, solution and procedures that are compatible with all these conditions and features.
Subsequently, a proposed filtration method will be introduced for achieving this objective. All actions will be displayed on multiple filters that represent the site/project conditions, scale, problems and opportunities (e.g. Table 10). Any measure/solution that does not comply with one of these filters will be withdrawn. So that, the set of remaining measures that correspond to these filters will form the appropriate procedures for integrating WSUD with this type of projects, refer to Figure 11.

Table 10: Definitions of filters

Filter name	Symbol	Description
Project Type	**F1**	Indicates that the project belongs to renovation type … not a new design.
Implementation Scale	**F2**	Indicates that the implementation will be an urban or/and building scale, not planning.
Water Resources	**F3**	Solutions will depend mostly on Greywater & Potable water. Limited solutions will rely on rain water cause of the very low annual rainfall average.
Site Opportunities	**F4**	Illustrated in point 5.6 Site (Water Sensitive) Opportunities & climatic conditions.
Site Problems	**F5**	Illustrated in point 5.7 Site (Water Sensitive) Problems.
Residential Level	**F5**	Indicates the low residential level … neither medium nor high level.

Source: The researchers

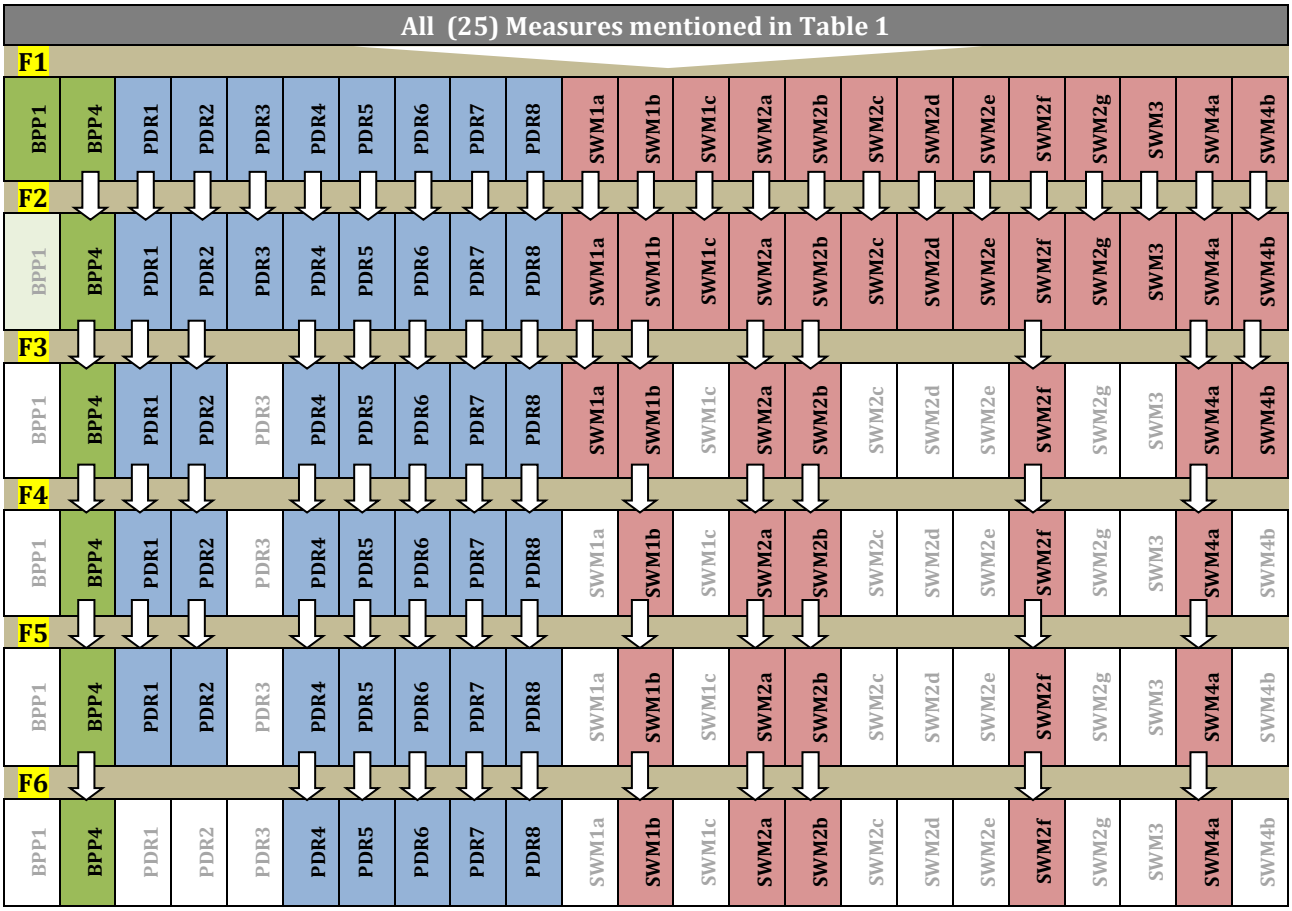


Figure 11: Filteration of measures. *Source: The researchers*

5.8 Guidelines for WSUD implementation potentials

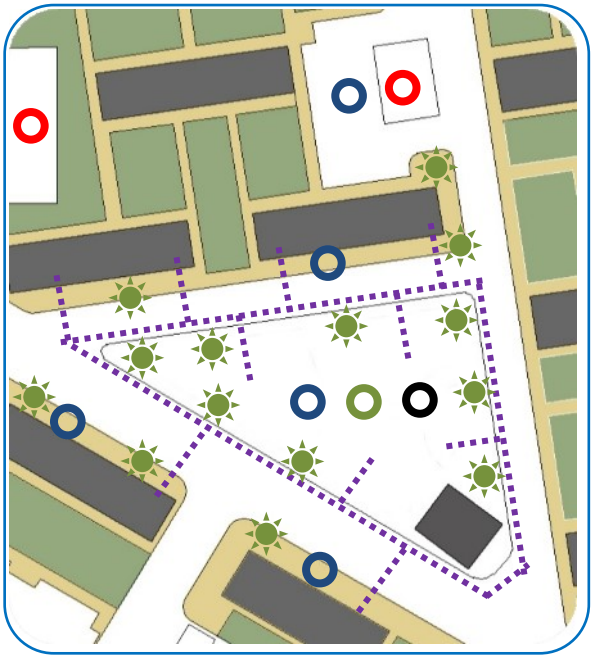
According to filtrated measures, problems and opportunities of site, proposed guidelines of measures implementations will be presented to identify ability of WSUD potentials in enhancing urban life (e.g. Fig. 12). This will be investigated through addressing problems and opportunities effectively. Furthermore, the proposed guidelines framework will be examined according to principles of WSUD. Solutions can be distributed upon three zones: intermediate zone, in-between spaces & built blocks.

INTERMEDITE ZONE

- **Potential Measures:**
  - Reticulated Recycled Water to utilize the recycled supply as a non-potable water source.
  - Grey water Treatment & Reuse to reduce sewage flows and achieve savings in potable water in irrigation.
  - Biotopes & Changing landscape form to add the aesthetic amenity of ponds, water features and green surface.
  - Aquifer Storage to store waste water and rainfall under parking area (in peak periods) to be reused.
  - Street trees & pits to improve aesthetics and reduce the need for manual water.
  - permeable and porous paving To reduce the accumulation of rainwater
  - Passive evapotranspiration with vegetative cover for runoff volumes reduction (while peak periods)
- **Problems Solved:**
  - Negative impact of rainfall drainage line will be disposed.
  - Replacing garbage tanks areas and improve visual image.
  - Improving pavement conditions.
  - Eliminating the phenomenon of stray animals.
  - Reducing unused sunny areas
- **Gained Opportunities:**
  - Supporting external usage and toilet flushing with recycled grey water through run off drainage line.
  - Improving air quality of public open spaces.
  - Using wide open areas for underground aquifers.
  - Supporting social dimensions with multiple treatments.

Implication of WSUD Principles

P 1 | P 2 | P 3 | P 4 | P 5

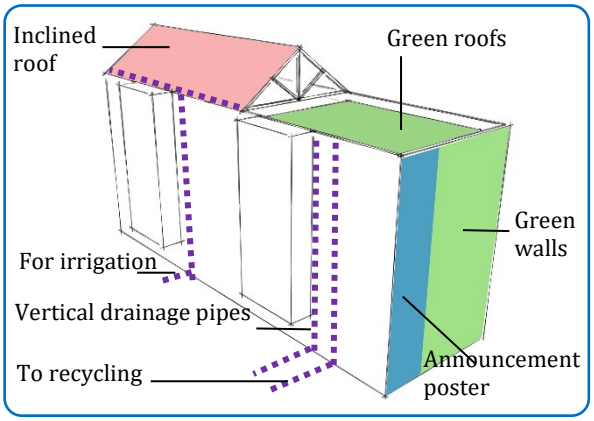


Built Blocks

- **Potential Measures:**
  - Roof top retention using inclined roofs partially to reduce runoff flows and enhance architectural identity of project.
  - Green Roofs & walls to reduce runoff volume and provide thermal and social benefits.
  - Grey water Treatment & Reuse by using external vertical pipes & debris filter canal around block boundaries.
  - Water Quality Education using on-wall announcements.
- **Problems Solved:**
  - Preventing rainwater intrusion into upper floors.
  - Renovation of external finishes.
  - Minimizing maintenance & insulation costs of roof.
  - Reusing of drainage pipes as an architectural element
  - Preventing graffiti.
- **Gained Opportunities:**
  - Conserving visual identity of residential blocks of SCA.
  - Utilizing horizontal parts of roofs socially with its view.
  - Utilizing the two empty facades effectively.

Implication of WSUD Principles

P 1 | P 2 | P 3 | P 4 | P 5



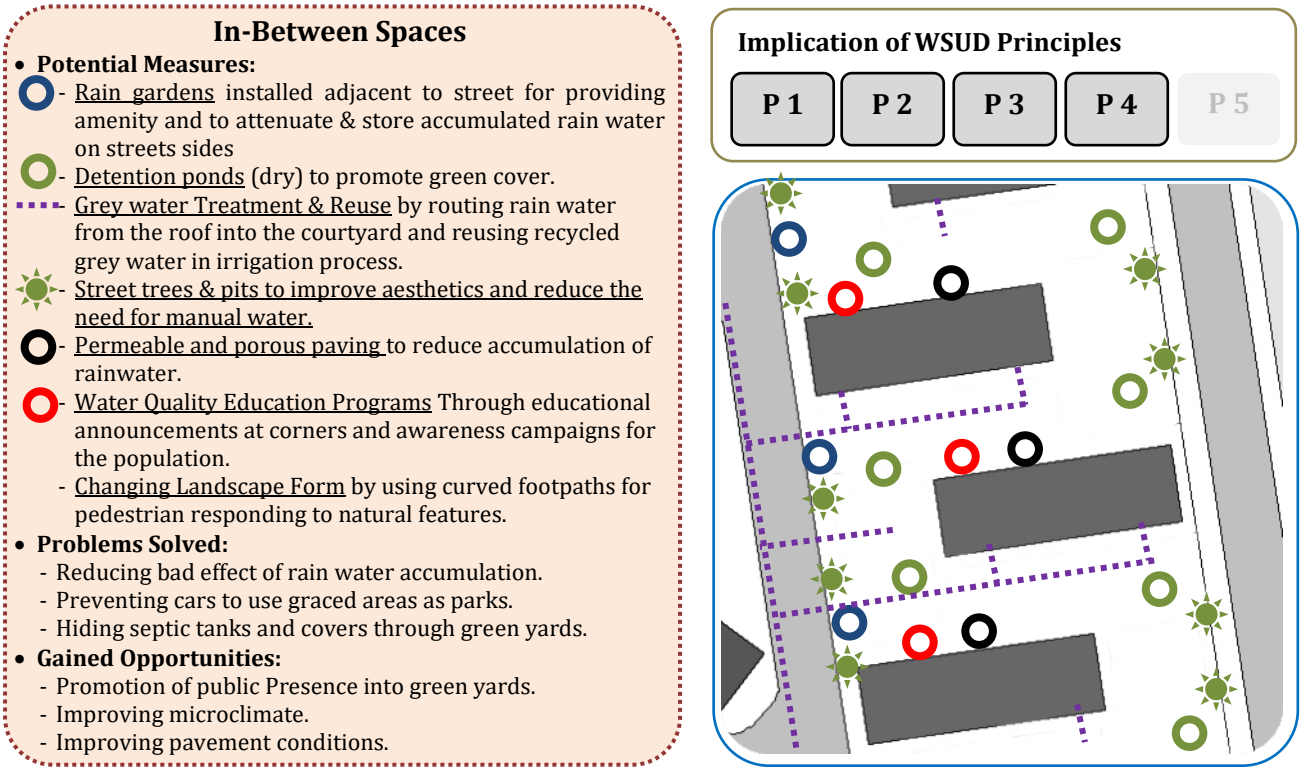
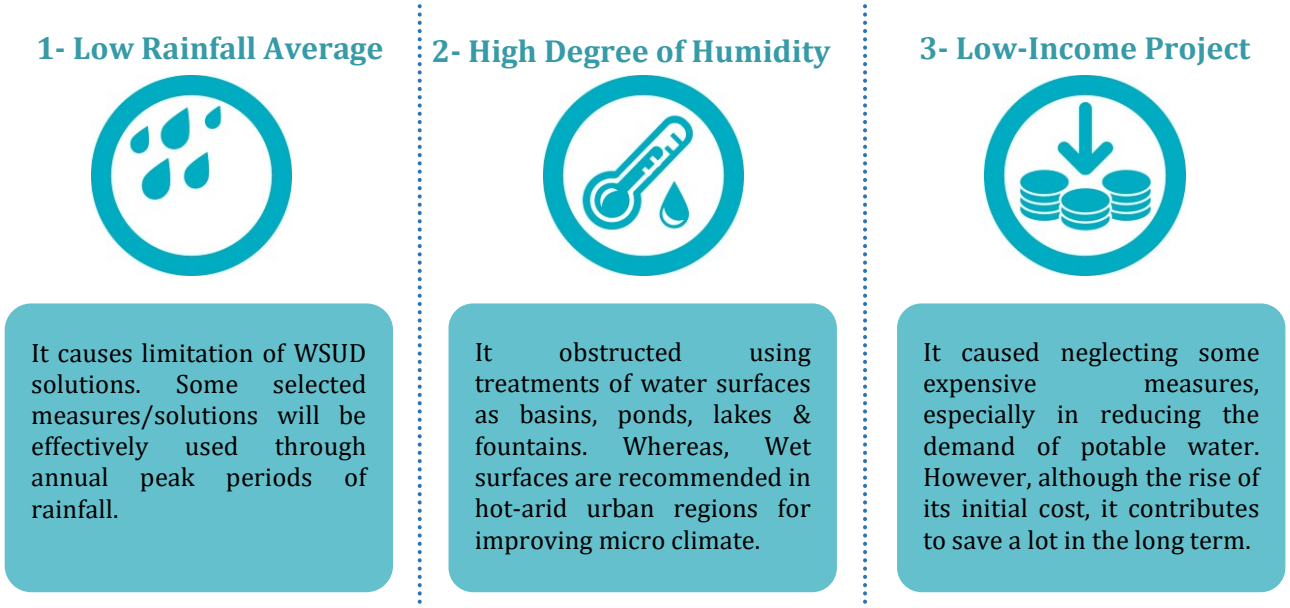


Figure 12: Guidelines of WSUD implementation in case study. *Source: The researchers*

After illustrating the framework of proposed guidelines, it is clear that, specific 6 keys contributed to formulate its main objectives & executive steps. These keys are related to aspects and conditions of case study. In addition to, selection of solutions/measures compatible with site conditions and redirecting it to exploit opportunities and solve site problems contributed to the achievement of WSUD principles and to help in enhancing sense of place for the community. Contribution of these 6 keys can be discussed in the following figure (e.g. figure 13):



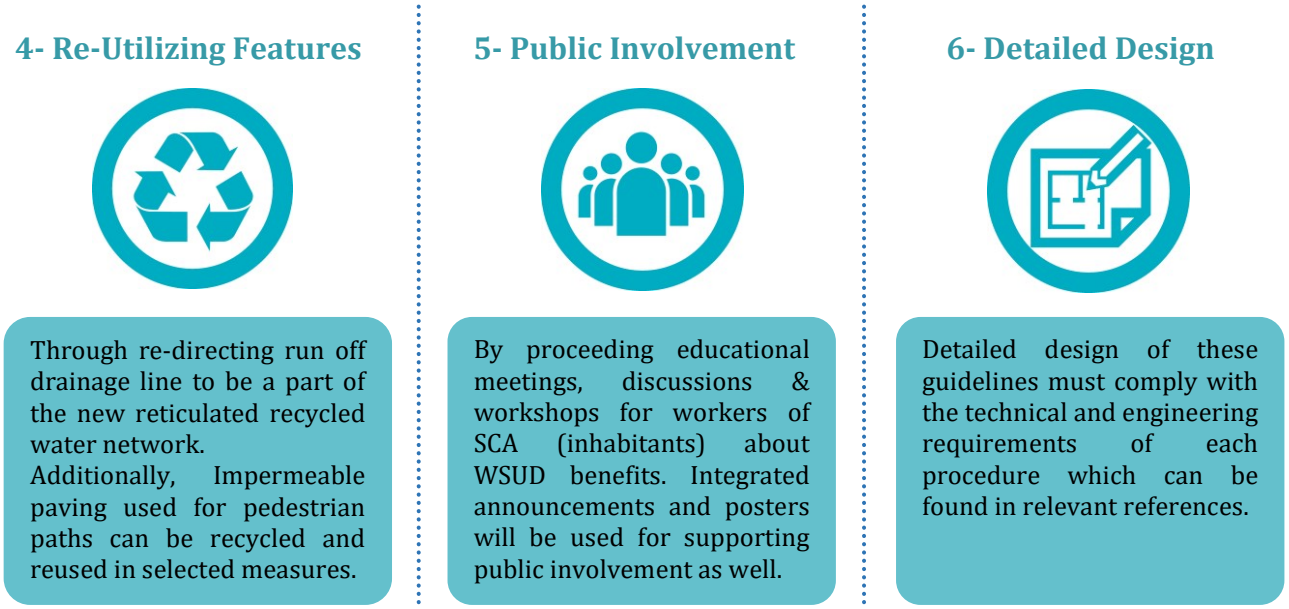


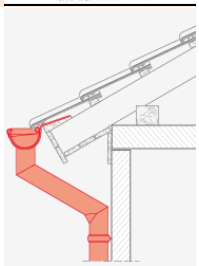
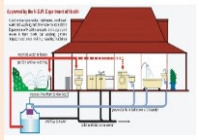
Figure 13: Contribution keys of proposed guidelines. *Source: The researchers*

6. CONCLUSION

The results and findings of this research have corroborated with the ideas, issues and concepts introduced and discussed in the literature. The research reveals the contribution WSUD can participate with in the rehabilitation of low-income residential projects. Within mentioned constraints for our case study and handled filtration process, the research reached that WSUD can participate in three items of the six items of rehabilitation standards discussed formerly in this paper (building structure, plumbing, and environment). The other three items are out of concern in WSUD measures and applications.

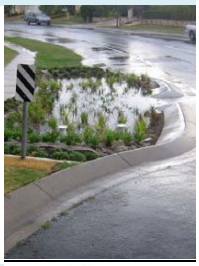
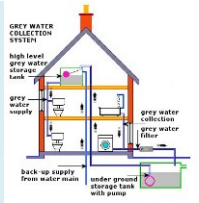
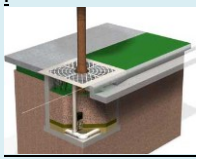
The aspects that WSUD can participate with for supporting rehabilitation process (within these three items of rehabilitation standards) for low-income residential projects are summarized in the following table (e.g. Tables 11 & 12):

Table 11: WSUD contribution in Rehabilitation process (Building structure and Plumbing items)

Rehabilitation standard Items		Aspect	WSUD Contribution	Shot
Building structure	**Wall construction**	**Exterior wall coverings**	Whenever there is an intent to install new wall covering: • They should be weather tight. • They should be of elegant visual appearance. • Reasons for specific covering should be considered (**e.g. green wall**).	
	Roof construction and drainage	**Roof/ceiling framing**	The roof framing should carefully consider that: • Roof drainage slopes are towards the perimeter edge. • There should be a controlled water collection and discharge system (**e.g. inclined rooftop**).	
		Roof coverings	For the long-term durability and habitability: • Roof coverings should provide a waterproof barrier. • The roof covering materials should be able to shed water (**e.g. green roof**).	
		Roof gutters and downspouts	The following should be carefully considered when installing gutters: • They should be properly sized, positioned, secured, and connected to the structure to facilitate roof drainage collection and discharge. • For each roof slope, they should be placed at the bottom edge of it. • There should be at least one downspout for each 600 ft² of drainage area.	
	Green building	**Use the land responsibly**	The following should be put in consideration: • To conserve open space, clusters should be kept together on smaller lots. • Impervious surfaces should be limited to reduce local water sources contamination (**e.g. green surfaces, permeable paving & rain gardens**).	
		moisture resistant houses	The following should be Kept in mind: • Buildings should use green materials and technologies (**green roof/wall**).	
		Wisely use the earth's natural resources	For water resource, consider the following: • Best water resource use with no harm to health or environment. • This includes: usage, disposal, reuse, or recycling options (**e.g. grey, recycled and waste water management**).	
Plumbing	**Water supply**	**Support of piping**	When installing pipes: • All pipes should be properly supported to prevent sagging/breakage. Noise should be reduced through proper support, insulation, design techniques, and neat installation.	
	Plumbing fixtures	**General requirements**	All plumbing fixtures should be made of materials impervious to water with adequate seal (**e.g. water conservation**).	
		Installation of fixtures	When installing fixtures and appliances: They should be free of leaks (**e.g. water conservation**).	

Source: The researchers

Table 12: WSUD contribution in Rehabilitation process (Environment item)

Rehabilitation standard Items		Aspect	Description
Environ-ment	**Premises and dwelling condition**	**Prioritization of a safe sanitary environment**	• The site should provide a safe and sanitary environment for occupants. • Problems in site drainage should be solved (e.g. water conservation).
		Drainage	Drainage system should consider the following: • Places near buildings should be free from large or deep depressions that routinely collect stagnant water. • Places near buildings should be free from improper grading or settling that causes erosion or the potential for infiltration of water into buildings. • Surface drainage should be diverted to a storm sewer conveyance or other approved point of collection to avoid hazard (**e.g. rain gardens**). 
		Cisterns	Cisterns safety considerations **for grey water collection**: • Cisterns should be evaluated to look for any hazards that may be present. • Cisterns should be properly filled and covered as necessary for safety. 
		Paved surfaces	Concerning **permeable (porous) paving**: • It should be free from hazards which can cause tripping and falling. • Paved surfaces adjacent to the foundation should not slope towards the structure to avoid drain towards the foundation. 
		Trees, shrubs, and landscaping	For an efficient landscaping, consider the following: • A fine finish grading should be done around buildings and across the in-between spaces "yards" (**e.g. Passive evapotranspiration**). • These yards should be seeded or sodded with appropriate grass and/or ground cover "simple landscaping" (**e.g. biotopes**). • If trees and shrubs are planted, they should be put as far as possible from the buildings to avoid foundations split and crack from trees roots (**e.g. street trees and pits**). • The turf selected will have an impact on the water bill, and maintenance and watering requirements, thud should be considered carefully (**e.g. rain gardens**).  
	Occupant health	**Water supply**	Potable water should be supplied for all dwellings through safe plumbing system for the occupants' health (**e.g. potable water conservation**).
		Sanitary drainage	As for **grey water** reuse after treatment: All plumbing fixtures (e.g. sink, lavatory, bathtub, shower, toilet, etc.) and appliances (e.g. dishwasher, clothes washing machine, etc.) should be properly connected to a sanitary drainage system, whether a public system or an approved private one.

Source: The researchers

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