Towards Green Stormwater Management of Heritage districts.

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Abstract:
Climate change is a stressful matter on the heritage assets and heritage districts that are vulnerable to the effect of all changing weather conditions. In addition, increased rainfall and flooding, humidity, and stormwater also can affect negatively on the heritage districts causing (fragile ornaments destroy, fungal growth, molds, erosion, and decay). Many heritage districts located in developing countries have traditional combined sewage systems for both of rainwater and domestic sewage. This leads to making these districts at greater risk of flooding in the case of heavy rains than the other districts that have separate rainwater sewage. "The combined sewage systems of the greater Cairo backed to 107 years ago and it is not capable of receiving more than 4 mm of rainfall by the head of the sewage company of Cairo ". According to the history data of precipitation from 2009 to 2012 performed by the researchers, the city received 12.3 mm/hr on 17th Jan. 2017, 5.2 mm/hr on 5th Dec. 2018, and 4.8 mm/hr on 17th Jan. 2011 as examples. This illustrates that the current sewage systems are unable to drain these heavy rainfall volumes causing water flooding the heritage districts of Cairo damaging the fabric of their heritage assets which has a certain geometery help in this deterioration. **This study aims to** outline the management plan for the rainfall of stormwater of heritage districts according to the criteria of green neighborhood rating systems tools. The historic El-Moez Street is selected (one of the oldest districts in historic Cairo constructed between the years 969: 1171) as a study area. From the comparative study of 13 of the green neighborhood rating tools that have been used all over the world, this study has selected only two systems (GBC quartieri and LEED v 4.1 for cities and communities) to evaluate the rainwater management in El-Moez. St. According to this study, the rainwater runoff volume has been managed in El-Moez street by the grid pavers of basalt. The landscape areas are insufficient to earn any points in the management of stormwater credits of both of (GBC quarteri) and (LEED v 4.1 for cities and communities) due to the lack of the application of LID and GI rainwater management strategies such as the lack of green areas that are located in the heritage district. Additionally, not adopting the rainwater store systems that can be reused in harvesting or indoor applications and the greater area of impervious surfaces rather than the permeable areas that decrease the rainwater infiltration to the groundwater. The green rainwater management credits in the evaluation of heritage districts do not include any considerations or special criteria for the heritage buildings in the assessed districts. Consequently, none of them set criteria for protecting the facades of heritage buildings that could have fragile objects destroyed by heavy rains. Results revealed the main outline of stormwater management of historic districts that have the same aspects of El-Moez urban hierarchy.

Keywords:
Green Stormwater Management, Heritage Districts, Historic Cairo, El-Moez Street, Neighborhood Rating Systems.

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1. Introduction
1-1. Addressing the environmental risks
By the time at 21st century, climate change considers as an environmental risk studied by international organizations, where it goes beyond natural disasters as no one can predict the climate change’s impact, thus it is classified as a priority at risk management. (Jokhilito, 2000) highlighted this risk to deal with it when an emergency happens, but it should be inscribed daily as a routine.

Staniforth, Fielden also introduced the early definition of risk as the probability of loss as it increases when hazards meet vulnerability. Hazards defined possible vulnerability as the level of loss that is related to certain risks and the idea of risk formulated in the risk guideline in 2010. He connected between risks and vulnerability where he defined hazard as a disaster event in a certain density in certain places and defined weakness as the amount of loss that an element can bear from certain hazards. This concept ensured by UNESCO 2005 as the administration elements cause risks. (Stovel, 1998)

The risks of the heritage districts consist of ensured or probable risks that can threaten their heritage assets. The risk of stormwater is one of ensured risks including material deterioration, structural deterioration, authenticity loss, and cultural significance, while probable risks are reduced by legal protection level, modifying its legal situation, conservation policies, regional planning, armed conflict… etc. Risk management including the risk management of stormwater in the heritage districts depends on the perception of the risks sources during the rehabilitation project and after the completion of the project. (UNESCO, 2010)

1-2. The stormwater risk on the heritage districts

Increased rainfall and flooding, humidity, and stormwater are the most risks resulted from the climate change affecting negatively the heritage assets. The character of Urban and the geometry of the streets and buildings are assumed to have relationship with the risk impact on the heritage districts as a follows: (World Heritage Committee, 2006)

- **Increased rainfall and flooding:** the heavy rainfall and the resulting flooding are the risks that threaten the heritage buildings, while the traditional rainwater drainages in heritage sites could unable to drain the heavy rainfall. This may happen if they are not clean or blocked leading to water flooding and damaging the fabric of the heritage buildings whose materials were not designed to withstand prolonged immersion. Post flooding drying may encourage the growth of damaging microorganisms such as molds. Rapid flowing of rainfall could lead to eroding the monuments and heritage buildings. Heavy rainfall also could increase the soil moisture resulting in greater salt mobilization and consequent damaging crystallization on decorated surfaces of heritage building through drying.
- **Humidity:** the higher temperature and increased rainfall lead to a more humid environment that could be ideal for fungal growth as well as insect and pest infestations. This leads to damaging the internal of fabric of the heritage buildings, especially timber and other organic materials that may be subjected to increased biological infestation leading to rot and decay. Humidity affects the exterior of the heritage buildings by arising the fungi growth.
- **Storm waters:** strong winds combined with stormwater causes structural damage of heritage building and damages the heritage roofs as tiles, windows, awnings, gypsum or wooden ornaments and other features of heritage buildings. The objects that are ripped off and fall cause the danger to the people who live or work in or around the heritage buildings.

1-3. Challenges of the stormwater risk management and monitoring:

The major challenge of the stormwater management is the funding, where there is no grey stormwater infrastructure at the heritage districts. If it exists, it may be cost because of maintaining, operating, and recycling. The stormwater runoff volume is exposed to evaporation resulting in wasting this clean source of water. The pollution challenge is also the essential risk to the storm water management, as the recycle depends on keeping the water clean. This matter is a hard condition for the historic districts that have high urban density including some industrial activities. (Quadriga, n.d.). In addition, heavy urbanization also affects the stormwater management due to the infiltration patterns such as using the impervious surfaces and extending the urban footprint compared to the green areas. (Sustainable prosperity, 2006).

2. Green management of storm water strategies in urban districts

The runoff of rainwater is one of the causes of pollution for water bodies. The waterproofing of soil is resulted from urbanization processes (the construction of roads and parking) produces rainwater containing suspended solids and other contaminants. These contaminants involve pesticides, fertilizers, and fluid leaks of vehicles, which are the danger to animal species on water bodies. Increasing in rainwater volumes that are drained by sewage systems can cause overloading the sewage systems and decreasing the efficiency of water treatment plants. Moreover, this causes the frequency of the runoff of rainwater on impervious surfaces that can lead to an increase in flood and erosion. (GBC Italia, 2015, 351-355).

Green infrastructure (GI) and low-impact development (LID) can reduce the volume of rainwater runoff. Their techniques range from low-cost and low-engineering systems to complex systems. Vegetation and soils are used in urban and suburban areas to manage and treat rainwater volumes naturally rather than drain to sewage systems. The techniques and strategies of (GI) and (LID) rainwater management depends on minimizing the buildings footprint and the amount of impervious cover using preamble surfaces and porous asphalt. The strategies of infiltrating, detaining, and evaporating (by using the vegetation covers) or storing rainwater runoff to reuse it for irrigation or for indoor applications are adopted. Additionally, rain gardens, green roofs, green walls, vegetated channels, vegetated filtration strips, and bioretention. (Arazan, 2015) (USGBC, 2019, 57) (GBC Italia, 2015, 351-355).

Figure 1. LID and GI strategies of rainwater management, source: Arazan, Nancy. (2015).

3. International green neighborhood assessment tools

Green neighbourhood can be defined as moderately dense and mixed-use district. It has been designed at a human scale ensuring a diversity of services and amenities, activating neighbourhood, and orienting public transportation to "green". (Vivian et al, 2018).

A green neighbourhood assessment system is a tool that evaluates sustainability performance of the target neighbourhood/ districts by a set of criteria. These criteria take the environmental aspects, high energy performance strategies, and the quality of life of the inhabitants into consideration. There are two types of green neighbourhood assessment tools: decision-making tools such as neighbourhood scale planning (e.g. HQE sustainable urban planning, Ecocity, Eco-Districts Performance and Assessment, SPeAR, and One Planet (Communities) Living,) and third-party building assessment systems. (e.g. LEED (ND, communities and cities), BREEAM (Communities), CASBEE (For Urban Development), GBC Quarteri, Green Star (Communities), BCA Green mark for districts, Pearl community rating system and DGNB districts. (Sharifi and Murayama, 2013) (Reith and Orova, 2015).

Vivian and others make a comparison of twenty the international green neighborhood systems in 2018. (Vivian et al, 2018) according to their study. This study chose the most used system tools for each country and updated the system tools. Some of them has found out LEED neighborhood and LEED community tools (one for new neighborhoods and the second for existing neighborhoods). The research also added a new tool as GBC quartieri for Italy and prohibited the systems tools that apply for the city scale and cannot be applied on neighborhood scale, such as Eco city, CASBEE for city and CASBEE for city pilot version. Table (1) listed 13 of the international green neighborhood systems. This table included last version, the origin of tool, and the ability of using the tool internationally or locally. If the system tool could assess existing or new neighborhoods or both and if the tool could have rainwater management credit, the heritage context was taken into consideration.

Table 1. A comparison of 13 of the international green neighborhood tools. Source: researchers

		Last version	**Country**	**Local vs international**	**assess existing neighborhoods**	**assess new neighborhoods**	**Has heritage context considerations**	**Rainwater credit**
1	**LEED**							
1a	LEED ND (Neighborhood)	2009	USA	Inter.	×	√		
1b	LEED community and cities (plan and design)	2021		Inter.	×	√	√ **High priority site**	**Stormwater management**
1c	LEED community and	2019		Inter.	√	×	√ **High priority**	**Stormwater management**

	cities existing						**site**	
2	**BREEAM**							
2a	BREEAM communities	2012	UK	UK only	×	√	√ Local vernacular	• **Flood risk assessment** • **Rainwater harvesting** • **Water pollution**
2b	BREEAN comminutes international	2012		Inter. except UK	×	√		
3	GBC QUARTIERI (GBC Italia, 2015).	2015	Italy	Italy	√	√	√ Conservazione delle risorse storiche e riuso compatibile "Conservation of historical re-sources and compatible re-use"	• **GESTIONE DELLE ACQUE METE-ORICHE "manage-ment of rainwater"**
4	DGNB districts. (DGNB, 2020).	**2020**	Germany	Inter.	×	√	√ Value stability	• Water cycle systems
5	CASBEE UD for urban development. (CASBEE, 2014).	**2014**	Japan	local	×	√	√ **History and culture**	• Rainwater utilization • Reduction of rainwater discharge amount
6	Green star communities. (GBCA Website)	**2016**	Australia	Inter.	×	√	√ Culture, heritage and identity	• Integrated Water Cycle
7	BCA Green mark for districts version 2. (BCA, n.d.)	**2012**	Singapore	Inter.	×	√	√ Conservation and Integration of Existing Structures and Assets	• Stormwater managemen t
8	Pearl community rating system. (ADUPC, 2010).	**2010**	Abu Dhabi	Abu Dhabi Only	×	√	×	• Stormwater managemen t
9	Green townships. (IGBC, 2010).	**2010**	India	Local	×	√	Social and cultural initiatives	• Rainwater harvesting
10	HQE sustainable urban planning. (HQE, 2021).	**2021**	France	Inter.	×	√	Water cycle management	• Heritage, landscape and identity

From the previous table, only two systems' tools can evaluate existing districts/ neighborhoods and can set heritage context considerations in the case of evaluating the districts that have one or more heritage assets. The research selected (GBC quartieri and LEED v 4.1 for cities and communities: existing) to evaluate the rainwater management in El-Moez. St. at historic Cairo.

3-1. GBC rating system tool:

Green Building council Italia (GBC Italia) is a non-profit organization and is a part of world GBC. It has an agreement with USGBC and used categories and credits from the LEED rating system tools. (GBC Italia Website1). GBC rating system tools have been developed for the specifications of the Italian market and for constructing healthy and energy-efficient buildings with a low environmental impact. GBC Italia has launched four rating system tools until December 2021 as **GBC Historic building**, **GBC home** for residential buildings, **GBC Quartieri** for planning neighborhoods and urban districts, and **GBC condominiums** for multi-stories residential buildings. GBC Italia Website2.

GBC Historic building system tool has been launched in 2016 (last version) and tackled two different approaches: the criteria set by LEED rating system and the extensive know-how gained in the restoration world. It is the only rating system tool currently available worldwide for historic buildings. (GBC Italia, 2021). GBC historic building is identical to historic buildings that were built before 1945 with artisanal and pre-industrial techniques on 50% of the existing technical elements. The tool can also assess the historic buildings establishing after 1945 when they have pre-industrial techniques and historical and cultural values. This tool can be applied on historic buildings targeted by conservation, rehabilitation or major renovations projects including installing HVAC systems, implementing adaptive reuse, or improving the envelope performance with the preservation of the values of historic buildings. (GBC Italia, 2018). GBC Italia added a new category to typical seven categories named " Valenza storica VS" referring to "Historic value".

3-1-1. GBC Quartieri

GBC Quartieri is a rating system tool that can be applied to both new construction districts and redevelopment of existing urban areas. An integrated approach adopted the quality of life, public health, and respecting the environment including the heritage context of urban area (if it would be existed). It encourages the practices oriented the analysis of the urban area combining with environmental preservation, public transport promotion, areas with pre-existing structures, development of services and ,social functions. So, it can be considered as a useful tool for municipalities for the promotion, incentive, and sustainable redevelopment of the urban areas. It can be applied to the urban areas whose size have two buildings as a minimum to areas with size up to 1300000 m2 as a maximum (310 acres).

This tool has 110 points and any project should earn a minimum of 40 points for certification. GBC has 4 levels of certification: certified (40-49) points, Silver (50-59) points, Gold (60-79) points, and platinum for (80+) points, while it has 5 categories such as site location and links, district organization and planning, infrastructure and sustainable buildings, innovation, and regional priority.

GBC Quarteri tool has embedded heritage context considerations through "Conservazione delle risorse storiche e riuso compatibile" credit that means in English "Conservation of historical resources and compatible reuse" under the "infrastructure and sustainable buildings". The credit aims to promote the conservation and compatible reuse of historic buildings and cultural landscapes that may be existed in the district. These assets have a significant content of embodied energy and different values that should encourage preserving them and not demolishing them within the targeted developed area. All intervention strategies could be allowed if all required approvals would be taken from the heritage assets authorities. The project can earn 1 point if the urban area has carried out a conservation strategy for at least one historic building or one cultural landscape object. The project can also earn an additional 1 point if the urban area contains up to five historic buildings. 100% of areas of these buildings could be redeveloped. If the urban area has more than five historic buildings, 90% of their areas could be redeveloped to obtain the additional point. (GBC Italia, 2015, 351-355).

- **Stormwater management credit:**

The credit is "Gestione delle acue meteoriche" that means "Stormwater management". The credit aims to control the volumes of rainwater that does not discharged in sewerage networks and to reduce pollution and soil washout due to the runoff of rainwater, to prevent flooding, and to promote the recharge of groundwater through infiltrating into the pavements' materials or landscape areas. The project can earn 1 point for managing the volume of 80^{th} percentile rainfall event, 2 points for the volume of 85^{th} percentile, 3 points for the volume of 90^{th} percentile, and 4 points for the volume of 95^{th} percentile. The credit using the daily rainfall data is at least 20 years. The project could use (LID) and (GI) strategies to manage the volume rainwater to earn the points of credit. (GBC Italia, 2015, 363-370).

3-2. LEED rating system tool:

LEED (Leader in Energy and Environment Design) is the most used green rating system in the world and it provides a framework for high efficient, cost-saving ,and healthy green building. (USGBC Website1). LEED was founded in 1993 and had lunched the first version in 1998. (USGBC Website2) LEED v4.1 became the last one that has been used since 2019 and it provides third-party verification of green buildings from new constructions to existing buildings, from individual buildings and homes to entire neighbourhoods, districts, and from communities to entire cities. In addition, the ability to assess interior spaces. (USGBC Website3).

For neighbourhoods, districts and city scale systems, LEED presents **LEED v4 Neighbourhood development tool** that can be used for new neighbourhood-scale projects nearing the completion (up to 75% constructed). It was completed within the last three years. (USGBC Website4), **LEED v4.1 for Cities and Communities (Plan + Design) tool** can be used for new cities and communities with planning/ designing stage. (USGBC, 2021). **LEED v4.1 for Cities and Communities(existing) tool** can be used for cities and districts that are more than 75% of their area. (USGBC, 2019).

3-2-1. LEED v4.1 for Cities and Communities (existing) tool

According to section (3), the research also selected the LEED v4.1 for cities and communities to evaluate the study area and GBC quarteri. The LEED's tool is the global rating system and the certificating tool used for evaluating the sustainability and the quality of life in a city or community. It has defined the term "cities" as the political jurisdictions by their municipal governance. It also defined the term "communities" as very urbanized location as districts, counties, and developed or owned urban areas. It has110 points and any project should earn a minimum of 40 points for certification. LEED has 4 levels of certification: certified (40-49) points, Silver (50-59) points, Gold (60-79) points, and platinum for (80+) points. It has 9 categories such as integrative process, natural systems and ecology, transportation and land use, water efficiency, energy and greenhouse gas emission, materials and resources and quality of life, innovation, and regional priority. (USGBC, 2019, 9, 12).

LEED v4.1 for cities and communities tool has embedded heritage context considerations by "High-Priority site" credit under the category of transportation and land use. The credit aims to encourage the preservation of heritage structures and sites that may be existed in the district. A project can earn 2 points if adopting a strategy for heritage buildings in the targeted district such as (rehabilitation, preservation, or restoration). In this context, the project should take all required approvals from the local authorities of heritage assets. (USGBC, 2019, 46).

- **Stormwater management credit:**

The credit aims to reduce rainwater runoff volume, prevent flooding, and recharge groundwater. It has two options for the targeted project to earn the 2 points of the credit. Option (1): if the targeted district is exposed to flooding incidences in the past five years, it presents stormwater infrastructure that has been designed, and the strategies that have been adopted to inspect and ensure maintenance of existing stormwater facilities in the district.

If the district has exposed to flooding, the project should provide (LID) and (GI) strategies that have been used to manage the volume of 60^{th} percentile rainfall event. The option (2) is based on installing green stormwater infrastructure in the district by demonstrating that 35% of land area has green stormwater infrastructure providing bioretention and infiltration services. (USGBC, 2019, 57).

4. El-Moez St- Historic Cairo.

For understanding universal value of historic Cairo, its monuments were various and backed to different eras as "Fatimid, Ayyubid, Mamluk, Ottoman, 20^{th} century and others" where the historic layers of its urban fabric go back to the Middle Ages. Considering historic Cairo, impressive materials witness were constituted for international importance on the strategic, commercial, intellectual, and political level of the city during the medieval period. UNESCO has listed old Cairo that currently named as "Historic Cairo" in the world heritage list in 1979. (ICOMOS, 1979).

In 969, the Fatimid established Cairo at one of the historic eras and the design of their new capital (Cairo that called Al-Qahera in Arabic) is based on the main street (named later El-Moez Street) for the basic established city that had surrounded with defensive walls. (Beeson, 1969). The main street started from Bab-Al Fotouh gate from the north till Bab Zwilah gate at the south, the urban expansion from the south for increasing the length of the original length of the El-Moez street. This street represented multi layers of history and reflected outstanding civilization values. The original design of the street had an urban space between the eastern and western palaces, which were destroyed at the Mamluk era and many religious buildings were built in the location of the palaces.

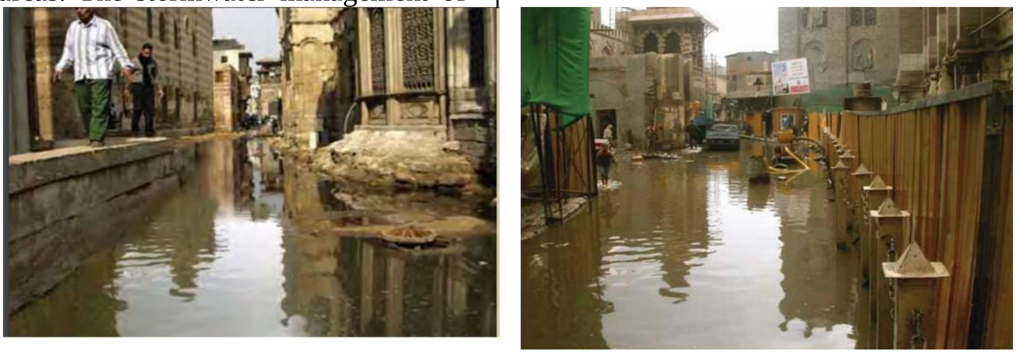
Mamluk Sultan "Enal" in 1457 asked his assistants to widen the main artery of Cairo "El-Moez street", because its capacity was not suitable for the numbers of citizens. In addition, the horizontal extension of the upper floors of old buildings reached to the middle of the street. Therefore, he destroyed parts of those buildings to make the street and its buildings at the same line. Another process was historically proved by the Mamluk sultan Quitbay to increase the capacity of the street. He was Mamluk sultan Al-Ghouri who achieved those developments by constructing mosque, palace, wekala, sabil and Al-Ghouri market and he asked to stretch the street more at that time.

A huge intervention affected negatively the urban structure of Moez by the French campaign. The campaign French leader Napoleon gave instructions to his army to remove all the alleys doors that were designed to separate the urban fabric into semi-closed zones according to the hierarchy of old street of consisting of streets Alley then Sub-Alley "named Atfa in arabic".

The streets previously had different levels and after destroying their doors, the streets were on one level. This leads to non-homogenous designed city representing stormwater management according to the hierarchy destroyed by Napoleon. In the era of Khedive Ismail in the mid of the 19^{th} century, a new street called El-Mosky has been established to connect old Cairo with its other new expanded areas where most of high and intermidiated-level of people walk. This leads to low level of historic Cairo district.

In the 20^{th} Century, Al-Azhar Street has been established with the urban fabric, urban morphology, public spaces unity, hierarchy, and demographic composition of historic Cairo. Al-Azhar street and El-Moez street are divided and each of them has a different community and properties. One of them is used for touristic purposes while the other is used for commercial purposes. Thus, the visual series of the whole street had been lost. These layers of Historic Cairo including El-Moez Street lead to huge infrastructure problems because the levels of the streets changed many times in different eras. In addition, the street lose the stormwater network and the sewage network was damaged as its capacity could not designed for overwhelming the population number. After the great buildings were established in the place of previous building consisting of 2 and 3 floors. All the underground water was pumped from the broken pipes of water and sewage or from the Nile. This is due to the lower level of the historic Cairo than the surrounded areas. The stormwater management of Historic Cairo started from the development plan of the stakeholders. (Ministry of culture, 2008).

In 2002, the Egyptian government carried out the rehabilitation of the Historic Cairo project. The project aimed the northern part of El-Moez Street in the initial of 2002. This stage reestablished deteriorated the infrastructure of the historic Cairo that backed to 120 years ago including the portable water and sewage systems, electricity networks, installing rainwater drainages, lowering the level of the street by 0.7 m to the level of the street in 1920s. In addition, installing basalt pavers for the main street and granite tiles for the sidewalks, and reusing the original basalt tiles in the secondary streets. (Historic Cairo Project, 2006) (Tadamun, 2017). See figures (2) and (3).



Figures 2 and 3. The deterioration of the infrastructure of Historic cairo and its negative impacts on El-Moez street before the rehabilitation project in 2008.
source: Ministry of culture"Al-Muizz Lidin Allah Street- the greatest street", a book published in 2008, by ministry of culture, Egypt. Pages 178, 181.

5. The evaluation of stormwater management of the study area:

The study area is located at the northern part of El-Moez Street and it is the spine of Historic Cairo revealed by figure 4. This area has been selected for having four heritage houses and one multi-uses heritage complex that represents the regional and social uses and the interference between heritage and non-heritage buildings. This area also has one of the most valuable alleys in the Historic Cairo named "Hart El-darb El-Asfar" shown in figure 5. All of these features make the study area to be a model for studying the stormwater management of heritage districts that could be applied on other parts of the street, other heritage districts having the similar features of El-Moez street.

Figure 4. The location of the study area on the map of historic Cairo. El-Moez Street shown in red color.
source: Google earth on 13 Dec. 2021. El-Moez Street showed in red colored line on the map.

Figure 5. the map of study area of El-Moez street. source: the researchers.

According to the visits of the study area by the researchers and the authorities of the sewage of the Historic Cairo, the current stormwater management can be described as a following:

a- There are rainwater drainages in the main street of El-Moez St., every four rainwater drainages collect rain to one manhole of domestic sewage. It can be considered as a combined sewer system.

b- The basalt grid pavers of El-Moez St. with both types (rectangle tiles and square tiles) can infiltrate the rainwater volume to groundwater with porosity 14%, and 30% respectively. Figure 6 shows the porosity of the basalt pavers that have been used in El-Moez St. see also figures 7 and 8.

c- In most alleys and secondary streets of historic Cairo as Haret Eldarb El- Asfar st., rainwater runoff drains to manholes of domestic sewage that opens manually in the rain events. See figures 9-11.

d- The surface water drainage system takes rainwater from roofs of the Heritage and non-heritage buildings of the district to domestic sewage.

e- The surface rainwater of the paved courtyard of the heritage houses drains to the surface water drainage system and collects rain to manholes of domestic sewage.

f- The two main courtyards of (the heritage house no.3) have landscape areas that can infiltrate the rainwater to groundwater.

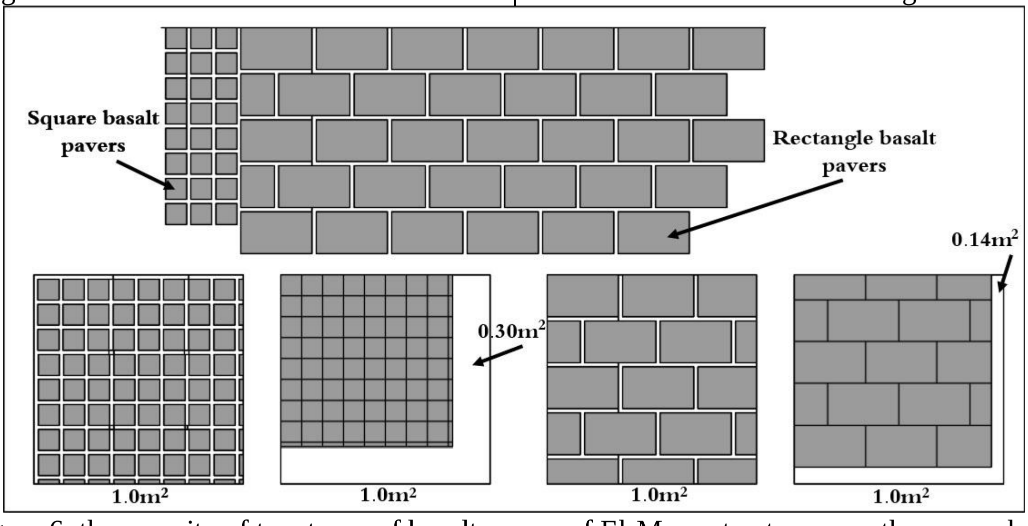


Figure 6. the porosity of two types of basalt pavers of El-Moez street, source: the researchers.

Figures 7 and 8. Shows the basalt pavers of El-Moez street.

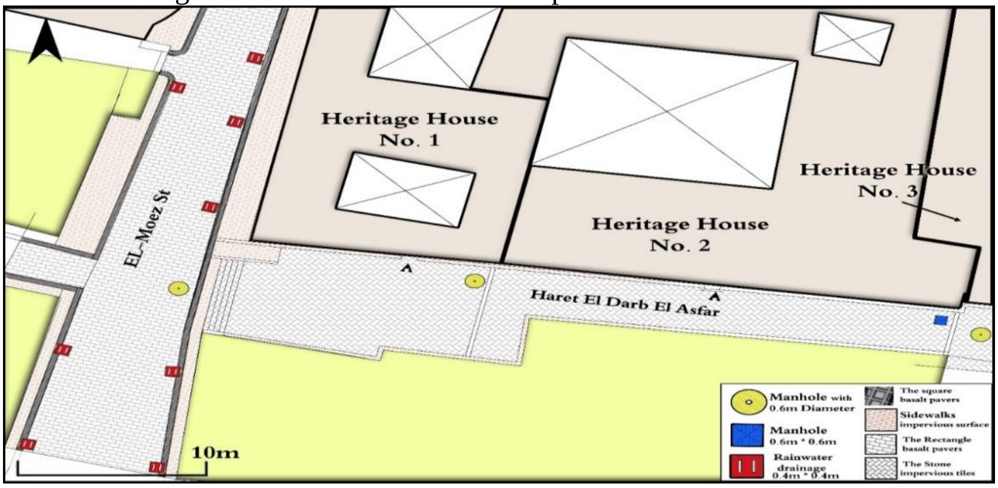


Figure 9. the map of the study area shows the rainwater drainages and sewage systems. source: the researchers.

Figures 10 and 11. The stone impervious tiles of Haret Eldarb el asfar, and the location of the manholes.

		
Figure 12. the main backyard of the Heritage House no.3, source: Ibrahim Kassem	Figure 13. the courtyard of the heritage House no.2. Source: Historic cairo/Facebook.com	Figure 14. the courtyard of the heritage house no.1. Source: Al-Mu'izz ledin llah street/Facebook.com

5. **The evaluation of management of stormwater of the study area that is located in El-Moez St. in perspective of green rating systems' tools.**

5-1. Stormwater management -GBC Quarteri tool (2 points):

Step 1:

According to the head of the sewage company in Cairo: "*The combined sewage systems of the greater Cairo backed to 107 years ago and it is* not *capable of receiving more than 4 mm of rainfall*". (Nassar, 2019). The research used the historical precipitation data from "worldweatheronline.com" that provides precipitation data for Cairo from 2009 to 2021 "13 years". The table 2 highlighted the top days' precipitation that have more than 4 (mm per day and per hour) in the last 13 years.

On 11th April 2015, Cairo received the biggest precipitation estimating 22.3 mm/ day. Cairo also received 12.3 mm/hr. on 17th Jan. 2017, 5.2 mm/hr. on 5th Dec. 2018, and 4.8 mm/hr. on 17th Jan. 2011.

Table 2. the top total precipitation per day/ hour of Cairo from 2009 to 2021. Source: researchers based on the data available on http://worldweatheronline.com

dd/mm/yyyy	Total precipitation (mm) per day	Maximum precipitation (mm) per hour
17/01/2010	**12.4**	**12.3**
18/01/2010	**8.1**	2.8
17/01/2011	**9.5**	**4.8**
28/04/2011	4.4	3.9
27/11/2011	4.3	3.2
13/12/2013	5.1	1.1
09/01/2014	4.3	3.0
15/02/2014	4.6	2.3
03/11/2015	**10.0**	3.6
04/11/2015	**22.3**	**4.2**
09/04/2016	4.8	4.1
12/04/2017	6.1	3.5
05/12/2018	7	**5.2**
05/03/2019	**10.1**	3.6
15/04/2019	5.0	3.3
22/10/2019	5.4	2.9
12/03/2020	4.7	1.8
23/02/2021	**9.4**	3.0

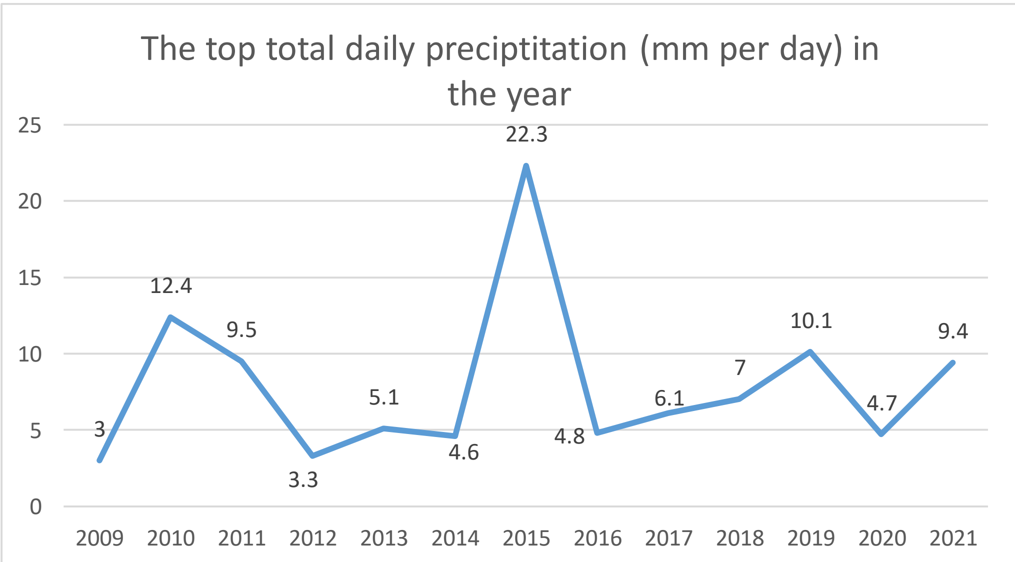


Figure 15. showed the top total daily precipitation of Cairo in the year (from 2009 to 2021). Source: researchers based on the data available on http://worldweatheronline.com

Step 2:

The paper uses LEED rainfall events calculator that has embedded percentile function to determine the rainfall heigh P (in mm) corresponding respectively to the 60th, 80th, 85th , 90th ,and 95th percentiles of rainfall events. See table 3.

Table 3. The historical data of the total rainfall of Cairo and the volume of rainwater required to be managed onsite from the 60th percentile to 100th percentile. Source: researchers based on the excel sheet of LEED according to the data available on http://worldweatheronline.com

Historical Data of the rainfall	mm	Volume (Vt) m3
Total rainfall from the 60th percentile storm event (mm)	**6.82**	**60**
Total rainfall from the 80th percentile storm event (mm)	**9.64**	**85**
Total rainfall from the 85th percentile storm event (mm)	**10.03**	**88**
Total rainfall from the 90th percentile storm event (mm)	**10.56**	**93**
Total rainfall from the 95th percentile storm event (mm)	**13.39**	**118**
Total rainfall from the 98th percentile storm event (mm)	**18.74**	
Total rainfall from the 100th percentile storm event (mm)	**22.30**	

Step 3:

According to table 4, the total surface of all impervious surfaces= 8796 m2

Table 4. shows the total area of each surface of the study area, Source: researchers.

	Total area (m2)	The area of impervious surfaces (m2)	The area of permeable surfaces (m2)
The Rectangle basalt pavers (0.34* 0.2 m)	426	366	60
The Square basalt pavers (0.1*0.1 m)	61	43	18
The other impervious tiles of sidewalks	679	679	0
The total area of impervious surfaces of the roofs of the non-heritage buildings in sector C	2985	2985	0
The total area of impervious surfaces of the roofs and the courtyards of the heritage buildings (4 buildings)	4723	4723	0
The total area of landscape of El-suhaymi house	395	0	395
The total areas	9269	**8796**	**473**

Step 4

Calculate the volume of rainwater required to be managed onsite (Vt)

Vt= A * P/1000= 8796 *13.39/1000=118 m3

* **A** is the total area of impervious surfaces (m2) in the site.

* **P** is 95% rainfall depth (mm)

Step 5

Calculate small storm hydrology method runoff coefficient (Rv)

Rv =0.05+ (0.009* the percentage of impermeable surface of total site) = 0.05+ (0.009* 94.89)

Rv =0.904.

Calculate the current volume of stormwater that is managed onsite (Vr)

Vr = A* Rv* P/1000 = 473*0.904*13.39/1000=5.72 m3, **it represents 4.85% only from the required volume to be managed onsite.**

The runoff volume has been managed in the site by the grid pavers of basalt and the landscape areas in the site that is insufficient to earn any point in the management of stormwater credit of GBC quarteri rating tool. It should manage 85 m3 of total rainfall from 80th percentile storm event to earn 1 point as a minimum.

6-2. LEED Communities and cities: Existing, Rainwater management (2 points):

There are no official reports/ records for flooding incidences in the past five years in historic Cairo. Thus, this paper selected the option 2 for the rainwater management credit.

Table 5. The total area of the surfaces of the study area, Source: researchers.

	The area (m^2)
• Total area of walkways basalt pavers	487
• Sidewalks	679
• The roofs of the buildings	7708
• The total landscape area of the courtyards of the heritage house No.3.	395
Total area	**9269**

The total area of the porous materials and landscape areas	**882**
35% of the total area required to earn 2 points of LEED.	**3442**

The current walkways basalt pavers that can infiltrate rainwater and the total area of landscape equal 882m^2 constituting only 9.5% of the total surfaces area of study area does not meet the required minimum proportion of the credit (35% of land area that should has infiltration services).

7. Results and conclusions:

Many heritage districts located in developing countries do not have separate rainwater sewage system. They have combined system or the semi-separated system such as it is applied in the last rehabilitation project of historic Cairo. Both systems could not drain the heavy rains leading the heritage district to face the threat of flooding that threats the fabric of its heritage assets. Adopting LID and GI rainwater management strategies and techniques in these districts such as (installing raingarden, green roofs, or green walls, using permeable surfaces, and basalt pavers, increasing landscape areas, and/or storing rainwater runoff volume to reuse it for irrigation or for indoor applications) will decrease the rainwater runoff volume that drains to sewage systems.

The green rainwater management credits that have been used in the evaluation of heritage district do not include any special criteria for the heritage buildings could be appeared in the assessed districts. Therefore, none of them set criteria for protecting the facades of heritage buildings that could have fragile objects and could be destroyed by heavy rains.

The rainwater runoff volume has been managed in El-Moez street by the grid pavers of basalt and the limited landscape areas that are insufficient to earn any points in the management of stormwater credits of both of (GBC quarteri) and (LEED v 4.1 for cities and communities). This is due to the lack of the application of LID and GI rainwater management strategies such as the lack of green areas located in the heritage district, the lack of adopting the rainwater store systems that can be reused in harvesting or indoor applications and the greater area of impervious surfaces rather than the permeable areas leading to decrease the rainwater infiltration to the groundwater.

Recommendations:

The research recommended for the study area and all similar sections at El-Moez district including its alleys, arteries, and other heritage districts that have similar aspects to study area to:

1. Increase the landscape areas in the streets and the courtyards of heritage houses.
2. Increase the use of permeable surfaces in the walkways after studying the impacts of this strategy on the level of the ground water and its effect on the heritage buildings, that leading to decrease the volume of runoff of heavy rainwater that drains in sewage system.
3. Adopt the rainwater store systems that can be reused in harvesting or indoor applications.

The research recommended separating the rainwater sewage from the domestic sewage in heritage districts to protect the heritage districts and their heritage assets from the risk of flooding in the case of heavy rains. These heavy rains could damage their fabric and affect negatively them such as (destroy the fragile ornaments, fungal growth, molds, erosion, and decay). In addition, conducting future studies on the impact of stormwater on the facades of heritage buildings and the way of protecting their fabric from the threats of erosion and the damage that could be caused by heavy rains.

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