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The Role of Sustainable Infrastructure in Resilient City Production

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Abstract
Currently 54% of the world's population lives in cities and this rate is expected to reach 66% in 2050. These enormous numbers of people may face various kinds of risks if their cities exposed to natural or human disasters. This requires taking the necessary measures to preserve their lives and properties, through special planning and design measures related to city's infrastructures and buildings to increase their abilities to withstand threats and raise cites potentials to protect the city and its inhabitants from hurt and damage, or at least minimize them. As the majority of the city's components, whether infrastructure or built environment, are rigid components and do not have the flexibility to cope with any kind of disasters, therefore it is necessary to look for new type of infrastructure and buildings that are flexible and capable to face risks. Here appears the **general research problem** related to city weakness and its inability to cope with risks. And the **special research problem** concerning the need to shift to a new type of city called the resilient city. And how this shift can take place? And what are its requirements? **The aim of the research** is to identify resilient city elements like resilient infrastructure that are capable to resist expected or unexpected environmental conditions especially rainstorm. **The hypothesis of the research** is that designed sustainable infrastructures are capable to resist environmental hazards and will help to produce the resilient city.
Keywords: Resilient city, Sustainable drainage infrastructure, urban floods.

1. Introduction

Cities are made of complex interconnected weak fragile systems that are unable to cope with any expected or unexpected internal or external threats, whether they were environmental or non-environmental phenomena. These systems contain several elements such as buildings, public spaces and infrastructure, that define cities nature, character and standard of living, but in the same time they are threatened by natural and human hazards. So there is a need for strong and flexible elements that can withstand these threats and risks, in order to build a base for a modern type of cities called the resilient City. Statistics in 2001 show that the world exposed to 700 natural disasters caused the death of 25000 people and the loss of 47.5 billion dollars (Munich Re group, 2001). These loses requires measures to face disasters and find ways to reduce its impacts on cities around the world. These measures linked to risk reduction policies that aim to:

• Make communities flexible and capable of confronting all kinds of threats.

• Prevent or reduce risks facing cities inhabitants and their properties in the long term. (UN Commission of Sustainable Development). Urban risks can be identified as one of the risks that facing cities around the world, and there is a need for a flexible city model capable to face shocks and disasters without being subjected to direct chaos or permanent damage, because it is planned and designed in advance to cope with such threats. These cities also have the ability to recover from disaster effects, for cities may be affected by shocks but it will not destroy them, and this will help cities to be developed stronger and better.

2. Cities risk reduction policies

All parts of cities are exposed to damage during disasters; this includes its infrastructure, buildings, transportation networks or its energy production and transmission systems. Increasing the strength and rigidity of these facilities to increase their resistant to risks is not enough, for there is a need to adapt special design conditions and regulations to increase flexibility in them. Researcher Godschalk points out that the policy of reducing urban impact should aim to create resilient communities capable to cope with extreme conditions in resilient city that he describes as a "network of sustainable systems and societies" that includes:

- The physical system represented by the city built environment and considered as the body of the city that must continuing working even if the city exposed to risks. And if part of it stopped, the process of restoration will be quick, and other stand by systems will replace the damaged ones. So we need flexible built environment, and without them cities will be weak and vulnerable.
- Community system: this represents the mind of the city directing its actions and determining its specific needs to deal with disasters, this will require a conscious system that can work effectively even in extreme emergencies facing cities.

The old methods of coping with shocks focused on increasing the strength and resistance of city's physical system, because the failure of these systems after trauma will lead to direct casualties. While modern methods focused on community system, and the importance of educating communities to improve the ability to deal with

disasters and reduce risks. This will produce flexible members of the new community. Therefore, new cities should be flexible rather than rigid and breakable, that will enable them to function in all circumstances whether the risks were natural or human assaults, because there will be good embedded environmental protection measures in city planning and infrastructure capable to resist risks (Godschalk, 2001,271-282).

3. Resilient

The term "Resilient" developed in the seventies of the last century within the field of (ecology), the researcher (Holling) indicates flexibility as the insistence on maintaining relationships and links within the system besides it measures the ability of the system to absorb shocks and resist variables (Holling, 1973, p.17). Flexibility is also defined as the ability of the system to absorb disturbances and reorganize until it restores its original function, composition, and personality. These definitions also includes the ability to learn from past and subsequent disturbances and shocks (Post Carbon Institute, Resilience, 2012) Therefore, resilience can represent the ability of society and ecosystems to absorb disturbances while maintaining the same basic configuration and modus operandi. It also indicates the ability of systems to self-regulation and accepting internal and external pressures. The principle of flexibility has been adopted since the 1980s as a basis for analyzing the relationship between man and the environment to find out how humans affect ecosystems (Janssen et al., 2006). The (International Panel of Climate Change: IPCC) identified flexibility as the ability of the social and ecological systems to absorb internal and external influences and the ability to restore the basic structure and methods of work and to maintain the same self-reorganization capacity and the ability to absorb these influences (IPCC, 2007).

4. Urban resilience

Urban resilience is a relatively new principle that still lacks clear definition (Jabareen, 2012) as the term evolved from biology, urban resilience can be defined as the ability of cities or urban systems to cope with a wide range of shocks and pressures caused by economic, technical or cultural conditions, besides the impacts of climate change (Kerr and Menadue, 2010). However, this definition conforms only to biological trends but does not take into account the complexity of urban functions. Urban resilience can therefore be seen as "the degree of change that cities can endure before reshaping on new bases." This shows that the concept of resilience does not always require returning back to the state of balance, but needs to shift to a new situation that allows him to live longer to face and resist more challenges, researcher Areefi points out that cities have these capabilities. Urban resilience differs from other types of resilience. This principle was developed by the (International Council for Local Environmental Initiatives: ICLEI) to suit the resilient city principles that consist:

• A complex set of multidisciplinary systems.

•Multiple systems with different physiological, organizational, social and economic characteristics.

Urban resilience therefore can be considered as the ability of urban systems to meet certain levels of stress by:

- Having flexible systems capable to absorb shocks from the beginning of their impact.
- Distributing stresses on all systems to avoid concentrating it on a particular system.
- Restoring functions of various systems within a short period of time to avoid lose and collapse.
- The existence of alternative systems in case of losing a particular function.
- Designing systems on the base of safe collapse to avoid catastrophic failure.
- Developing the ability to identify problems and deal with disturbances.
- Prioritizing solutions in facing risks.
- Providing independent rapid response sources to contain crises.(ICLEI,2011)

5. Resilient City

The (International Council for Local Environmental Initiatives: ICLEI) has identified resilient city as "the city that afford greater flexibility in its institutions, infrastructure, social and economic life." Therefore, resilient cities work to reduce their vulnerability to risk, and develop flexible infrastructures capable to respond to environmental, economic and social changes in long-term in a sustainable manner. Thus resilient city represents a comprehensive principle of urban resilience that local governments seek to apply in all environmental, social and economic issues.

5.1 Resilient city characteristics

Arup Planning and Engineering Services developed resilient city attributes:

- Flexibility: that means the ability to change, develop and adopt alternative strategies on the short- and long-term depending on changing requirements. Thus it is possible to return back to the old solutions and strategies, or there will be a need to develop a new type of theses solutions, preferring the simple ones.
- Abundance: that means affording many reserves capable to meet the unexpected increase in demand and able to respond to the maximum environmental, social and economic pressures. Abundance is

related to diversity and to ability to adapt alternative strategies through providing different solutions and options by changing the function of some urban parts to be the alternatives to the damaged ones.

- Multi sources: that means the ability to provide various forms of financial, technical and social support through the combination of human tasks with the necessary expertise to meet these pressures.
- Safe Failure: this requires designing infrastructure and buildings based on the ability to absorb shocks and its effects avoiding catastrophic failure if the upper design limits exceeded. This means if part of the system fails gradually or abruptly, it will not affect the other parts or it will be affected to the minimum, keeping in mind the idea of emergency failure.
- Responsiveness: that means the ability to reorganize in order to restore function and order after failure. Therefore speed is an essential issue in responsiveness to minimize losses and avoid future failures.
- Ability to learn: direct experience and failure are key tools in the learning process. Therefore individuals and institutions should have the ability to understand their past and learn from their mistakes to avoid falling again; this will help to take the precise decisions in the future.
- Depending on local ecosystems: flexible urban systems attempt effectively to control the life of their urban dwellers and facilitate access to their sources of life. This includes assessing local ecosystems that support human survival and taking the necessary steps to conserve these natural resources for survival and utilization, including flood control, temperature regulation, air purification and food production locally (da silva et al., 2012).

Researcher (da silva) in ARUP states that resilient city attributes are:
(Organized actions seek to avoid cities the catastrophic consequences of internal and external influences of the expected or unexpected disasters and reducing the possibility of their system collapse, besides it helps to rehabilitate and stabilize city after disasters that lead to change over time. All these attributes can be applied to the city buildings, infrastructure and institutional networks, thereby increasing flexibility in urban system).

6. The resilient society

According to resilience and resilience city definitions, a resilient society means the ability of a society to urbanize, respond to and recover from disasters quickly. The Crescent and Red Cross organizations have conducted researches on this type of societies in different urban and rural areas, in several countries like Sri Lanka, Indonesia, Thailand and Maldives, to prepare for future challenges (Mayunga, 2007) and these researches resulted the following:

- A resilient society is an educated groups having the ability to evaluate, manage and monitor disasters and able to learn new skills from their past experiences.
- A resilient society is an organized community having the capacity to diagnose problems and identify priorities to move towards them.
- A resilient society is a community associated with other communities as supporting backups, who will provide them with services when needed.
- Resilient societies are communities having services and infrastructure such as transport, water, electricity, sewage networks besides housing with the potential to maintain and renew them.
- Resilient societies are communities having strong economic potential and possessing a wide range of employment opportunities with a good income and diverse and flexible ability to accept variables and respond to them.
- Resilient societies are communities having the ability of self-assessment and the potential to improve and maintain their capacities. (IFRC, 2012)

These studies also identified the importance of knowledge and health as major factors influencing resilient societies. People's awareness and their individual knowledge are the main drivers to deal with disasters and recover from them. Therefore, knowledge and health is the centre of resilient society characteristics. Resilient community contributes to disaster risk reduction and works through sustainable development perspective that aims to minimize city damage by addressing vulnerable areas exposed to damage through planning and design (Sanderson, 2010).

7. Resilience and urban planning

Planners and decision-makers are making efforts to face economic and environmental impacts without paying attention to the social consequences that negatively may affect cities and their inhabitants, especially in poor areas. Urban planning plays an important role in resilient cities formation, and it needs flexible strategic thinking to produce adaptable urban spaces (Jabareenm, 2012) capable to adapt complex forms of diverse functions; and will help to form the resilient city. Researchers Karrholm and Nylund points out those resilient urban spaces can deal with variables without losing its original character. This process starts from adaptation to transition, is a difficult challenge for urban planners and it needs cooperation between urban planners and policy makers from

one side and local governments from the other side to take the needed steps and strategies to develop new planning and building codes and regulations (Karrholm and Nylund, 2012), so there is a need to include environmental and social factors in planning measures to reach the maximum flexibility. This means that urban resilience is application flexibility principle on the city as a whole system. To gain flexibility, city and its elements must accept transformation in the sense that they need to be able to cope with disturbances. Urban resilience does not related to developing living standards according to life variables, but it is related to catching positive outcomes of these variables and transformations. The main challenge of urban resilience is the need to broaden points of view and go beyond flexibility to include social, economic and environmental aspects within this concept; this will help for better understanding of city resilience and will show how cities should move towards this goal (Jabareen, 2012). Therefore resilience will appear as a process, not just a case, begins with some kind of internal or external turmoil and continue with state of adaptation and transformation. It can also be described as a reorganization matter (Carpenter et al., 2012). At this stage, the city appears as a living system swinging forwards and backwards. Thus, disturbances will be an incentive for a new type of organization and development (Moberg and Hauge, 2011, p.3), to produce systems initial character that has been restored.

However, according to resilience definitions, the output will depend on the concept of resilience and its objective. If the disorder is perceived as a threat, it is normal a system will return back to its first stable state. But if the disorder is seen as an opportunity for future development, it is better to adapt new systems capable to accommodate the future evolving situation. Researchers such as Moberg and Hauge Simsonsen emphasize the need to learn through flexibility, disorders, past successful experiences or mistakes. So they indicate that resilience is similar to urban planning, for it requires learning from the past, and they add diversity to resilient principles; that includes ecological and social aspects. (ICLEI) refers to the collective social benefits of applying resilience, for it shifts attention from growth and efficiency development to the need for smooth recovery (IPPC, 2007, p.65). Researcher Evans stresses that resilient should be the goal for the city and its society. Climate change can be a catalyst for adaptation this process. The best practice for achieving resilience is experimentation and there is no single solution to create resilience in the system, so there is a need for creative thinking and constant transformation (Evans, 2011).

8. Resilience and sustainability

Resilience differs from sustainability. Researcher Zolli points out that while sustainability seeks to bring the world back to equilibrium state, resilience sought to find new way to deal with an imbalanced world (Zolli, 2012). Researcher Biello refers to (New York) sewage systems, that have been able to operate during major storms and hurricanes, but have led to water pollution, (Biello, 2012). Therefore, the relationship between resilience and sustainability can be similar to the relationship between adaptation and mitigation. Resilience has been applied to different forms of cities such as Eco-efficient city, carbon city and place based city, so cities are constantly changing due to many reasons such as demographic change, different spatial patterns and economic crises, this makes cities not stable, and making them similar to humans and to other natural systems. Thus researcher Arefi notes that cities and living organisms have similar characteristics like:

• Disaster and disease recovery.
• The ability to absorb changes and adapt them.

But cities and communities seeking for higher levels of resilience will face higher risks of change and threat. Cities always test its actual ability to resist climate change and to various forms of external and internal threats. And because cities are complex multidisciplinary phenomenon, it needs constructive cooperation between several partners, besides clear understanding among urban planners and architects to upgrade efficiency of their projects by using new concepts in planning and design. Cities sometimes viewed as the main cause of the negative social and climatic impacts, however, opposite views suggest that cities can play a key role in transforming for positive state, including new innovative resilient solutions in its infrastructure and buildings and even in its inhabitant's lifestyle. Therefore there is a need to plan resilient cities to create resilient urban communities (Arefi, 2011).

9. Resilient infrastructure

Urban societies rely heavily on different types of infrastructure. These systems may fail in times of crisis or disaster. And because of the interconnection between their parts, one part failure of the system will lead to the total network collapse and will affect a large geographical city area inhabited by large number of the population. Therefore there is a need for resilient infrastructure that can reduce failures incidence (Chang, 2009). Researcher De Bruijne points out that resilience in infrastructure covers wider issues than protection and preservation, it includes rescue and maintenance strategies for these systems to maintain its function even during disaster. Therefore, the (National Infrastructure Advisory Council: NIAC) has defined resilient infrastructure as "the ability of infrastructure to minimize the size and / or damage period".

The research will focus on storm water systems to address the problem of urban flooding due to heavy

rainfall. Floods are natural seasonal phenomenon, and it plays an important role in the environment, but when it occurs in urban areas and within its built environment it may cause urban floods and will harm these areas and its inhabitants. Urban growth is one of the main causes of urban floods because it:

- Changed land uses.
- Deleted green areas and replaced them with solid surfaces do not absorb water.

This increased the amount of collected rainwater in urban areas (fig-1) and increasing water flowing speed due to the nature of paved land water passes over, this make cities exposed to flooding and deterioration of their environmental condition due to the interruption of sewage systems and damaging cities environmental conditions that will affect its inhabitant's health. Therefore, the accumulated storm water in cities has been a matter of concern for city administrators, and city sewage systems because city drainage systems have turned into unsustainable one. Therefore, the sustainable approach of these systems has become one of the topics that should be addressed to solve urbanization consequences. And this requires focusing on managing urban rain water issues by disposal or utilization, to be the basis to design city sustainable sanitation systems that should be integrated with other resilient city elemnts (Andoh and Iwugo, 2002).

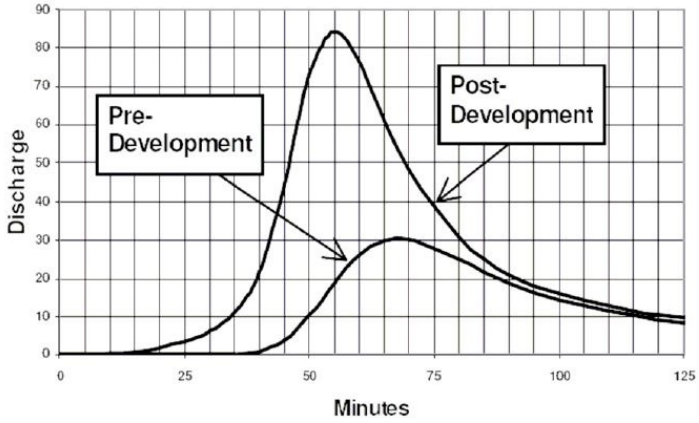

Fig-1 the effect of urbanization and urban development on rain water discharge quantity
http://wgbis.ces.iisc.ernet.in/energy/water/paper/urbanfloods_bangalore/floods_city.htm

The amount and quality of rain water collected in cities has become an important issue to be addressed within sustainable sanitation systems, so researcher Coffman proposed the (Low Impact Development: LID) concept to deal with this issue by establishing open green areas as a part of the rainwater drainage system for booking and filtering rainwater to become as an essential part of the urban city fabric. This method mimics the natural way of dealing with rainwater, and aims to:

- Reduce water flow in urban areas.
- Maintain water collection time to obtain the required time to discharge it naturally through various ways such as increasing discharge corridors and increasing surfaces roughness.
- Using basins to reserve rain water at peak times.
- Designing additional water retention tanks to prevent emergency flooding.

Beside that other trends appeared, such as (Best Management Practices: BMP) concept that emphasis on:

- Not focusing on specific points for rain water treatment and liquidation, but depending on several distributed points of treatment and liquidation within the city to address the effects of land use change at the lowest cost.
- Reducing the amount of accumulated rainwater.
- Reducing water flow.
- Using water reservation systems like special designed facilities or through open areas and parks. (USEPA, 2001). Both (LID) and (BMP) concepts are often combined and used together to complete each one the other.

Urban sanitation systems can also be improved by focusing on (Sustainable Urban Drainage Systems: SUDS), that apply sustainability concepts and try not to transfer rainwater drainage problem to other urban areas spatially and temporally, these systems will improve city urban design and control environmental risks through:

- Improving the state of the built environment by reducing the quantity and quality of rain water problems.
- Increasing city possibilities and diversity of controlling the amount and the speed of rain water flowing.
- Minimizing the impact of rain water on urban areas and increasing its aesthetics and coast values.
- Improving biodiversity by affording protected areas for different types of wildlife in urban areas.

Another approach of dealing with rain water in urban areas is the (Water Sensitive Urban Design: WSUD),

which researcher Langenbach describes as "a joint collaboration between water management departement from one side and urban designers and landscape designers from other side to take into account all phases of rain water cycle In the city and its urban areas, keeping in mind supporting ecological, economic, social, cultural and sustainable environment. According to Wong, this approach seeks to protect urban water environment in such a way that social values and urban controls are the basis for urban design decisions. This approach seeks:

- Integration between drinking water, rainwater and sewage water systems managements.
- Integration of wastewater management from individual to regional level.
- Integration of sustainable urban water management with architectural designs and landscaping designs.

The principles of rain water treatment are based on several principles as follows:

- Prevention of pollution through treating rain water before it intervenes into the sewage system. This include cleaning roads, traffic corridors and parking lots from soil and waste (SEPA, 2011) as well as increasing community awareness about this problem.
- Controlling the source through treating rainwater near the area of collection and thus reducing the need for additional treatment stages in other sites. This can take place in private property or in public green areas such as green roofs or rainwater collection systems. (Falkirk council 2009)
- Site control: rainwater collected from surfaces, parking lots and public squares is collected in storage tanks or filtration areas, allowing temporary water retention and reducing the amount of urban wastewater. (SEPA, 2011)

10. Sustainable drainage infrastructure

There are several systems involved in sustainable rainwater drainage systems, it includes:

10.1 Rainwater lakes: There are several names for these lakes, such as wet lakes, reserving water lakes and sustainable lakes. The design of these lakes varies from single lake to several ones (Brown et al., 2001a). These are human-made lakes designed to resemble natural ones (Fig. 2), but in rare cases natural lakes are converted into these lakes (Heal, 2000). It is important that the lakes are designed so that they can work in rainy and dry times. Its areas ranges from 2-3% of the total area want to be treated, so it is difficult to find such areas in densely populated urban areas. The annual conserving cost ranges from (3-5%) of its construction coast (USEPA, 2006a).

Fig-2 Rain water lakes
http://www.roads.maryland.gov/m/index.aspx?PageId=119

There are many methods to improve the performance of these lakes, like creation more than one lake, this helps water to move from one lake to another (Brown et al, 2001a), these lakes help:

- Increasing the ecological diversity of plants and animals.
- Adds vitality and beauty to its surrounding areas that encourage sport and recreational activates.
- Rises nearby property prices between (25-10%).
- Creating environmental education places (Heal, 2000).
- Provide water reserves that can be reused for Irrigation and treatment water partially before entering underground. (Wanielista and Yousff, 1993).

10.2 Dry lakes: These lakes collect rain water for a short period of time not to exceed (14) hours, and reduce the speed and the amount of rain water it treats water partially (USEPA, 2006a). The depth of these lakes ranges between (1-2) meters (Figure -3). These lakes can be designed among external green areas and landscape. And it can be used for recreational purposes in hot areas or when there is a significant long time between rainfalls times most frequently (USEPA, 2006a).

10.3 Rainwater filtration systems: These systems aim to redistribute rainwater harvesting areas by using suitable soil for water filtration (NCDENR, 2007b). These systems improve the soil's ability to discharge water by increasing the contact surface area of the soil; this will help to improve water penetration. These systems include different forms of treatment methods such as:

Fig-3 Dry lakes
https://www.google.iq/search?q=dry+extended+detention+ponds&source=lnms&tbm=

Fig 4 Permeable paving and surfaces
http://www.lastormwater.org/green-la/low-impact-development/residential-solutions/permeable-pavements-or-porous-pavement-systems/

10.3.1 Permeable surfaces: These include various forms of sidewalks, footpaths and cars parks that help leaking rainwater into the ground (Figure -4).

10.3.2 Drainage channels: They can be erected on the sides of roads and car parks and will help the accumulated rainwater near the streets and squares to penetrate to the ground through special designed channels (Fig. 5).

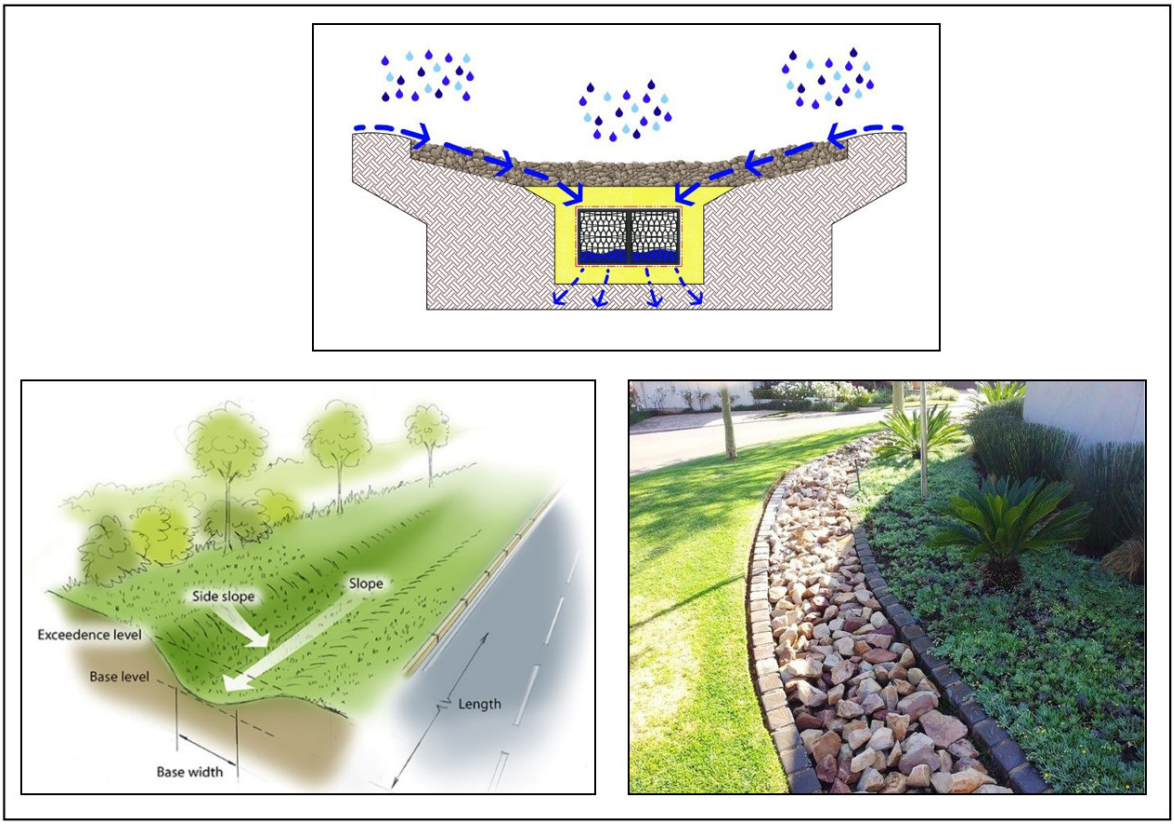

Fig-5 Drainage channels
http://www.scout.com/home/build/forums/5254-exteriors/14883006-construction-of-a-driveway-trench-drain

10.3.3 Filtration basins: These are type of (Best Management Practice: BMP) that is used to manage storm water runoff, prevent flooding. It can be erected beside parks and roads in different shapes and designs as in (fig-6).

10.3.4 Rain gardens or (Bioretention basins) These are places used to collect and treat storm water. It consists of a grass buffer strip, sand, organic layer, planting soil, and plants. They appear in different designs and add aesthetics to the surrounding areas, and they can be implemented on the sides of squares, parks and streets (Fig. 7) (Hinman, 2005).

Fig-6 Filtration basins
https://www.google.iq/search?q=dry+extended+detention+ponds&source=lnms&tbm=isch&sa=X&ved

Fig-6 Filtration basins

Fig-7 Rain gardens
http://www.grantsgardens.com/blog/post/645/Rain-Gardens-Stop-Runoff--Remove-Pollutants-And-Return-Water-To-The-Aquifer#.WTKYzeuGPIU

10.4 Intelligent rainwater drainage systems: There is another form of resilient infrastructure which in some time called smart infrastructure, as found in Malaysia, where there is a three-storey underground car tunnel, but in disaster times it can be used as a drainage channel. This tunnel is the second longest tunnel in Asia with a length of 9.7 kilometers; it is designed to solve the problem of waterlogged bottlenecks in the capital Kuala Lumpur, but it is designed to be used for draining accumulated rain water during periods of heavy monsoon rains that lead to urban floods in the capital. The tunnel can discharge rain water by changing the use of the first floor from car passage to discharge water channel. In the case of increased rainfall, the second tunnel level will be used also as rain water drainage and thus the whole car tunnel will entirely transformed to huge drainage system (Figure 7). After the heavy rain fall finished, the tunnel will return back to its normal usage. In this example we note the high degree of flexibility in tunnel design and its flexible utilization for two different purposes according to environmental conditions. (Kannapiran, 2005)

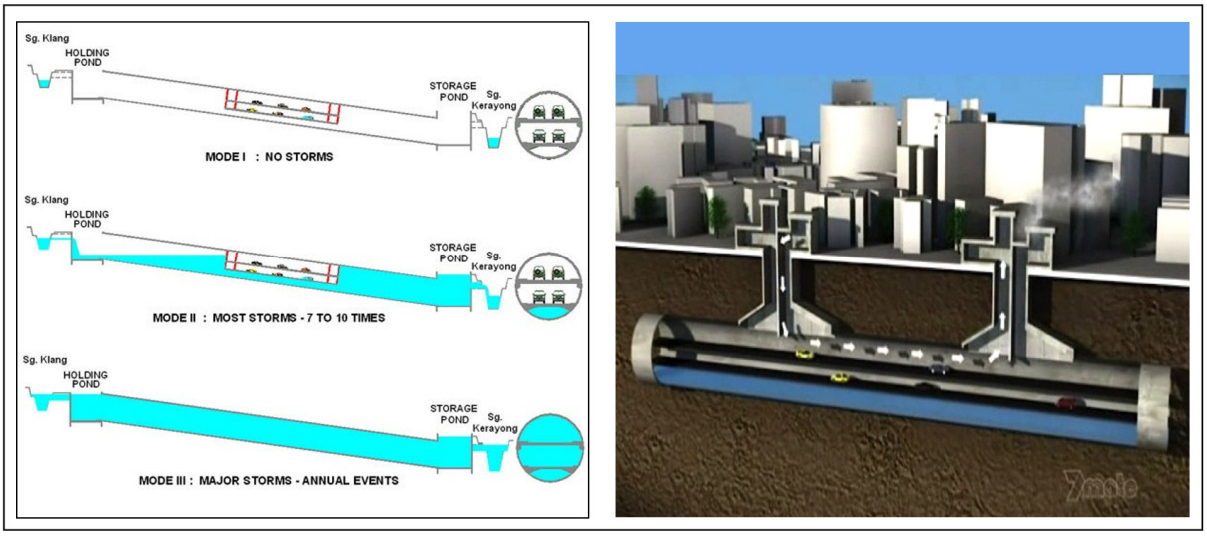

Fig-8 Intelligent rainwater drainage systems(Malysia)
https://www.google.iq/search?q=smart+tunnel+malaysia&source=lnms&tbm=isch&sa=X

11 - Urban Floods and Infrastructure in Iraq

Iraqi cities suffer from the problem of intensive rain at certain periods of the year, this causes floods in urban areas that affect life and work in all city facilities. This situation occurs due to the lack of water drainage systems and because cities infrastructure are not capable to cope with unexpected and unexpected environmental emergencies due to the lack of resilience in cities urban planning and design. That makes cities and their infrastructure collapse in front of simplest natural environmental phenomena such as rain (Figure -8) therefore cities have proven that they cannot withstand external influences, even if it has a limited impact. The big question appears what will happen if these cities exposed to major disasters or risks? So, there is a need for deep thinking about this problem and solve this problem by moving towards sustainable infrastructure to protect cities and their inhabitants from environmental threats to produce the resilient Iraqi citiy.

Fig-9 Rain water floods in Iraqi cities
https://www.google.iq/search?q&فيضانات+مياه+الامطار+في+بغداد=tbm

12. Conclusions

• The research considers urbanization affect urban areas and changed its land use and it surface nature that caused increased urban floods in cities around the world. That made these phenomena risk threats cities, and this risk will grow bigger in the future due to global climate change. So this subject should be addressed by governments and urban planners and architects to prevent urban floods and minimize its impacts on cities and its inhabitants by shifting to a new resilient kind of planning cities and designing its elements.

• The research sees the need to shift towards resilient city model, by adapting flexibility and resilience in city's planning, infrastructures and buildings design in order to increase their capacity to withstand against expected and unexpected risks and disasters like urban floods.

•The research considers sewage systems, including rainwater drainage, as one of the infrastructure that must be resilient and flexible to avoid their failure due to urban floods during seasonal heavy rain and to prevent damages to the city.

• The research considers sustainable infrastructure as a form of the resilient infrastructure that can solve the problem of urban floods or at least minimizes its negative impacts on urban areas, besides:

- It is easy-to-implement.
- Simple to be used and maintained.
- It will add extra green areas to the city.

• The research considers that the implementation of sustainable infrastructure within the city and its boundaries will:

- Increase the aesthetics of the city and will increase its land value.
- Improve the city environment and will add extra recreation areas to it.
- Afford natural reserves for wildlife in urban areas.
- Contribute in reducing city temperature and pollution.

• Research finds that the best type of sustainable infrastructure is dry lakes because they fit the nature of Iraqi warm climate and the divergence periods of rainfall.

• The research considers water filtration systems represent another type of sustainable infrastructure that can be applied easily within cities and its urban areas, even if it is overcrowded, because it can be implemented to busy streets and walkways and car parks within the precise dimensions underground in a way that does not contradict with what is on site.

• The research considers that the resilient infrastructure is just a part of city elements, so there is a need to design and deal with the rest of city components and its built environment in a resilient manner, to integrate all these elements to produce the resilient city that is capable of standing in front of the various threats and risks.

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