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THE CREATIVE ROLE OF GREEN ROOF IN INFORMAL AREA: A PROACTIVE AND REACTIVE TOOL FOR PROMOTING, MEASURING, AND GUIDING GREEN ROOF DESIGNS AND IMPLEMENTATIONS

Reham Ibrahim Momtaz [a*]

[a] *Department of Architecture Engineering, Modern Academy, EGYPT*

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ABSTRACT

The urban growth of Cairo over the last few decades has resulted in a deteriorated urban fabric. So, many comprehensive environmental problems have occurred. The utilization of green roofs in informal areas reduces pollutants in the atmosphere and also compensates the lack of green areas at the urban level. The paper aims to provide a tool that can be applied on any form of green roof design especially on the buildings exciting in the informal areas. In addition, landscape designers can use it as a guiding and monitoring tool during the design process to achieve the maximum social, environmental and economic benefits. The paper concluded that an expected shift of interest regarding the ecological and social human dimensions have been noticed and also, improving the environmental aspects. Therefore, the design of green roofs is a multidimensional process that includes environmental, aesthetic, social and economic aspects.

1. Introduction

Cairo has experienced a tremendous urbanization in the form of informal settlements in the past five decades. This has resulted in a deteriorated urban fabric and many comprehensive environmental problems. Therefore, green roofs are considered a solution in informal areas to promote and contribute social and environmental aspects.

The utilization of environmentally friendly green roofs is becoming a popular alternative to conventional roofing systems, which were identified lately as one of the most promising fields for promoting social-environmental solution; however, there are few studies have been conduct on green roofs in informal areas.

*Corresponding author (R.Momtaz). Tel: +201115005605 E-mail: reham.momtaz@yahoo.com.
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2. Green Roofs – Definitions

Green roofs, also known as vegetated green roofs or eco-roofs, are nascent, somewhat isolated, anthropogenic patches consisting of membranes, engineered substrate, and assemblages of plants placed atop buildings or other structures (Cutlip, 2009). Green roofs have appeared due to advanced building materials, evolving design techniques and emerging ideas about how to make our built environment more sustainable and humane(Getter & Rowe, 2006; Weiler & Scholz, 2009).

Places where green roofs have been promoted include cities with pressing environmental problems and/or compelling visions about creating more resilient and beautiful infrastructure (Richard, 2015).

2.1 Benefits of Green Roofs

There are many potential benefits of green roofs. These may be considered to fall into three main categories, social, economic and environmental benefits, which improve the surrounding climate change, biodiversity and increase green spaces in urban areas.

2.1.1 Environmental benefits

Green roofs present the opportunity to expand the presence of green areas by covering concrete roofs of buildings. Hence, improve climactic conditions, reduce urban heat island temperatures and retain the rainwater.

Thermal Reduction & Energy Saving

Green roof can reduce the heat flow through the roof by 70% to 90% in summer and 10% to 30% in winter, which reduces the consumption of the energy demanded in the building up to 75% (Liu and Bass, 2005). Not only does the green roof positively affect the conditions within the building, but also it reduces electricity costs, improves climactic conditions and reduces Heat Island Effect (Santamouris, M. 2014).

Water Management

Green roofs decrease the rate of runoff from the roof (Frazer et al.2008), Based on studies 75% of rainwater could be retain, through releasing it back gradually into the atmosphere via condensation and transpiration, while retaining pollutants in their soil (Hathaway, et al., 2008).

Eco- Friendly

There are limited green areas in high density urban settings which, face shortages of natural habitat such as some species of plants, insects, and animals. It has been found that green roofs can attract beneficial insects, bees, birds, and butterflies through integrating the natural environment on the roof and providing habitats for these species (Townshend, D. 2006).

Reduce Urban Heat Island effect

Urban heat Island effect (UHI) is described as the difference in temperature between densely populated cities and the surrounding countryside. Cities are generally hotter than the countryside because of the lack of vegetated areas. Moreover, the large number buildings with heat production properties and the insufficient natural cooling, result in blocking the wind (Townshend, 2006). Vegetation –whether on ground or roof- can have a cooling effect by decreasing some of the city's heat through the process of evaporation and transpiration, plant materials absorb heat and produce oxygen, resulting in lower ambient temperatures (Oberlander, 2002).

2.1.2 Community and Social Benefits

Based on scientific studies, living in green environment reduces symptoms stress and provides a positive effect on social cohesion. Simply having a view of greenery provides a spiritual connection to nature that missing in the current city (Ulrich,1984).

Aesthetics & New Amenity / Recreational Space

Dense urban environment has limited regions of green areas so the utilization of green roofs in these areas provides several benefits , for instance by providing a suitable green eco-friendly area this will offer opportunities for social interaction between neighbors, resulting in a better healthy living. The sights, scents and sounds of a green roof add infinitely to the richness of experiences , quality of life , satisfactory and wellbeing (Kuo & Sullivan, 2001).

Visual Aesthetic Value

An obvious and significant benefit of a green roof is the attractive view offered to overlooking buildings. This is of great importance in densely urban areas, where the views of roofs are often associated with grey concrete slabs and mechanical equipments (Kuo & Sullivan, 2001, Sullivan, et al., 2004)

Improved Health and Horticultural Therapy

The accessibility of outdoor space and views of natural settings has proven to have a positive impact on human health. Psychological Studies have found that even visual access to a natural environment results in reduction of stress, sickness and ailments. Furthermore, it has improved overall health, job satisfaction, productivity, and reduced violence (Ulrich, 1984). The interaction of individuals with a natural environment has been shown to increase pride of place and encourage social and physical activity (Fettig, 2006).

2.1.3 Economic Benefits

A green roof is a big investment, and the return on that investment may not seem obvious at first. But in fact, the economic benefits of a green roof are quite substantial. Some types of green roofs affect the owner's financial position as well as it has a positive impact on the local economy. (Krajčovičová & Šprochová, 2007; Santamouris, et al., 2007):

- Prolonged membrane durability and longevity - protecting the roof
- Local job creation
- Energy saving
- Reduce community resistance to new developments.

*Corresponding author (R.Momtaz). Tel: +201115005605 E-mail: reham.momtaz@yahoo.com.

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2.2 Green Roof Types

There are three main types for green roofs: extensive green roof , intensive green roof and semi intensive green roof . It has been discovered that there are many differences between these types, which contain a broad range of private and public considerations , that must be investigated at beginning of the design process , such as the maximum load , maintenance, plant selection, and the expense budget , which are corresponding to the desired green roof type.

2.2.1 Extensive Green Roof

Extensive green roof considers as a good choice for large areas with maximum benefits such as, lower maintenance requirement, lower nutrient levels and little irrigation requirement (Zinco, 2014). Moreover, Extensive green roofs include: modular tray systems (rolls of growing medium vegetation) and loose laid systems (varying depths of growing medium in basic layers of green roof) which, require a substrate depth of 60 - 200 mm and can placed on existing roofs of either a sloped or flat roof . Sedums , grasses and some wildflower species are the best choices of plants that can be utilized in Extensive green roof (Tolderlund , 2010).

2.2.2 Semi-Intensive Green Roof (Hybrid Green Roofs)

As the name implies, hybrid roofs are a combination of extensive and intensive roofs which requires a substrate depth of 120-200 mm which are considered as the best of both green roof types due to versatility for different roof styles and can be utilized variety of plants (Grass, Herbs and Shrubs) with less maintenance and cost compared with intensive roof. Nutrient levels, irrigation and maintenance requirements are periodically needed in this type (Annika, 2010).

Table 1: The comparison between different types of green roofs.

Variables	Extensive Green Roof	Hybrid Green Roofs	Intensive Green Roof
Irrigation	Rarely	Periodically	Regularly
Maintenance	Low	Periodically	High
Plant communities	Moss-Sedum-Herbs and Grasses	Grass-Herbs and Shrubs	Perennials, Shrubs and Trees
System build-up height	60-200 mm	120-250 mm	250-400mm on underground garage > 1000 mm
Weight	60 - 150 kg/m^2	120 - 200 kg/m^2	180 - 500 kg/m^2
Costs	Low	Middle	High
Use	Ecological protection layer	Designed Green Roof	Park like garden

2.2.3 Intensive Green Roof / Roof Garden

Intensive green roofs are containing grasses, ground covers, flowers, shrubs and even trees that providing a biodiversity, recreational and amenity spaces on the roof, which requires a substrate depth above 250mm. Hence, fertilization, irrigation and maintenance requirements are permanently required in this type (Townshend, 2006; Quesnel, 2011). Moreover, they often include paths and walkways allowing movement between different architectural features. Benches, tables, planter boxes, greenhouses, ponds and fountains offer people places to relax, dine or work in a garden-like settings (Sidonie, 2011). Table 1, the criteria can be used to characterize three different types of green roofs.

2.3 Design and Implementation Considerations of a Green Roof

The design and implementation of a green roof project is relatively straight forward, when the following standards are considered which promote climate change, biodiversity , health and well-being for humane as well as it will increase green space in urban areas.

All green roofs require some degree of accessibility. Some green roofs might only be accessible for maintenance and other green roof gardens are designed specifically for daily use, which are implemented with accessibility of disabled and high volumes of visitors and users.

2.3.1 Soil used for agriculture (agricultural environment)

The selection of soil used for agriculture is crucial to ensure the success of all types of green roofs in short and long terms. So, it should be lightweight substrate with a high ratio of inorganic and organic material. The factors to be considered are: load of garden, climatic conditions of the building site, drainage works, and plant species (Quesnel, 2011).

2.3.2 Vegetation

Architect and agronomist should together decide which plant species suitable to be used, this decision will be taken according to several considerations such as, client budget, investment allocated for maintenance, available resources, aesthetic features, functional purpose of the roof, climate for the construction site, construction loads, green roof type, plant growth rates and consumption rate, agricultural fertilizers, supplies and availability of materials (Carpenter, 2008).

2.3.3 Green Roof Maintenance

All traditional and green roofs need maintenance. One of the main reasons for the failure of the green roofs is the lack of adequate maintenance for the first five years. Maintenance is critical of the green roof design requirements and functional purpose for which it is built (Annika, 2010). Owners and users should know the value of maintaining the roof garden and know its short and long term results .The following should be considered during design development to ensure ease of maintenance for green roofs during and after installation (Tolderlund , 2010):

- Access for equipment and inspections following construction.
- -Irrigation system, growing media and plant selection
- -long-term maintenance requirements and survival of the green roof vegetation.

2.3.4 Structural Standards

Understanding structural load are one of the most important factors affecting the design of a roof garden .structural integrity of the building must be verified prior to consideration of retrofitting the building with a green roof. For both existing and new construction, it is essential that a multi-disciplinary team of structural engineers, and landscape architects be involved early in the process to ensure that the buildings structural characteristics and site conditions are appropriate for green roof installation(Tolderlund , 2010).

During construction the temporary placement of heavy components such as trees, growing media, concrete cast-in-place planters, walls and furniture need to be carefully planned and

*Corresponding author (R.Momtaz). Tel: +201115005605 E-mail: reham.momtaz@yahoo.com.

calculated. Structural load bearing capacity analysis should include the following(Tolderlund , 2010):

- Waterproofing membrane (Green roof retrofit will also more than likely need a new membrane)
- Plant weight at maturity
- Fully saturated growing medium and drainage layers
- Weight of all components including dead and live weights for all phases of the green roof.
- Function and type of green roof
- Plant selection.

3. Review of Experience the green roofs internationally and locally

The paper aims to study the integration of green roof with buildings according to international strategies as an approach to energy saving, reduction of heat island effect and other environmental benefits. On the other side a local experience has been studied which, known as "productive gardens on the roofs of Egyptian housing".

3.1 Urban Greening, Shanghai

Urbanization has created serious environmental problems in Shanghai, including its climatic and ecological effects and environmental pollution. Urban areas have higher air temperature, more hot days, and lower relative humidity. the large scale construction of urban green system “urban greening” launched by Shanghai government has to mitigate the heat island as shown in figure(1) (Linli &Jun,2012), where green roofs help Shanghai city breathe, cleaning environmental pollution while at the same time offering a place of peace and relaxation for residents. By 2020, Shanghai is planning to plant two million square meters of extensive green roofs will be added to the roofs top and walls of Shanghai’s buildings.

Figure 1: Urban greening concepts. (Source: University of Greenwich, UK)

3.2 Ahmadabad slums , India

Mahila Housing Trust team (MHT) roof projects in Ahmedabad and Bhopal have demonstrated that modular roofs can reduce temperature by 5-6° Celsius. The roofs were painted white which reduce temperature 2° Celsius and utilizing climbing plants on the walls and adding a green roof above kitchen to cool homes too as shown in Figure 2, all these solutions led to reduce the energy consumption and electricity costs (Mahila Housing Sewa Trust).

 

Figure 2: Implement cooling roof solutions

3.3 Al-Zawya Al-Hamra, Cairo

There are many different methods to plant the roofs. In Egypt, extensive green roof is used on the roofs of the buildings known as “container gardening” which considered to be less formal and cheaper than other methods. In container gardening, few modifications are made on existing roof structures. The planters are using Containers which made from plastic or recycled-wood, and filling it with soil and plants as shown in Figure 3. This system is producing leafy crops such as parsley, radish, and carrots (Attia and Mahmoud, 2009).

Figure 3: Al-Zawya Al-Hamra green roof farms
(Source: Central Laboratory for agricultural climate, 2006)

4. Towards to Design Guidelines for Green Roofs

The paper managed, through conducting a profound theoretical review, to define Design Guidelines for Green Roofs which play an important role in the development of informal areas in a suitable way for the Egyptian society as shown in Table 2.

4.1 Case Study

Like most informal settlements, Tora has began its land transformation by substandard commercial subdivision with small dimensional plots, building on the overall area without leaving minimum construction setbacks. The urban fabric is very compact as shown in Figure 4. The small surface areas result in a tight living spaces that usually contradict with the number of inhabitants per family.

*Corresponding author (R.Momtaz). Tel: +201115005605 E-mail: reham.momtaz@yahoo.com.

Table 2: Proposed Design Guidelines for Green Roofs

Design Standards	**Construction Standards**
Easy access on to building's roof	Waterproofing membrane
Availability of lighting elements	Saturated weight of the green roof components
Accessibility of the disabled to the building's roof	Imposed loads such as access by people
Access of used materials to building's roof	Remove excess water through a closed cycle to recycle
Stable surfaces that are slip resistant	Use of recycled water in irrigation
Soil quality is proportional to local	Effect of pergolas on loads
climate conditions	Plant weight at maturity
Plant life is commensurate with climatic conditions	
Water elements	
Type of roof garden	
Different types of plants	
Environmental Standards	**Economical Standards**
Plants grow at normal rate	Availability of material for maintenance in relation to financial budget
Climate factors, evaporation rate and drought impact	Prices of seeds, seedlings and fertilizers suitable for budget
Temperature Regulation – Reduction of Heat Island Effect	Suitable budget for green roof type to be designed
The environmental purpose to be achieved from the green roof	Reduce and ease routine maintenance.
Social Standards	**Aesthetic Elements**
Public Health	Availability of Shades
Community Integration	Visual Aesthetic Value
Increase correlation to place.	Other aesthetic elements (sculptures, carving, stones)
Encourage social activity	
Encourage physical activity .	
Having a sense of place	

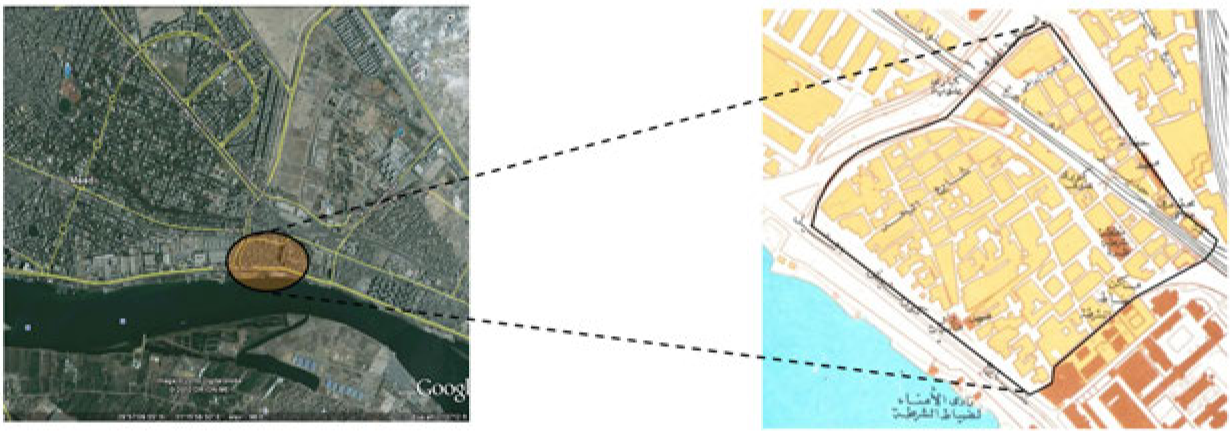

Figure 4: Location Study (Left photo: courtesy of Google Map)

4.1.1 Land Uses Analysis

Figures 5 and 6, the residential and commercial residences represent 74% of areas, craftsman residences represent 16%, while entertaining, religious, and educational places represent 1% each. Open spaces in Tora are limited to streets with minimum pedestrian walkways as well as the markets (Souq) which are usually created in the collective nodes found in main streets that the daily pedestrians routes in and out of Tora.

Figure 5: Land use of Tora

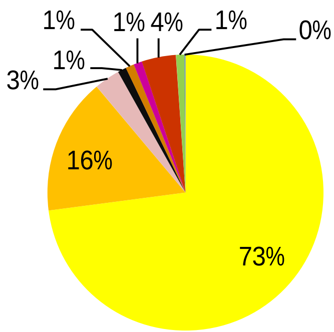

Figure 6: the percentage of land uses

4.1.2 Building condition of Tora

Although Tora is considered as an unplanned area, as shown in figure (7,8) ,the analysis concluded that 9% of the buildings are in good condition, while 48% are in moderate condition, and 43% are in bad condition. In addition, 67% of the constructed buildings in Tora are concrete structures, This construction consists of light weight reinforced concrete frame and local red bricks for the construction of walls, older houses represent30% which using the walls bearing system.

Figure 7: Building condition of Tora

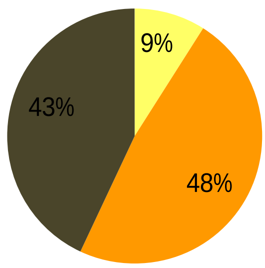

Figure 8: The percentage of building condition

4.2 Questionnaire Analysis

The questionnaires were designed by editing a set of questions which investigate and determine the significance of Proposed Design Guidelines for Green Roofs. One hundred questionnaires' copies were distributed equally to civil engineers, architects and Tora's residents. The researcher had to explain and clarify the questionnaire type every time, but without clarifying the purpose of the questionnaire to avoid directing the answers to a certain direction. All questionnaires were manually tabulated, and information was processed on the computer using the statistical research program "SPSS" in preparation for performing the following statistical process:

*Corresponding author (R.Momtaz). Tel: +201115005605 E-mail: reham.momtaz@yahoo.com.

Descriptive analysis was used to determine the central tendency of the sample, where a variable are collected in the scales. It was used to calculate the values of the different variables of the questionnaire. Standard deviation: It shows the degree of dispersion and distribution of the values of the variables, i.e. the extent of dispersion of these values with respect to a variable, i.e. the degree of proximity or distance among them as well as the frequency through which it shows the number of experts who chose the relative weight of the question between (1-5) as (1) is the lowest relative weight, and (5) is the highest relative weight and (0) is inappropriate.

Component Analysis (Factor Analysis)Analysis of the residents , architects and experts' opinions on the bases of Proposed Design Guidelines of garden roofs in Tora (variables) to determine the weight and significance of each variable and to be able to reduce the variables to less ones. If the number is greater than 0.5, the variable is strong, and if it is less than 0.5., the variable is weak.

4.2.1 Analysis of experts and architects' questionnaires

From Table 3, the highest percentage was Construction standards (27.35%) which indicated that structural integrity of the building must be verified prior to consideration of retrofitting the building with a green roof. the design standards were the second rank and the environmental standards were at the third.

Table 3: Descriptive analysis of the importance the main standards in design guidelines

The main standards in design guidelines	Mean %	Std. Deviation	Frequency %
Design standards	21.92	4.073	21.417
Construction standards	27.35	8.660	21.25
Economic standards	10.76	6.188	57.46
Environmental standards	15.96	8.747	54.7
Social standards	13.65	5.783	42.35
Aesthetic Elements	10.36	0.453	22.41

Illustrated by Figure 9, through the analysis of design standards of informal areas, the strong and weighty mean were Availability of lighting elements, extensive green garden (modular tray systems), stable surfaces that are slip resistant, and soil quality is proportional to local. On the other side, the buildings were not equipped for Accessibility of the disabled to the building's roof.

According to analysis of construction standards, the weakness points are represented in remove excess water through a closed cycle to recycle and use of recycled water in irrigation.

In Figure 10, through the Descriptive analysis of economic, environmental and social standards of informal areas, the most variables were significant and important except encouraging physical activity, according to aesthetic elements analysis, the roof design could always be guided to integrate types of plants planted with other softscape features that could provide an aesthetically pleasant view of the roof.

Table 4: Descriptive and Component Analysis of the Design Guidelines for green roofs in informal areas

Design Guidelines for Green Roofs		Descriptive analysis		Component Analysis	
		Mean	Variance	1	2
Design Standards	Easy access to building's roof	4.017	337.1	.597	.369
	Availability of lighting elements	4.465	1.389	0.583	0.565
	Accessibility of the disabled to the building's roof	2.522	2.769	0.249	0.075
	Access of used materials to building's roof	2.600	1.217	.483	-.096-
	Stable surfaces that are slip resistant	4.225	1.594	.839	-.070-
	Soil quality is proportional to local	5.300	1.472	.851	.392
	climate conditions	5.620	1.927	.886	.031
	Plant is commensurate with local climatic conditions	3.956	1.282	.519	-.112-
	Water elements	2.771	1.378	.213	.711
	Type of roof garden:				
	Extensive green roof (modular tray systems)	5.050	1.851	.834	-.153-
	Intensive green roof	1.462	1.632	.177	.375
	Semi- intensive green roof	2.442	1.934	.397	.782
	Different types of plants	5.563	1.356	.753	.365
Construction Standards	waterproofing membrane	7.134	1.662	.677	-.009-
	Remove excess water through a closed cycle to recycle	6.154	1.773	.432	.663
	saturated weight of the green roof components	8.002	2.657	.835	-.272-
	Imposed loads such as access by people	7.806	1.563	.519	-.112-
	Effect of shades on loads	5.852	2.367	.566	.412
	structural integrity of the building	8.026	0.764	.432	.676
	Plant weight at maturity	7.806	2.137	.850	.096
Economic Standards	Availability of material for maintenance in relation to financial budget	13.65	1.219	.726	.065
	Prices of seeds, seedlings and fertilizers suitable for budget	14.75	1.449	.761	-.217-
	Suitable budget for green roof type to be designed	9.05	0.607	.574	.665
	Reduce and ease routine maintenance.	12.55	1.446	.741	-.045-
Environmental standards	Plants grow at normal rate	13.1	1.315	.755	.063
	Climate factors, evaporation rate	14.25	1.823	.787	.073
	Reduction of Heat Island Effect	9.13	3.255	.634	.396
	the environmental purpose to be achieved from the green roof	13.52	1.456	.730	.275
Social Standard	Public Health	9.727	1.325	.843	.086
	Community Integration	8.619	1.132	.832	.282
	Increase correlation to place .	9.228	1.387	.856	.104
	encourage social activity	8.859	1.227	.848	-.117-
	Encourage physical activity .	4.848	1.477	.519	-.110-
	Having a sense of place	8.719	1.494	.835	-.306-
Aesthetic elements	Availability of Shades	16.63	1.283	.419	-.115-
	Visual Aesthetic Value	20.61	1.505	.721	-.029-
	Other aesthetic elements	12.76	2.915	.489	-.238-

*Corresponding author (R.Momtaz). Tel: +201115005605 E-mail: reham.momtaz@yahoo.com.

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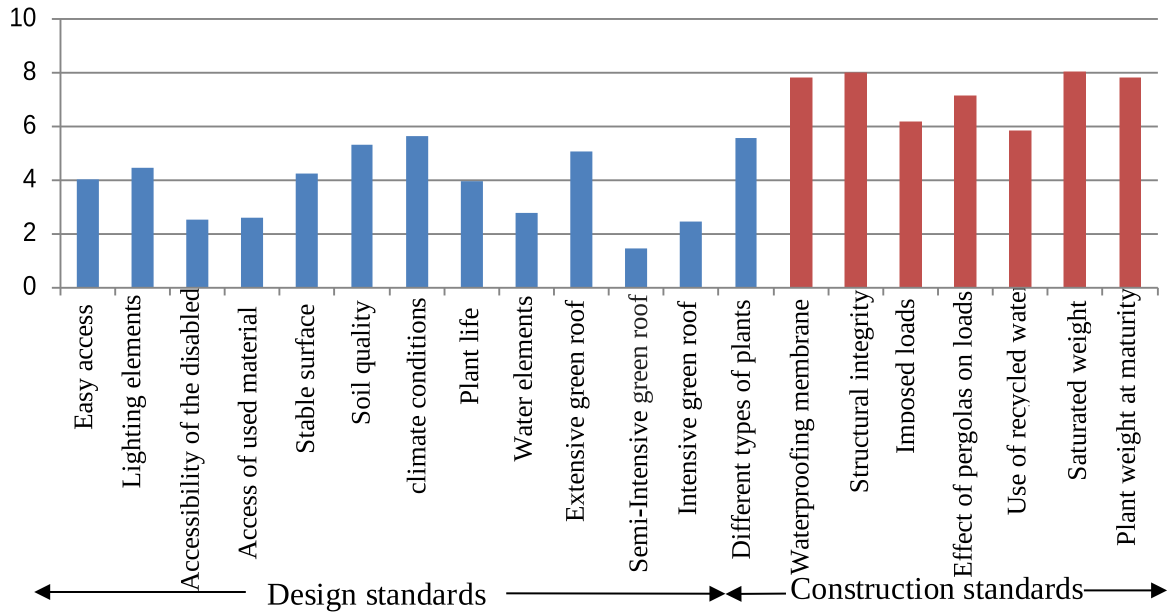

Figure 9: Shows a Descriptive analysis (Mean) of Design and Construction Standards

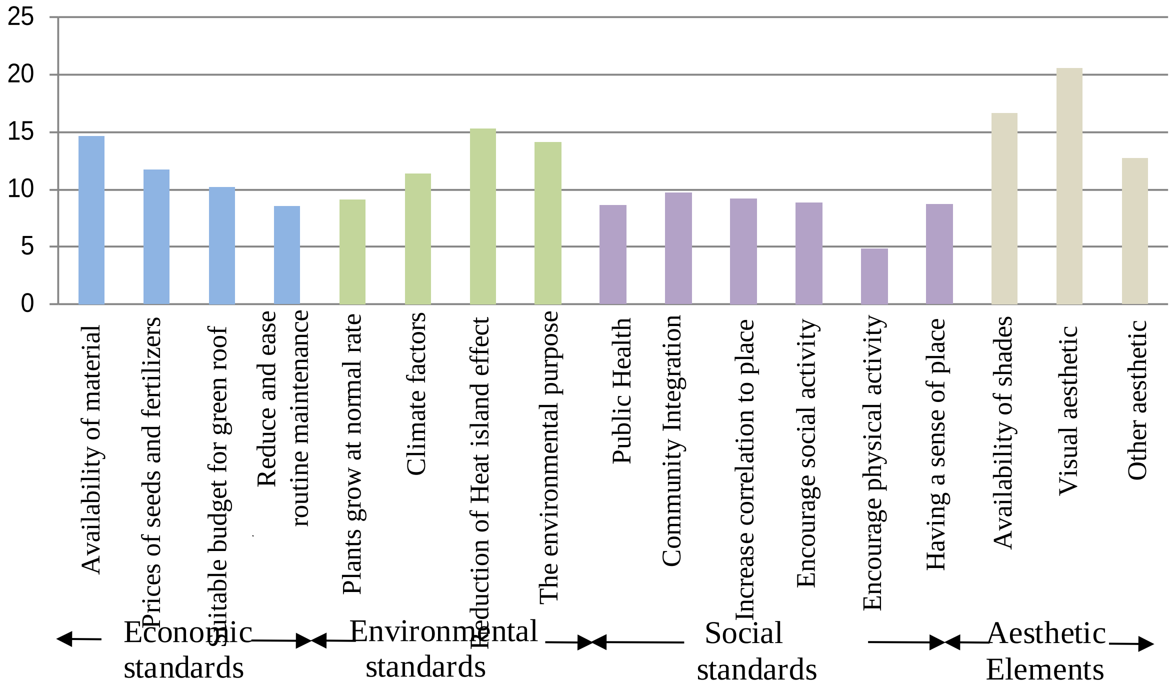

Figure 10: Shows a Descriptive analysis (Mean) of Economic ,Environmental ,Social standards and Aesthetic Elements

4.2.2 Analysis of Tora Residents' Questionnaires

Tora residents' questionnaires contained social, economic, and aesthetic standards, which might be considered the importance standards for residents and could be contributed positively to guide architects during design and implementation process.

Table 5: Descriptive and Component Analysis of Tora residents opinion for green roofs

Design Guidelines for Green Roofs.	Descriptive analysis		Descriptive analysis	
	Mean	Variance	1	2
Economic criteria				
Availability of material for maintenance in relation to financial budget	10.67	1.325	.68	-.271-
Prices of seeds, seedlings and fertilizers suitable for budget	10.12	.9568	.612	-.407-
Suitable budget for green roof type to be designed	10.33	1.6793	.618	.562
Reduce and ease routine maintenance.	18.88	1.9648	.888	.028
Social criteria				
Public Health	10.89	.9564	.860	-.250-
Community Integration	6.58	1.2378	.774	.238
Increase correlation to place .	7.22	1.0251	.786	.168
encourage social activity	10.31	1.5780	.885	.028
encourage physical activity .	5.72	1.4489	.618	.562
Having a sense of place	9.275	1.2160	.872	.186
Aesthetic Elements				
Availability of Shades	14.71	1.3290	.878	.047
Visual Aesthetic Value	18.70	1.1749	.890	.083
Other aesthetic elements (sculptures, carving, stones)	16.58	1.8594	.883	.268

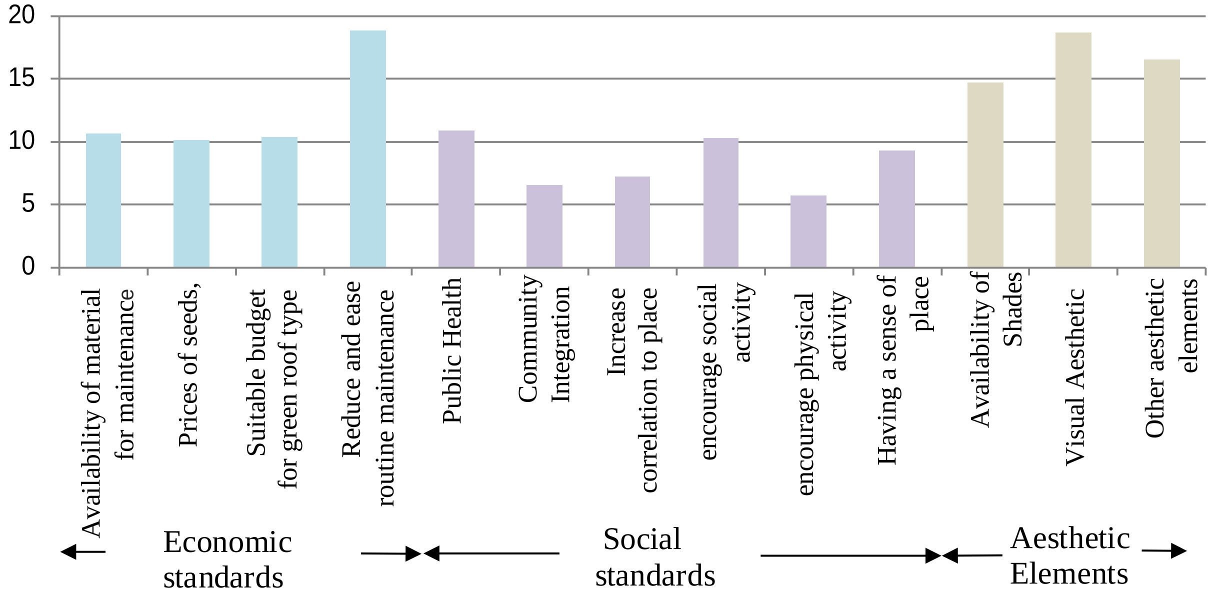

Figure 11: Shows a Descriptive analysis (Mean) of Economic ,Social standards and Aesthetic Elements

Illustrated by Figure 11, Through the Descriptive analysis of Economic ,Environmental ,social standards and Aesthetic Elements of informal areas, according to Tora's residents' opinions , the most variables were significant and important except encouraging physical activity and The residents expected fulfill the aesthetic objective of green roofs.

5. Finding and Recommendation

The paper managed, through conducting a profound theoretical and practical analysis, to define design guidelines of roof garden especially in informal areas and to provide a tool that can be applied on any form of green roof design in existing buildings which was shown in two stages:

*Corresponding author (R.Momtaz). Tel: +201115005605 E-mail: reham.momtaz@yahoo.com.

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The first stage composes of theoretical review of green roofs' Types, benefits of green roof, and review of international and local experiments for utilizing green roofs. the main aim of this stage is to determine Proposed design guidelines for green roofs as shown in Table 2.

The second stage composed of detailed analysis of informal area (Tora), which had covered the land uses, building condition, and investigating quality and quantity of open/green space.

Figure 10: Illustrate the difference between current situation and proposed design

Also, the case study depended on descriptive and component Analysis of the Proposed design guidelines of green roofs, as shown in table (3).The proposed vision for " green roofs in Tora " focused on buildings with good condition to provide extensive green roofs(modular tray systems), some shade areas and visual aesthetic value for residents. Utilizing extensive green roofs in Tora are suitable for roofs with little load bearing capacity and sites, which requires low maintenance, suitable for the financial position of residents, easily adapt to different designs and also can contribute to environmental, social and economic return for residents living in areas that lack adequate open spaces. Furthermore, residents' amenity had to be taken into consideration during the green roof design processing, through provided shades and shelter from wind and sun, to promote comfortable use, see Figure 10.

The defined variables, utilized and conducted from analytical study, that aim to provide a tool that can be applied on any form of green roof design in existing buildings especially informal areas, as presented in Figure 11, among the findings of this study are the following:

Social-economic Standards

Social standards represent 13.65% of design guidelines, due to improve the function of rooftops which, mainly used for storing old and unused stuff and promote social returns through Improving public health (2.87%), having a sense of place (2.35 %), community integration(1.9%) and encouraging physical activity (1.5%). On the other side, Economic standards represent 10.76% of design guidelines that achieve through availability of material for maintenance, suitable prices of seeds, seedlings and fertilizers and possibility of reduces routine maintenance.

Construction Standards

Construction standards represent 27.35% of design guidelines that include dead loads and live loads which are the most significant indicators for retrofitting the building with a green roof. For existing buildings, the architects must verify the structural integrity of the building(4.6%), investigate the imposed loads(4.5%), saturate the weight of the green roof components (4.3%), and the effect of shades on loads (3.9%).

Aesthetic Elements

Aesthetic elements represent 10.36% of design guidelines, that can be achieved through availability of shades (3.44%), visual Aesthetic value (4.27%) and other aesthetic elements such as sculptures, carving, stones, etc. (2.4%).

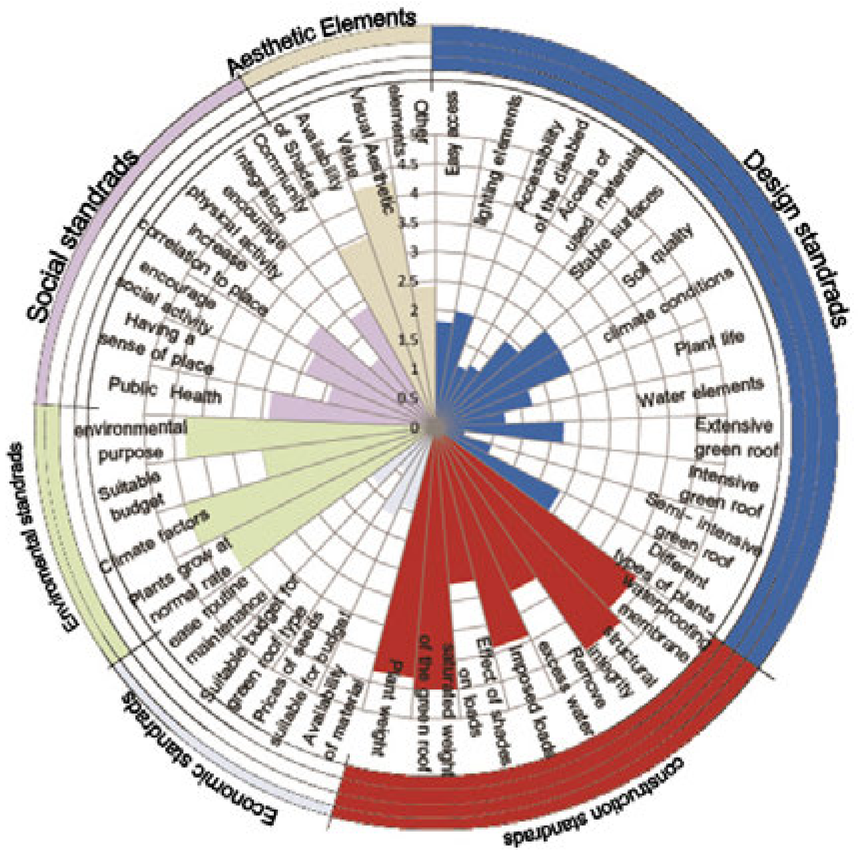

Figure 11: Guiding and Monitoring Tool for Green Roof

Environmental standards

Environmental standards represent 15.96% of design guidelines. Extensive green roof

*Corresponding author (R.Momtaz). Tel: +201115005605 E-mail: reham.momtaz@yahoo.com.

(especially modular tray systems) is considered as the best utilizing green roof type in informal areas. Even though, modular tray systems may have lower effect on reduce urban heat island effect comparing to the other green roof types. Climatic factors, evaporation rate and drought impact (4.5%), plants grow at normal rate (4.1%), surrounding environment and temperature regulation are essential determinants of the success of a green roof. Moreover, the environmental purpose to be achieved from the green roof represent 4.3% of environmental standards.

Design standards

Design standards represent 21.92% of design guidelines, that can be achieved through achieving easy access to building's roof (1.76%), availability of lighting elements (1.96%), accessibility of the disabled to the building's roof (1.11%), accessibility of used materials to building's roof (1.14%), soil quality is proportional to local climate conditions(2.32%), plant life is commensurate with local climatic conditions(2.46%), water elements (1.37%), select the suitable green roof type according to the building condition(3.93%) and utilize Different types of plants(2.44%).

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Associate Professor. Dr. Reham Ibrahim Momtaz is currently an Associate Professor in the Architecture Engineering Department of Modern Academy for Engineering and Technology, Cairo, Egypt. She obtained Bachelor and Master of Architecture from Cairo University, Egypt. She was awarded a PhD degree from Cairo University, Egypt. She has embarked on a few researches in the areas of sustainable and green architectures.

*Corresponding author (R.Momtaz). Tel: +201115005605 E-mail: reham.momtaz@yahoo.com.
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