International review for spatial planning and sustainable development, Vol.1 No.3 (2013), 41-52
ISSN: 2187-3666 (online)

The Application of Vertical Greening to Urban Rehabilitation and Maintenance

Kuang-Hui Peng[1*]
1 Graduate Institute of Architecture and Urban Design, National Taipei University of Technology
** Coresponding Author, Email: khpeng@ntut.edu.tw*
Received 1 November 2012; Accepted 29 May 2013

Key words: Vertical Greening, Green Building, Urban Rehabilitation and Maintenance, Eco-city

Abstract: Site greening is one of the nine indicators of green building in Taiwan. In built-up urban areas, buildings have been crowded without spare space for planting. Thus, encouraging residents planting perennial vine is a strategy which allows it to self-cling to the building surface or supporting structure so that the amount of green increases. It can reduce the building wall insolation and heat load thereby adapting indoor temperature, saving energy, purifying air, water, and soil, promoting urban ventilation, and reducing noise, and increase eco-efficiency. Taiwan has constructed neither vertical greening specification conforms to subtropical areas nor localized characteristics. The paper aims at exploring how to promote the application of vertical greening that increases green quantity as well as how to regulate maintenance of it in urban renovation. We believe we are benefited from it, and it helps to implement the ideal eco-city. Through the literature review and foresighted design point of view, the paper first introduces the relationship and development between vertical greening and green building and follows by the vertical green technology which increases green space and creates urban green network. Moreover, analyzing issues requires technology and innovation of vertical greening to apply urban rehabilitation and maintenance. At the end, it concludes: way of arranging plants in groups, natural irrigation, rainwater recycling system, reason why we encourage vertical greening, and need of amending the Special Chapter of Green Building Standard or providing Management and Maintenance Regulation of Vertical Greening.

1. INTRODUCTION

For the problems of global climate change and global warming in recent years, the countries around the world set low-carbon environment as their goal. The United Nations appealed to the urban and rural development that it is necessary to protect the global environment and focus on the integration of individual and surrounding environment. It is also important to create a healthy, comfortable living environment, emphasis ecological balance on urban and rural planning, biodiversity, resource recycling, renewable energy, and other sustainability issues. As the above, green building and ecological city have become two of the most important trends. In Taiwan, 97% of the buildings are considered as built-up, and their existence generally does not meet the ecological needs (Architecture and Building Research Institute, 2012). Thus, future urban renovation and environmental planning should

emphasize green building to the ecological city's development and place people at the center of the design process.

In 2008, Taiwan has launched "The Eco-city and Green Building Promotion Program." Eco-city and green building assessments are included in "The Implementation Regulation of Periodical Overall Review of Urban Planning." The regulation has amended in 2011 which said that the process of conducting overall review of urban planning need to develop a system of water and green network principles. Our government has learned that green building and network are important to achieve an ecological city. However, the existed cities are crowded by buildings and artificial facilities. How should the combination of green building and urban renovate? How to apply vertical greening technology to the existed urban building façade?

In order to promote urban rehabilitation and maintenance effectively, government have granted funding to encourage residents to renovate building façade when the walls look bad or leak. It can be classified as "wall face lift" option which we change a normal wall into a green wall and reach urban renovation with ecological landscape. However, the cost of green wall is still being criticized for having an extremely high price; thus, we need to improve qualities, reduce costs, combine renovation with urban renewal mechanism, and promote with government incentives. It would then recondition urban area gradually by green building construction methods of design and innovative technology. Through the literature review and foresighted design point of view, the paper first introduces the relationship and development between vertical greening and green building and follows by the vertical green technology which increases green space and creates urban green network. Moreover, analyzing issues requires technology and innovation of vertical greening to apply urban rehabilitation and maintenance.

2. VERTICAL GREENING AND GREEN BUILDING DEVELOPMENT

The wall which covers with greens by self-clinging or growing on supporting structures is known as vertical greening. Vertical greening, also known as façade greening, green wall, planting wall, vertical garden, living wall, or ecological wall, is essentially a living and self-regenerating cladding system for buildings (Kingsbury & Dunnett, 2008). Self-clinging plants are used without supporting structure since they attach themselves directly to the building surface. On the other hand, supporting structure greening wall uses wires or trellis which allows plants to "climb."

Vertical façade engineers need to consider the essential elements, sun shine, water, soil, and etc., of greening growth conditions in both cases. It turns out to be that by using natural or pipeline watering to sustain plants' lives, shallow-rooted plants are able to grow in the walls of different angle, and stems and leaves of plants will grow directly or indirectly attached to the building surface. Plants which grow in the surface of building wall can be artistic, improve the urban landscape, increase green coverage rate, reduce indoor temperature that helps to reach efficacy of biodiversity environment and urban greening.

The use of climbers or trained shrubs to cover the surface of a building is long established in practice (Kingsbury & Dunnett, 2008). Since Blanc

(2008) announced his work in Paris in 1988, it has created and promoted the art of ecological wall. For instance, Zurich's Maschinenfabrik Oerlikon (MFO) Park set up a giant double-walled, three-sided green wall construction which is built of steel with tensioned cables supporting the climbers as part of the redevelopment of a former industrial area for new uses (MFO-Park, 2012).

The Japanese pots drip irrigation module system was developed in 1990s. They also established Urban Building Greening Plan Guidance and promulgated "Landscape Act" in 2004. Landscape Act, Urban Greening Act, and Outside Advertising Act have been three Acts of landscape which encourage architectural, green design in three-dimension. Aichi Expo in 2005 has set a giant green wall called "Green Lung" to promote its slogan "Love, Earth" declaration, emphasize environmental protection and sustainable development, and show modern green wall technology. In 2007, Seattle, Washington, USA, they issued green performance indicators to study three-dimensional vegetation technology such as green roofs or green walls. Blanc, who was invited in 2007 to the National Concert Hall in Taiwan, announced the first vertical garden in Taiwan. He used a common plant to construct the green wall named "Green Symphonic Poem," and triggered a wave of domestic, ecological green building/wall. Parts of the local government based on the demand of landscape has specified mandates that for any new case of construction, its fence must be built as green wall so that it safeguards the environment during construction. Additionally, it must enclose safe function which will provide a better interaction between pedestrian and city. This is an example which shows international trends for green building and vertical vegetation greening and applies them to urban renovation and environmental planning.

In fact, green building has different names in different countries; for example, in Japan, they call it Environmental Symbiotic Housing; in Europe, they call it Ecological Building or Sustainable Building. Green Building System is the name we use in Taiwan that is similar to the United States and Canada. As they name it differently, definitions and connotation are slightly different. Regardless of the differences, the demands for building development are emphasizing on environmental conservation, sustainable architectural planning, reducing environmental loading, and achieving symbiotic environment. We also focus our improvements on energy efficiency, better use of resources and materials, better indoor environment quality, and carrying capacity. So the comprehensive interpretation of green building can be defined as "The pursuit of human health and comfort, symbiotic environment, and sustainable development of human living environment through architectural designs." The narrow meaning of it refers as "Consuming the least resources, using the least energy, and generating the least waste during a building life cycle which is from production of construction materials, design, construction, management, and dismantling."

In September 1999, Green Building System implemented in Taiwan and was able to bring us and subtropical high temperature and humid climates into harmony. We included four factors: Ecology, Energy Saving, Waste Reduction, and Health, which are so-called green building EEWH evaluation and labeling systems in the early stage. Greening volume, rainwater conservation, water resource, daily energy-saving, carbon dioxide reduction, waste reduction, and improvement of sewage were the seven indicators evaluation system which was developed afterwards. The addition of two indicators, biodiversity and indoor environment, in 2003, it became the "Green Building Nine Assessment Indicators System." Thus, green building

is often interpreted as ecology, energy saving, waste reduction, or healthy building.

In order to promote and enhance the green building standards in Taiwan and encourage private enterprises to adopt comprehensive green building designs, the government revised and augmented "The Grading and Assessment System of Green Building" which graded building into five levels including qualified, bronze, silver, gold, and diamond. The grading system can be used as the basis by government agencies, developers and building designers for determining incentive policies. This followed international trends and enhanced the implementation of green building effectively. Additionally, easing the problems of urban heat island effect and deterioration of environmental quality strengthened green building policies in Taiwan. Our government therefore brought the concept of energy saving and environmental protection from green building into urban planning management. We believed these would promote the sense of green building, ecological communities, and sustainable cities through a comprehensive urban planning, design review and demonstration projects. Based on the above, our government introduced "Eco-city Green Building Promotion Program" in 2008. However, the ways of expanding practical applications with their ranges and creating greater environmental benefits from green building will be the current priorities of development of green building.

3. BENEFITS AND ISSUES OF VERTICAL GREENING

Due to the intensive urban construction and artificial facilities, extensive use of things which absorb or reflect solar radiations such as dark roof, walls, floors, uneven buildings, or impermeable pavement is needed. On the other hand, reducing the use of air-condition, heat emissions from automobile and motorcycle, air pollution, and other human waste heat which cause urban heat island effect is another important issue. In Taiwan, after few decades of rapid economic development and a high degree of industrialization, energy use increased by approximately 20 times, and energy consumption rate per unit area is probably one of the highest in the countries that the overall populations are at least ten millions. Heat island effect may be one of the most significant regions in the world.

The coverage that is affected by heat island effect becomes greater. This may also lead to a regional climate change and should be the urgent environmental problems (Liu et al, 2003). Based on the fact that tree-crown can absorb or reflect approximately 80% to 90% of the long-wave radiation heat, and transpiration of blades can consume a part of heat, we believed if we can moderately increase vertical green capacity of the city, the rehabilitation area will be able to reduce urban heat island effect effectively.

Lin (2010) pointed out that green walls are capable of reducing wall surface temperature effectively by 10 ~ 14 degree C and indoor temperature by 2.0 to 2.4 degree C. This leads to reduce the use of air-conditioners and improve energy saving. If we take a ton of air-conditioning and operate it without turning it off for 24 hours, the power costs is about NT$60. If we increase 1 degree C in an air-conditioned room, we can save about 6% from our electricity bills. In terms of office building, the electricity saving will be considerable. Japanese Urban Greening Technology Development Institution's experiments show that the implementation of green wall eases

acid rain and UV damage to buildings and waterproof layers and improves the durability of buildings.

The nine indicators of green building are closely related to plant greening; increasing greening volume, biodiversity, and site water indicators are directly correlated with them. In the past, we barely have any architecture with positively applying green design, rarely regard planting as architectural elements, and hardly consider the effect of vertical greening from an overall view of urban landscape in Taiwan. Through the literature review and analysis, the paper summed up following benefits for urban rehabilitation and maintenance:

1. Dust-proof, lower temperature, noise-proof, and energy-saving: vertical greening can decorate rooms, improve indoor microclimate, lower indoor temperature, increase humidity around 20%~30%, isolate noise, absorb dust, and reduce pollution.
2. Aesthetic and a better three-dimensional vision: green vegetation vertically set in the wall can shape the overall environment artistically, improve creative space effect, and provide social education function. It also gives three-dimensional stereoscopic visual effects from outdoor views by its uniqueness, distinctive kindness, and use of advertisement.
3. Positive impact on human mentality: green walls via advanced greening technology may have plants with various colors, forms, and textures. The natural beauty of it positively enhances landscape, improves residents' psychological feelings, and relieves pressure of modern life.
4. Increase green coverage and economize land: vertical greening can take an advantage of creating three-dimensional space of green network and lead to an increase of green coverage.
5. Create environmental bio-diversity: vertical greening supports the growth of dozens of beetles and spiders. In food chain, beetles and spiders are the best food for birds, and it leads to a positive impact on urban ecological environment.
6. Added value of the real estate market: although cost of vertical greening building is slightly higher than cost of normal building in general, the added value of the real estate market increases since it raises positive benefits such as saving energy spending and a better long-term quality of living environment.
7. Modifying measures and legal system: through continuous research and practical operation, the benefits from greening are the best references for promoting green building and legalization in vertical green measures and norms.

In order to make sure the integrity of the benefits of green building beyond the current assessment indicators and strengthen effectiveness of social, humanistic art, and community empowerment, the paper sums up issues related to technical research and innovation or relevant norms for promoting green building reference (Peng, 2010; Peng, 2012):

1. Safety concerns of supporting structure: although vertical greening in existing walls is able to improve urban landscape and building energy efficiency, is there any issue regarding compatibility or safety caused by traditional urban planning and architectural design regulations? In Taiwan, we are confronted by typhoon season during summer; thus, there is a need of concerning structural safety and having further norms for legalization.
2. Simple calculation of green building rating: a proposal of grading system which calculates the relationship between effect of carbon reduction and assessment of green building can facilitate the vertical greening promotion.

3. Innovative materials and the development of different types of units of green modules: the necessary measures to promote vertical greening is directly associated with reducing the costs of development and maintenance. Therefore, we need to develop a high strength, durable, weather-proof, and biocompatible vegetation green wall system.
4. Community's expectancy and way of localizing vertical green: in order to strengthen the positive physical and psychological impact given by green wall on residents, it is necessary to explore how residents are affected by green wall practically and psychologically. Also, what are their feelings toward the process of plant growth?
5. Reuse of construction fences: how to effectively promote the application of vertical greening to safety fences in construction sites? How to retain fences and make them renewable after completion rather than dismantling and wastes.
6. Water supply and drainage system: in order to maintain plants healthy condition, water supply, drainage system, and stability should be carefully designed, constructed, managed, and maintained. For instance, how to link feed-water system up with storm-water retention system? How does drainage system avoid pollution?
7. Subsequent maintenance: effective managements including watering, pest management, plant domestication, change plants, and so on are closely related to the sustainability of vertical greening. It is not a good idea to rely completely on costly professional factories. Therefore, how to educate people continuously? How to mold maintenance and warranty measures into management?

Aforementioned issues, derivatives of professional responsibility, acceptable quality standards, and risk of long-term maintenance commitment issues need to be well-arranged by legal system. Interdisciplinary integration from cooperation and practitioners including civil and material science engineering, architecture design, urban design, and law capacity is needed so that it supports our legal system to create better norms to problems.

4. VERTICAL GREENING TECHNOLOGY

Regarding to the application of vertical greening technology, we must consider the environmental characteristics of spaces of green wall and plant selections. Through literature review and field research, the paper has summarized the items including plants, vertical greening technology systems, and building external environment that are directly related to vertical greening technology in the following Table 1:

Table 1. Vertical greening of the building related items with impact factor

Item	Factor	Sub-factor
Plants	category	ground-cover, flower-looking, leaf-looking, climbing-vine
	growth nature	wind-enduring, drought-enduring, wet-enduring, acid-enduring, cold-enduring, shade-enduring, barren-enduring, high temperature enduring, salt--resistant, dust-resistant
	eco-nature	bird-attracting, butterfly-attracting, bug-attracting
	planting method	once planted, no maintenance; planting in batches, and subsequent periodic maintenance
	maintenance method	clipping, water supply, drainage, fertilization, disease prevention

	growth period	flowering period, fruiting period
	sense	the sense of sight (color), the sense of smell (fragrance), the sense of touch (quality)
Vertical greening technology systems	climbing	self-clinging to the building surface, the use of climbers supporting structure
	hanging	drooping from the wall type, drooping from the supporting structure type
	module	overall joining of supporting network, planting module type
Building external environment	building type	traditional courtyard houses (traditional architecture), terrace housing, condominium without elevator, high-rise housing
	greening position	roof, exterior wall, balcony, door, windowsill, fence
	impact factor	space: direction, number of story, effect of surrounding building (smoking hole, reflector, wind-tunnel effect) climate: sunshine, wind power, temperature, humidity, rainfall
	additional substance of facade	air conditioning, grille, canopy, advertising signboard, tube, hanging substance of external wall
	community environment	seashore community, existed plain community, riverside community, hillside community
	material of facade	wood, RC (reinforce concrete), brick, tile, stucco washing finish, cement, SS（steel structure）
	disaster	typhoon, earthquake, fire

The influencing factors we mentioned above particularly the wall microclimate in wind environment are needed to be carefully handled. It is necessary to find suitable treatments for rising wind, descending wind, and whirlpool and prevent construction side from being stripped by wind. Additionally, illumination of sunshine is going to be influenced by different directions of wall, surrounding environment, and colours of the wall; therefore, we must choose plants carefully. It is also necessary to pay attention to temperature changes and avoid using materials such as metal, concrete, stone, tile, and other materials that absorb heat or have good conductivity. Regarding plant selection, we should treat native plants as priority, pay attention to their firmness, barren-endurance, drought-resistant, and moisture-resistant, be able to properly affix them to wall which its thickness has to be applicable, maintain and replace plants easily, maintain their durability, and manage pest and diseases.

In response to the above, there are quite many vertical greening technologies recently. The paper summarizes them into six types of technologies in accordance with methods and characteristics of vertical greening in the following Table 2:

Table 2. Vertical greening technology types and cases

Case location	Materials and Mineral Resources Building, National Taipei University of Technology	National Concert Hall, Taipei	Park Lane, by CMP, Taichung	Green Gate, National Taipei University of Technology	Hassen Hotpot Restaurant, Taichung	Decathlon Sports and Leisure Goods Center, Taichung
Technique Type	self-clinging	non-woven felt	soilless culture frame	FRP vertical greening	plant-growing tube	1.continuous planting green wall 2. vine-covered green wall
Construction year	1980	2007	2008	2010	2012	2012
Greening Floor	5	2	16	8	2	3
Usage of a building	building of the university	National Concert Hall	department stores	building of the university	restaurant	hypermarket
Greening Type	self-clinging to the building surface	planting on felt layer by soilless culture	hanging planting trough on the insert panel of wall	planting in the soil package made of non-woven, and put in FRP box	planting in the plant-growing tube	planting trough by open, continuous cultivation
Container material	none	non-woven felt	stainless steel, non-woven felt	FRP, non-woven felt	HDPE connected pipe	zinc-plated iron, coconut fiber mesh blanket
Container Size	none	thickness: 5cm stainless steel stern layer:4cm felt layer:0.3cm weight:15 kg/㎡	thickness:22cm size: 50x80 cm weight: 75 kg/㎡ (with light media, planting)	thickness:6cm width:30cm	length:125cm aperture: 9~12cm width:50 kg/㎡ (with light media, planting)	size: 220x120cm width: 50 kg/㎡
Scale	1,200 ㎡	160 ㎡	1,850 ㎡	1,000 ㎡	125 ㎡	2,000 ㎡
Unit Price (NTD/㎡)	> 3,000	50,000~60,000	40,000~4,5000	8,000	16,000~20,000	picture element type:8,000 vine-type:5,000
Irrigating System	irrigating by rainwater	overflow pipe	overflow pipe	penetrating pipe irrigating system by rainwater	automatic detached drip irrigation	automatic drip irrigation
Drainage system	natural penetration	recycled drainage channel	horizontal drainage channel with metal	natural penetration	recycled drainage channel	drainage channel
Planting type	parthenocissus tricuspidata (sieb. & zucc.) planch, ficus pumila linn.	syngonium podophyllum schott and 51 kinds of common used plants in Taiwan	impatiens walleriana hook. f., lantana camara L., acalypha wilkesiana, nephrolepis exaltata schott., duranta repens etc.	parthenocissus tricuspidata (sieb. & zucc.) planch, pyrostegia venusta (ker) miers, antigonon leptopus hook. & arn., ficus pumila linn.	cuphea hyssopifolia H. B. K., nephrolepis auriculata (L.) trimen, codiaeum variegatum blume	duranta repens 'dwarftype', nephrolepis exaltata schott., asparagus densiflorus (kunth) jessop, asplenium antiquum Makino, chamaedorea elegans etc.
Picture						

As we introduced above, the natural type of self-clinging to building surface is planting traditional creeper which is attached, sucked, and climbed the wall by itself. It hardly climbs once it hits the smooth or high temperature wall. Moreover, this heavily relies on natural growth condition such as its soil layer and relying on air moisture created by rainwater; therefore, it grows slowly; it grows approximately one to two meters per year.

Consider the type that uses climbers supporting structures, seedlings can be fixed by human like planting droopy ivy so that it climbs through supporting frame. It achieves a better heat insulation effect since air layer forms between supporting frame and wall.

Another type of technology is planting trough directly on the wall. Whenever trough and panels are planted completed, greening is completed. If the wall structure is strong enough, we can apply this on higher floors. Although plant selection is less restrictive in this case, it costs more, and facilities for its completion, maintenance, and replacement must be considered.

As for the type of soilless cultivation, in order to provide water and minerals required by plants, we use non-woven fabric so that plants can gain its needs and grow directly on the fabric. In this way, we must select the

plants which can survive without soil substance. This greening technique fits in regions with stable climate.

The paper then divides each type of greening technology into five levels by its watering, greening, and cost as shown in Table 3:

Table 3. Technical types of vertical greening classification

Grade	Water supply	Configuration	Planting type	Construction prices (NT/㎡)	Case
★	less	adsorption type or epiphytic type	1~2	<3,000	Materials and Mineral Resources Building, National Taipei University of Technology
★★	little	climbing, hanging system	3~5s	3,000~ 5,000	Green Gate, National Taipei University of Technology
★★★	medium	frame soil bag, board on frame sash filling	5~10	5,000~ 10,000	Decathlon Sports and Leisure Goods Center, Taichung
★★★★	plenty	planting trough, potted, Black and soft basin, non-woven felt	10~30	10,000~ 20,000	Hassen Hotpot Restaurant, Taichung
★★★ ★★	numerous	planting trough, potted, Black and soft basin, non-woven felt	> 30	>20,000	National Concert Hall, Taipei Park Lane by CMP, Taichung

Note: More★ represent that the higher the grade of technology and maintenance, whereas represent the lower grade.

As the table shows, wall planting trough and potted plants can have many different choices on plants selections since it can be pre-cultivated and then relocated. But because it requires professional technology and knowledge, the cost of its construction and maintenance is much higher. On the other hand, although the cost of natural climbing way is much cheaper, it takes a lot of time to grow. Therefore, higher quality comes with higher price.

5. APPLICATION OF VERTICAL GREENING TO URBAN REHABILITATION AND MAINTENANCE

Future urban environment is going to focus on the ecological symbiosis and advocate the coexistence of human being, home, community, city, and nature. Thus, improving the existing urban old building façade by ecological greening will not only better off the old community environment but provide three-dimensional urban green ecological island-hopping network as well as significance of social education. The paper believes the integration of vertical greening, urban innovation, and maintenance should have at least the following benefits:

1. Creating three-dimensional multi-layer ecological space: a combination of community spatial structure and ecology should be diversified. Layered and progressive spaces should be consistent with living environment and provide various levels of biological differences. To improve urban environment, we should create different levels of herbal environment from greening open space to building façade, regulate climate change and

ecological habitats, and provide cross-species environmental elements with different seasons. Community residents can see the interaction of various environmental factors, energy-efficiency and a better quality of life.

2. Humanistic ecology in urban community: ecological significance does not fully imitate natural environment. The concentrated nature in urban environment is also artificial. Urban ecology should be a combination of natural species and urban human life. Vertical greening brings us an opportunity to apply humanity activities into ecological environment.
3. Improving green wall and permeable pavement: the urban environment is filled with artificial sites; thus, ecological community can be a one shining spot with limiting space but largest green resources and reduce urban heat island effect. Community is people-oriented activity space. We should maintain green ecological surface and create unlimited green with limited funding by innovative urban vision.

The current implementation of the urban renewal projects in Taiwan can be categorized by plan content, subsidy receiver, and grant category that are the followings:

1. Urban rehabilitation and maintenance: The New Taipei City Urban Renewal Rehabilitation and Maintenance Grant Program, The Taipei City Urban Renewal Rehabilitation and Maintenance Grant Program, The Taipei Urban Renewal Rehabilitation and Maintenance Planning, Design and Implementation of Funding Grants, The Subsidy for Public Facilities Maintenance Operations of Public Housing Communities of the Kaohsiung Urban Development Bureau.
2. Maintenance of public environment: The Creation of the Urban and Rural Landscaping Demonstration Projects.
3. Cultural preservation and maintenance: Regional Cultural Assets Environmental Preservation Revitalization Plan.
4. Community safety: The Action Program of Promoting the Whole People Forward for Safety – Constructing Safe Community Guidance Plan.
5. Residential fire safety: The Regulation of Subsidizing Congregated Housing for Fire Safety Facilities Regularly Inspection.

Figure 1 is collated from current implementation of the urban renewal program in Taiwan (Peng & Ding, 2009). The paper illustrates the scope and content of plan by a flat simulation and aerial schematic drawing respectively. I can be clearly understood where our domestic program is going to put the subsidy. The grants are closely related to rehabilitation and maintenance of the exterior of the building and external environment. Thus, applications and integration of vertical greening and urban renovation can be promoted in these and create a win-win situation for rehabilitation and preservation.

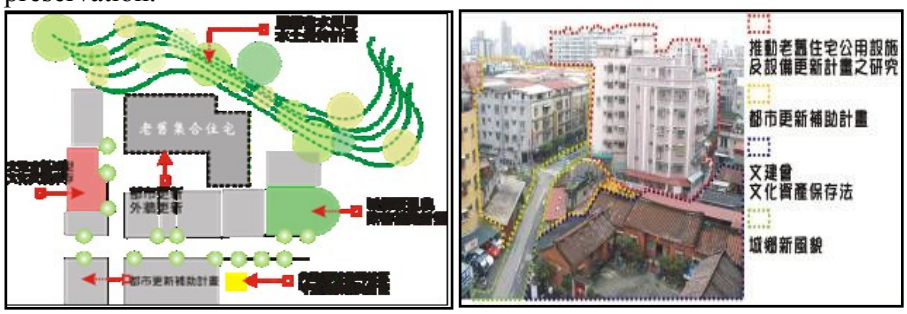

Figure 1. A flat simulation and aerial schematic drawing of implementation of the urban rehabilitation and maintenance program in Taiwan

6. CONCLUSION

Fragmented and scarce green space and highly dense urban areas have caused serious urban heat island effect. Vertical greening can increase greening amount, reduce urban heat island effect, improve the quality of outdoor and indoor air, beautify urban landscape, lower indoor temperature, increase energy efficiency, protect building structure, and reduce noise.

In the conclusion, the paper suggests the following points for those who are interested:

1. Different vertical greening system should take advantages from each system such as doing an experiment of planting trough into different segment and recording the improvements of natural growth rate.
2. We should look forward to design a plan for plants to self-generate and reach environmental symbiosis. The priority consideration is that green is naturally watered with rainwater recycling system which reduces maintenance and management costs.
3. In order to achieve a better performance of renovation, we should review the effectiveness of heat insulation and moisture-regulating effect and select the one that suits better according to different environment.
4. Expanding the use of vertical greening is a good way to rehabilitate high-rise congregated house building façade and sustain the green wall system.
5. We should promote local governments to green the construction site fences and strengthen inspection works for periodic maintenance. It aims to prevent plants from wilting which would lose significant amount of green and carbon reduction.
6. The central competent authority should be with the amendments of Green Building Standards Special Chapter or set vertical greening and maintenance regulations so that it can encourage promotions of green wall technology in rehabilitation and maintenance application of the existed building and community.
7. The related architectural regulations and application on vertical greening should be reviewed. How to provide the standards to encourage house-owners to implement vertical greening is important. Perhaps it can prevent secondary refurbishment for exterior wall or prevent owners from wasting space according to the competent authorities.
8. We should have systematic research on vertical greening with investigating related technologies of domestic and abroad. We can also set up green construction methods as well as different vertical greening benefit assessment.

ACKNOWLEDGMENTS

The author is grateful for the funding of research project from the National Science Council of Taiwan (NSC 101-2627-E-027-002-MY3)

REFERENCES

Architecture and Building Research Institute. (2012). *2012 Building Energy Efficiency and Improving Green Office Building Grant Program- Information for Applicants,* Taipei.

Blanc, P. (2008). *The Vertical Garden: From Nature to the City*, Norton, New York.

Kingsbury, N. and Dunnett, N. (2008). *Planting Green Roofs and Living Walls*, Timber Press, Portland.

Lin, H.T. (2010). *Green Roof and Green Walls*, http://www.risecare.com//

Liu, S.C., Liu, Z.R., Lin, C.Y., Xu, G.Z. and Lin, W.Z. (2003). "Taiwan's Western Plains Heat Island Effect", *Watch Taiwan*, Winter, Taipei.

MFO-Park, (2012). retrieved from Wikipedia, http://en.wikipedia.org/wiki/MFO-Park

Peng, K.H. and Ding, Y.C. (2009). *A Study on Rehabilitation Plan of Public Facilities and Utilities of the Existing Housing Community*, Council for Economic Planning and Development, Taipei.

Peng, K.H. (2010). *A Study on Green Wall Panel Technology to Promote Urban Rehabilitation and Maintenance*, National Science Council, Taipei. (NSC 98-2218-E-027 -012-)

Peng, K.H. (2012). "Vertical Greening of Green Building and Urban Rehabilitation", *Taiwan Environmental and Land Law Journal*, 1(4).