

STRATEGIES TO IMPROVE ROLE OF BUILDINGS IN ENHANCING LOCAL BIODIVERSITY

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Abstract

The impact of urbanism on biodiversity is beyond question and as cities prevail to become the new landscape, more connections is drawn between conservation and built environment design. What are the opportunities of the numerous surfaces in our city? Strategies like green roof, habitat box application can be the point of entry in enhancing local biodiversity but what are the potentials for buildings in conservation? To discuss the role of building in enhancing biodiversity, principles in urban ecology are reviewed as a contextual outlook. It is evident that building is an ecosystem on its own. The developments of the two tracks of conservation strategies on greenery and animals are also reviewed. It is argued that a more integral approach concerning system, animal life cycle, context is beneficial to strengthen the conservation role of building. In the end, several design considerations are outlined from the findings.

Keywords

Biodiversity, Urban habitat, Urban ecosystem, Nature inclusive design, Conservation

I. INTRODUCTION

1.1 Urbanism & Biodiversity

Urbanism is an inevitable trend and cities are expected to grow when more people prefer living an urban life. The negative impacts of human to nature will only perpetuate if not accelerate. While habitat fragmentation reduces quantity and quality of natural habitat, urban intensification and disturbance from human activities also challenge the livelihood of many non-human species. In Netherlands, with 16% of total land area as urban area, more than 50% of the wild bee species are under threat and 13 out of 20 of urban bird species are recorded with a declined population. In fact, the struggles of various species indicated a larger threat to our (CBS,2018)

1.2 Ecological design in an Anthropogenic environment

Biodiversity is well recognized as the basis of ecosystem that underlines all ecological processes. It is also crucial to human well-being and sustainable development. Biodiversity design is becoming the new norm in building standard and urban planning. Despite a clear ambition, there seems to be a mismatch in our built reality as demonstrated in the phenomenon of ecological dips. Ecological designs in an anthropogenic environment often downplay the complexity of nature as human interest remains the primary drives in most occasions. For example, green design is commonly perceived as biodiversity design and strategies such as green roof and nest box application are universal design protocols used in the building industries.

1.3 Role of building in biodiversity design

Perhaps cities are not built for wildlife, but cities are a form of habitat and we unknowingly

become the host. wildlife are found under- bridges and vegetations overgrow in vacant buildings. While our strategies with animals in buildings remain “on the surface”, the role of building in urban ecology and their potential as a conservation tool is yet to be explored. Urban Ecology is an emerging study aim to understand how ecological processes can coexist in urban landscape. As a subject of uncertainties, ecological design is challenging for architects. The Role of building can be seen as socio cultural role that acknowledge human aspect to a larger extent. The focus of this paper however will be on functional aspect regarding non- human species.

Main research question:

What are the strategies to improve the role of building in promoting local biodiversity?

Sub questions:

1. Which principles concerning biodiversity and ecosystem can be developed?
2. What are the strategies used in biodiversity design?
3. How can these principles be employed and the implication in building design?

II. METHOD

Knowledge from nature and ecology would be backbone for a sensible building design. Research is carried out across disciplines aiming to bridge the gap between studies. The research method used for this paper are literature review, scientific research and data collection of relevant precedence. The findings will be used as guidelines, evidence and inspiration for further design. Despite having a specific case study in Amsterdam, the research is carried in a more general sense as the ambition of the project is to expand knowledge and provide suggestions for similar study in the future. The research involves a degree of speculation. The limited source of validated reference implies subjective hypothesis. The translation of broad ecological knowledge may not be appropriate in architecture context as well.

III. URBAN IN NATURE: THEORETICAL LINKAGE

3.1 Biodiversity

Biodiversity is a dynamic system referring to the variability of living organism in all ecosystem and is the premise of a functioning ecosystem. It can be measured by the number, relative abundance, composition and interaction between species. The three conservation approaches are restoration, preservation and enhancing. The common regime of biodiversity conservation is preservation of a specific species population. In general, species composition is more important than species richness and local biodiversity is more relevant than in global scale. (Mace, Masundire and Baillie, 2005)

3.3 Ecological formation in city

Ecological succession is the gradual process which ecosystem develop in a timescale vary from days to years. It is demonstrated by spontaneous communities found in cracks, outgrown vegetation in vacant buildings and under-bridge taken over by wildlife. Study of ecological succession in city and on artificial surface in particular is limited, brown roof is the example of colonization by pioneer species. (Hui, 2011)

Biodiversity is localized and can vary in neighborhoods due to different anthropogenic factors. The theory of Niche states that two species settle in the same area cannot have identical niches, the differentiation of niche is the premise of species coexistence. The risk of conservation is the changes on relative abundance and food hierarchy of an area; urban parrots in Amsterdam is considered a problematic alien species which compete with native species.

3.2 Biodiversity and building

that adapt and survive in cities are generalists which have higher tolerance to living conditions can be (Blair, 1996). Synurbization describes the phenomenon of animals colonizing cities and demonstrates the plasticity of animals under anthropogenic pressure. (Luniak, 2004) These urban species show different traits from their wild version. They occupy building and technical objects, profit from human- derived food source and adapt to human customs. They also show tameness towards people. Organisms in city can be classified into urban exploiters and urban adaptor with different relationships to building, either *dependent or opportunistic*. While Urban species depend on buildings for survival, a large group of organisms, such as invertebrates and plants utilize urban surfaces for shelters and resources.(Gunnell, Murphy and Williams, 2013) Most non-human organisms can be found on the building envelopes including roof, walls, overhangs while some species can be identified inside buildings.

3.3 Ecological processes

Ecological processes are the interaction between biotic and abiotic elements that sustain ecosystem. Ecological processes are interlinked and can alter demographic structure and spatial distribution of vegetation and animals directly and indirectly. Thus, identifying the managing ecological processes most relevant on site can be a tool to enhance local biodiversity. (Bennett, Haslem, Cheal, Clarke et al, 2009) The table shows ecological process relevant to building design.

Ecological process category	Impressions in city
Climatic process	- o Contextual Precipitation Temp. humidity - o Microclimate
Hydrological processes	- o Surface and subsurface flow Artificial surface/ channels - o Water cycle
Biophysical habitat	- o Native soil properties - o Growing medium/ substrate properties - o Addition of toxins/ pollutants
Interactions between organism	- o Symbiosis (predation, herbivory, competition, parasitism, mutualism) - o Animal human interaction
Movement of organism	- o Movement in different scales & timeframe - o Seasonal: migration, pollination - o Daily: food/ shelter seeking; social interaction
Natural disturbance	- o Alterations to Biotope: New construction/ redevelopment - o Alteration to biodiversity: introduction of alien species, biased conservation measure, - o Long term influence: human disturbance

Reinterpretation of (Bennett, Haslem, Cheal, Clarke et al, 2009)

3.4 Artificial Ecosystem

Ecosystems in the biosphere are definable units containing both biotic and abiotic elements that work together as a whole. There can be in different scale: Micro (building) -> Messo (sloterdijk) -> Biome (Amsterdam/NL). (Hart and Littlefield, 2011) Ecosystem is by nature an open system which suggests an interflow of energy and matter between ecosystems no matter the scale. Artificial ecosystem is a human made system of plants, animals, and people living in an area. In general, artificial ecosystem has lower species diversity, simple and often incomplete food chain and is not self- sufficient. Zoology is a classic example of artificial ecosystem by putting animals in a designated climate. Eco- design is an artificial ecosystem design as well as the premise is Eco- mimesis which built forms imitate nature's processes, structure and function in the ecosystem.

3.5 Eco- Engineering

Eco- engineering refers to “environmental manipulation by man using small amounts of supplementary energy to control systems in which the main energy drives are coming from natural sources.” It is defined further as the engineering of new ecosystems designs that uses systems that are mainly self-organizing.

IV. NATURE IN URBAN: STRATEGIES & DEVELOPMENT

4.1 Greening

4.1.1 Urban green & biodiversity

“Biotope city” is the idea behind urban greening strategy to regenerate nature in city. Theoretically, urban greening benefit biodiversity by improving connectivity between biotopes by establishing linear or stepping stone green infrastructures. Vegetated building surfaces is believed to have a similar impact in a smaller spatial context. (Mayrand and Clergeau, 2018)

4.1.2 Roof Ecology

Green roof refers to layered system with a waterproofing membrane, growing medium, a vegetation layer and an irrigation system. Green roof is classified into extensive and intensive type depending on the soil thickness. Green & blue roof is a variant in combination with water system and the addition of solar energy system results in bio solar green roof system.

Recent green roof development focus on biodiversity considerations. Mille Arbres in Paris is a realized “house of biodiversity”. The project features two layers of roof hosting thousands of trees. It is a biomimicry of forest ecology and is managed by the League of Protection of Birds. Finding natural analog in green roof design is a strategy to include entire plant community and create wider range of habitat for animals. In Switzerland, variation in substrate thickness is adopted as a method to mimic nature microhabitat. (Marinelli, 2006) “Grassy Hill Roof” developed by Rooflife Amsterdam is a lightweight undulating polystyrene form to deliver different media depth without the usual heavy weight load.



Image 1. Mille Arbres in Paris

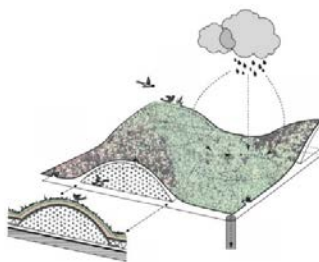


Image 2. Grassy Hill Roof



Image 3. Parkroyal Singapore

4.1.3 Wall Ecology

Despite the biodiversity potential, green roofs are disconnected patches elevated from ground which limited movement and formation of communities. (Francis, 2010). The development of wallscape ecology can potentially form a 3- dimensional urban landscape with Green roofs. Green

facades are for aesthetic purpose and involve climbing vegetation system. Living walls is a vertical extensive roof dominated by herbal plant. The biomimicry of green wall is stone walls and cliff in rocky habitat. Living wall system is detachable from building surface depending on the load bearing capacity of building is a limitation. Hydroponic technology can eliminate substrate layer and reduce weight of living wall. Façade modular system with prefabricated façade element is an expensive technical development. Modules are designed as pre-planted system with possible automatic watering system attached. Though the high construction and maintenance cost, it guarantees functionality in all seasons. It is also possible to achieve horizontal soil orientation within the module which allows more planting options such as perennials, shrubs and annuals. (Bouw natuur inclusief, 2019)

4.1.4 3-dimensional Ecology

The limitation for green wall is the depth of soil and the directional growth that limits habitat formation. There is a trend of negotiating floor area for plants which add spatial dimension to green typologies in building. However costly, green balcony and façade terraces form the new wall ecology in dwelling/ hotel projects. In Parkroyal hotel in Singapore, organic shaped terraces extended from each floor form the new façade. Great variety of species from trees to creepers are grown to attract birds and insects. Green balcony is a common practice in housing projects due to its direct benefit to residents. Deep balcony containers with integrated water system is developed to allow growth of trees and shrubs in Bosco Verticale project. The Bosco Verticale is an integrative approach which set the spatial criteria primarily for vegetation as a non-detachable system and human is the inhabitants of the “vertical forest”. (Boeri, 2015)

4.1.5 Managing the Green

Sustaining the greens is a challenge in green building which required proper water management and maintenance. Water cycle of building regarding rainwater collection/ retention and water recycling strategy is developed alongside with greening strategy. In Sloterdijk Plot O, a smart irrigation system is designed as an integral plan with green space. Nature is dynamic whereas architecture is static, it is suggested that attention on zones and layering can overcome this systemic clash. (Mayrand and Clergeau, 2018) Human input is required in green management. There is an annual Trimming in Bosco Verticale; in The Valley in Amsterdam, a permanent gardener is assigned to take care of the greenery and the management cost is co- finance by the residents and companies.

4.1.6 Small Patch Hypothesis & Ecological value

The greening strategy of building envelope is based on the hypothesis that the ecological value of a cluster of disconnected small habitat is similar to a continuous habitat with the same total area. However, it is suggested that the effectiveness of greening building envelopes is ineffective due to limited habitat provision. Typical natural species require a habitat of 53.3 ha while urban species require a minimum area of 4.4 ha. (Mayrand and Clergeau, 2018) In many projects, the total green area is used to represent the ecological significance whereas the degree of fragmentation and the format of green typologies is often omitted. While size of green area is important, ecological value is also determined species native-ness, variation, type (trees/grass) and function. Biodiversity potential of green roof can be evaluated by: 1) species diversity and richness 2) substrate type and depth 3) plant species 4) connectivity 5) green area ratio 6) ecologically responsible. (Hui, 2011,)

4.2 Animals

4.2.1 Conservation Overview

Conservation measures in city target on urban exploiters and adaptors most commonly bats, birds and bees. Conservation approach is either on protection and provision. Direct measures focus on behaviors of nesting and roosting and movement while indirect measures focus on food foraging, grooming and nesting material collection benefit from the greening strategies in previous chapter.

4.2.2 Animal friendly building

Collisions with glass windows, artificial lighting and urban acoustic are the major threats to avian species. Animal- friendly design strategy is widely used in legislation, product and building design to make our buildings less harmful for wildlife. Bird friendly building standard focus on window and façade design. Use of virtual barriers and signals is a common method to cope transparency and reflectiveness on glass façade. (Brown and Caputo, 2007) These design elements can be applied to both new buildings or retrofitted to enhance existing buildings and comparison is done regarding the effectiveness, cost, ease of application and lifespan of different element options. As an integral design principle, the 82- floor high Aqua tower in Chicago is considered to be safer to birds because of the undulating wave like balconies and fritted glass.

4.2.3 Nesting in building

Two types of nesting tool can be found in building depends the building- animal relationship (refer to 3.2) In a thesis titled Synanthropic Suburbia, the habitat potential of building component for depending species is explored. A range of building elements such as eaves and chimneys are transformed into multifunctional habitat elements. Nest box is commonly conceived as a tool to provide habitat for opportunistic insect, birds and bats. The appearance and placement in building are determined by design principles based on ecology studies. As a form of artificial nature, it is common in both new buildings and refurbishment of existing building. It can be applied as non-structural ready-made items, alternatively, there is a range of mass- produced habitat- integrated structural elements which can substitute standard bricks and blocks in buildings. Habitat elements can also be non- transferable customized design such as the habitat façade in Sloterdijk N1 N3.



Image 4.
Aqua Tower Chicago

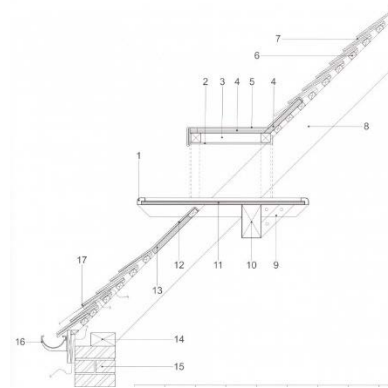


Image 5.
House Refurbishment for bird habitat

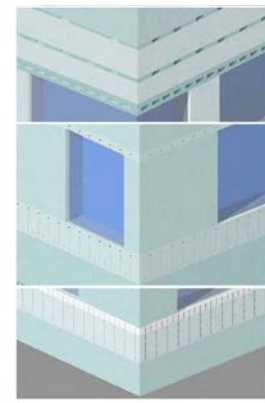


Image 6.
Sloterdijk N1 N3
customized habitat facade

4.2.4 Building standard & Challenge

Apart from a set of design and installation instructions, there are also strict guidelines regarding management and maintenance. For example, there is a management timeline for bee nest box which the maintenance window is from January to March regarding the nesting pattern of bees. Uncertainty is another challenge in implementing habitat designs in building, making optimization of habitat design impossible. The linkage between the quantity of next box and

effectiveness is yet to be established. It is suggested that the amount of nest box should equal the number of human occupants in the building, the study however did not cover the variation in program and availability of usable space for ecological intervention. (Gunnell, Murphy and Williams, 2013) Lifespan and service life of habitat element is another challenge, both continuous occupation and idling cause weathering of design element, deterring decay factor is an important research.

4.2.5 Cross- disciplinary development

Animal habitat developments is also noticeable in the practice of gardening, art and material science. Scientist carried out various studies to optimize insulation and comfort of nest box environment in order to increase usage and mortality rate of occupants. Garden is a testing ground for new forms of nest box design, insect hotel is developed into a modular system with a supporting frame and nest infill and Buginn pollinator brick is a system of a concrete shell and replaceable nesting core. Examples in material innovation include green charcoal developed by Mumbai scientists as an alternative construction material that encourages lifeform by porosity.

Multifunctionality is a common trait in these developments. Common coupling of functions includes: education and exhibition purpose, urban furniture for leisure, habitat/ planter product for aesthetics and to provide food in close proximity. While majority of developments are on nesting behaviors, there is limited advancement in other behaviors such as roosting and breeding.

4.2.6 Animal Aided Design

Animal aided design (AAD) is in essence a knowledge/ evidence-based design principle that use a species' life cycle to improve open space planning and conservation in urban landscape. By making animals integral part of the design process, the objective of an organized wilderness is to provide habitat requirements for a species to thrive in different stages and different living behaviors. The tool of AAD is species profile including biological data and connection with human. It is a method for wildlife recruitment in city and the conservation value depends on the target species. Developers can implement AAD to recruit species that are not native but popular to human occupants in their projects. (Weisser, Hauck, 2017) A conceptual design in USA integrated the whole life of butterfly into various building components, the building serves as a breeding ground, waystation and sanctuary for monarch butterfly. The connected roof & façade system provides food and shelter, terraces are used as stop over habitat and atrium can be used as semi- enclosed colonies that foster population growth.



Image 7,8.

Conceptual façade design that accommodate needs of butterfly in different life stages and acknowledge human by integration with human function as office and education purpose.

V. DISCUSSION & CONCLUSION

Knowledge is the prerequisites for building performance

It is clear that fragmented green balcony is unlikely to resemble quality of open green space and it would be unrealistic to compare a building to a park. The niche of buildings in urban ecosystem perhaps is the possibility of ecological datums and the vertical landscape they resemble. Knowledge of the ecological context and biodiversity profile is the prerequisite to create a positive ecosystem.

Re- orientating architecture in Ecology

We have been trying to incorporate the nature into our built environment ending up with buildings that are either too artificial, superficial or intolerant to nature. We should stop capturing the dynamic system in a static moment but adapt to the natural dynamics. Principles like AAD and vertical forest reexamine our relationship and design practice with nature. The spatial criteria for building changes instantly if we approve the spatial dimension of ecology and start to see buildings as a landscape, a form of habitat or an urban wildlife reserve that we are co-creating the artificial with the nature. In that way, nature enhance our artificial ecosystems which ultimately benefit our urban ecology. (Application -> Substitution -> Reconceptualization)

Quantitative and Qualitative considerations

A knowledge- based integral systemic approach with clear conservation goal describe the basic principle and an artificial ecosystem in building can be a design tool to enhance biodiversity. In addition to the basic protocols, radical moves can be carried out responsibly to (a) increase spatial ratio of conservation intervention (b) improve spatial quality for biodiversity (c) search new tools for biodiversity conservation.

1. *The Barren* – The basic form of a building should be animal- friendly with minimal hazard factor and responsibly articulated facade for building dependent species.
2. *Placeholder* – A formal framework for informality. The many unknown factors in ecological design make it impossible to control design outcome as we cannot control nature. While control can be implemented on in the beginning and on management, design should provide flexibility for nature to grow, ecological processes to occur and to an extent self-organizing.
3. *Interaction/ Interdependence* – Design relationship and draw connections. To make a viable artificial ecosystem, it is important to identify the symbiotic relationship of possible lifeforms and their movement in the area. ie. do they live independently or as a system altogether? The natural- artificial system interaction should be covered as well.
4. *Opportunistic* – Cross reference and examine materials on hand to maximize potentials within building capacity. This involves Reconceptualization, such as the implication of thickness and layering in façade, the possible application of relevant typologies eg. Roosting tower in buildings, or the hybrid typology of building components and habitat product.
5. *Multifunctionality* – As a follow up of the previous point, pairing an alternative function with conservation typologies in building can be strategic solution to uncertain occupation and seasonal idle period regarding animal life cycle. Inspirations can be drawn from various habitat/ furniture or / education projects in other fields.
6. *Hetero* – Diversity and variation regarding scale, type and function. The building should include a range of microhabitats mimicking a mix of ecosystems with hierarchy and take care of different animal behaviors such as roosting and breeding.
7. *Human acknowledgement* – The quality and quantity of greenery is positively related to the level of human involvement. Benefits to human is the obvious justification in the cases of green balcony and terraces. Practically speaking, it is hard to change the human- dominated nature in city and human will remain as the primary occupants of buildings. Greenery/ habitat box should be implemented in relation to human function.

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