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TRANSPLANTING HEAT ISLAND EFFECTS IN TOKYO

Danelle Briscoe

School of Architecture, IE University, Segovia, ES

School of Architecture, University of Texas, Austin, USA

HIGHLIGHTS

- Recent outcomes prompted by the Guidelines for Heat Island Control Measures (GHICM) in 2005 set forth by the Bureau of the Environment, Tokyo Metropolitan Government
- Rail-related Transportation infrastructure supporting living wall techniques as intensive heat island control measures in the central urban core of Tokyo

ABSTRACT

This research documents recent outcomes set forth by the Guidelines for Heat Island Control Measures (GHICM) in 2005 by the Bureau of the Environment, Tokyo Metropolitan Government. These guidelines incentivized development in general to implement such techniques as green roof, living wall and water-retaining pavements as intensive heat island control measures in the central urban core of Tokyo. The original research findings of this paper stem from a 2016 Snell Endowment for Transportation Research grant intended to disseminate such metrics as methodology for future transportation development, specifically focused on transportation infrastructure's adaptation of the GHICM and the implementation of living wall systems. This study qualitatively documents three living wall systems in transportation infrastructure design in the most intense heat areas defined by the GHICM: JR Tokyo Train Station Drop-off, Ookayama Station/Hospital and Ginza Station terrace. Ultimately, this comparative research facilitates transportation infrastructure optimization, novel implementation of green building techniques and heat-island reduction through physical and cultural potentials.

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1. INTRODUCTION

As measures toward sustainable urban development, cities today strive to improve public transport, encourage non-motorized modes, create pedestrian zones, limit the use of private cars, and otherwise try to undo the transformation of cities caused by automobile dominance (Pojani, 2015). More often than not however, the perceptions and positive factors of rail-related transportation overlook their inevitable and detrimental addition to urban heat island (UHI) effect. As a means to address and potentially transform this issue, Japanese development in or surrounding rail-related transportation infrastructure is advancing as a new form of ecological incubator through green building techniques, specifically through expansive, planted living walls, to mitigate this form of urban heat gain.

In 2005, the Guidelines for Heat Island Control Measures (GHICM) were created by the Bureau of the Environment, Tokyo Metropolitan Government (TMG). These guidelines incentivized all new development to implement techniques, such as green roof, living wall and water-retaining pavements, as intensive heat island control measures in specific central urban core zones of Tokyo. In the year prior to establishing the GHICM, the Japan Meteorological Agency registered an all-time high temperature in Otemachi, Tokyo of 39.5° Celsius as well as an overwhelming heat wave in the general Tokyo metropolitan area, where temperature stayed above 25° Celsius and lasted 30 days or more. This continued weather pattern suggested the marked progress of two forms of warming – global warming and the heat island phenomenon – in Tokyo. This paper focuses solely on the use of living walls as the means to alleviate radiant heat from the walls (and potentially contribute to an energy savings in habitable space).

Three documented case studies reside in the most intensive heat zones of Tokyo and demonstrate the significance of a symbiotic relationship between living wall systems and urban conditions of rail-related transportation infrastructure: the Tokyo Rail Station thoroughfare, the Ookayama Train Station/Hospital streetscape and Tokyu Ginza Station rooftop terrace. These living wall examples vary in their overall scale and component system but all perform with similar attitudes in enhancing the urban context. In addition to air quality and heat reduction benefits, these living walls additions are in service to improving a sense of space and are integral to the improvement of their urban environments. As a UHI mitigation strategy, a comparison of these case study and their qualitative effectiveness facilitates an approach that all transportation infrastructure and building design could follow to effect change for this typology and environmental design more broadly.

2. GUIDELINES FOR HEAT ISLAND CONTROL MEASURES

This GHICM document addresses the heat island phenomenon as a problem that should be the responsibility of numerous parties involved and offers, at a critical time, ways of implementing techniques in a manner befitting the heat environment conditions in the wards and other areas of any urban setting. The guidelines are intended for building owners and architects to use in newly constructing or expanding buildings. Actual incentives, whether financial or tax exemptions, have yet to be documented or if architects, designers and developers saw undeniable qualitative benefit as incentive enough.

2.1 Distribution

Japan's first railway started in 1872 as a single line connecting the Shinbashi district with Yokohama (Freedman: 2010). Today, greater Tokyo is dominated by the world's most extensive urban rail network where, as of May 2014, Tokyo rail lists 158 lines, 4,714.5 km of operational track and 2,210 stations. In the study, four Heat Island Control Measures Promotion Areas were designated –inner city areas, Shinjuku, Osaki/Meguro and areas around Shinagawa Station. The most critical of these zones, noted as Type I inner city, had obvious heat congestion around train-related transportation depots where crowded business areas coincide with relatively heavy thermal loads (<http://www2.kankyo.metro.tokyo.jp/heat/>).

2.2 Heat Islands

The train depot areas designated in Tokyo have the highest percentage of the area of the pavements in the road at 55% and the percentage of the area of the artificial coverings including buildings is also the highest at over 90%. In the daytime, approximately 160 W/m² of anthropogenic waste heat (sensible heat) is released and this figure is the second largest among the areas in the Type I the percentage of the area of the refractory walls is the highest (GHICM: 5). The GHICM policy was set forth for varying scaled projects: Commercial, Factories and Warehouses, Multi-Family and Single Family Housing. This research specifically focuses on commercial development of areas surrounding the heat generating train transportation stations in the Type 1-1 target zone in central Tokyo.

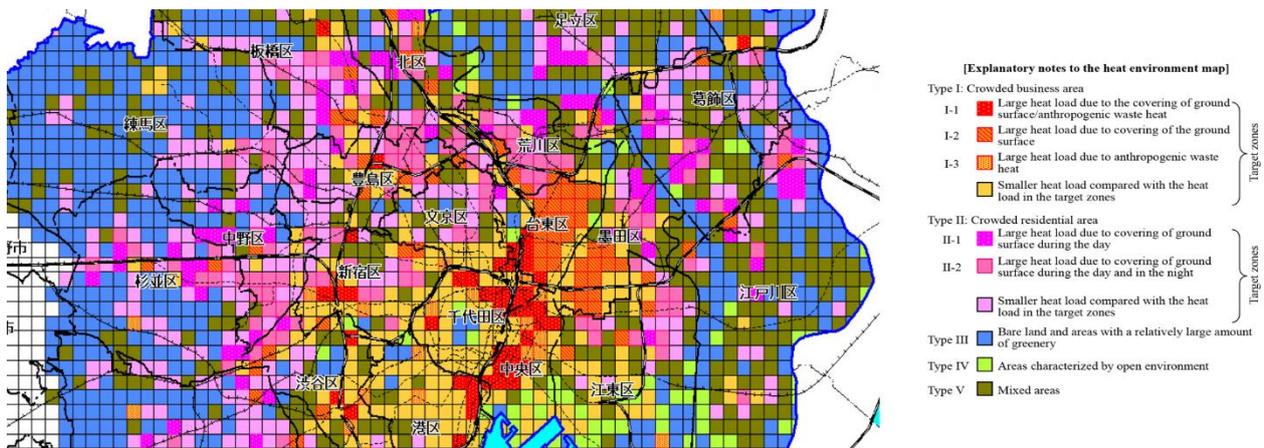


Figure 1: Partial Heat Environment Map Type 1-1 is area of focus for study. Source: © GHICM.

2.3 Control Measures

A menu of Control Measures is offered in the policy:

- Use materials (water-retaining construction materials, lawn blocks, etc.) close to the natural coverings to check a rise in the temperature on the ground surface.
- Plant trees (with large canopies) to create the shade to check a rise in the temperature on the ground surface and improve the heat environment for pedestrians.
- Green the rooftops of low-rise buildings to check a rise in the temperature on the surface of the rooftops (and to contribute to a saving of energy in rooms).

- In addition to rooftop greening, apply highly reflective paint to the rooftops of high-rise buildings to prevent heat from being stored and check a rise in the temperature on the surface of the rooftops (and to contribute to a saving of energy in rooms).
- Alleviate radiant heat from the walls by greening the walls (also to save energy internally).
- Install energy-saving systems and equipment and prevent heat from being taken inside in order to reduce anthropogenic waste heat and turn it into latent heat as well as to release heat from at a height to mitigate the effects of heat on the ground surface and pedestrians.
- Construct buildings with particular reference to the shape and configuration, and arrange them in a manner that does not prevent the wind from blowing in the prevailing direction in summer.

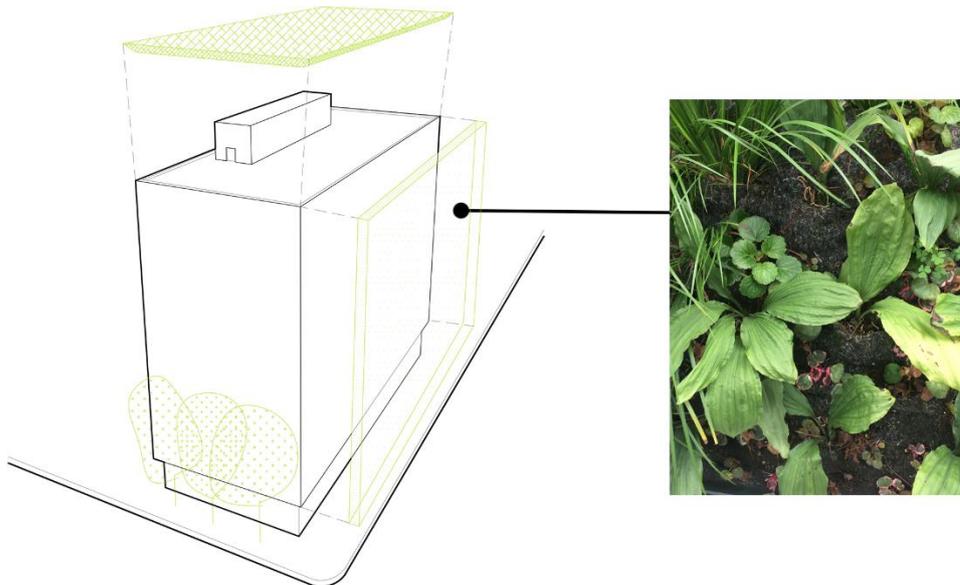


Figure 2: Diagram of Heat Island Control Measures for Commercial Buildings with living wall system example from Shibuya district. *Source: © Danelle Briscoe*

3. LIVING WALLS

Interest in sustainable development technologies which incorporate living systems into building design, such as green roofs and green walls, is growing in popularity. Further, the green building industry initiatives such as USGBC's LEED (Leadership in Energy and Environmental Design) and SITES (Sustainable Sites Initiative) are encouraging living technologies which improve ecosystem services of buildings and landscapes. In North America, many of these technologies such as the green roof industry are still under development and implementation is limited due to high cost of materials and installation even where there are incentives in place. Green walls potentially offer a cheaper alternative to green roofs in that the structure is easier and cheaper to support, reduced possibility of water leaking into the structure, a smaller footprint, and green walls have the added advantage of mitigating sound pollution and higher visibility (Briscoe, 2013).

To define further, a green wall contains plants, either supported on a trellis structure ('green façade') or rooted in growing media attached to the wall itself ('living wall'). It is further recognized as having potential and benefit to the urban environment as an alternative facade envelope that can be effective and natural air purifying systems that removes particulate matter (O_3 , VOCs and CO_2 from the air as it

passes through or across the wall). Similarly, a green wall can cool building surfaces, interior space and even reduce ambient air temperature around the building – helping to mitigate the urban heat-island effect (Charoenkit, 2016) Other urban benefits can include storm water mitigation through transpiration and soil infiltration and grey water upcycling (Fowdar, 2017).

In the cases studied, a living wall is used to address the urban thoroughfare, street and plaza. Given the vertical nature of living walls, the facade becomes a design fetish, but one with benefits. As stated in the GHICM, living wall systems are considered an effective measure for Type1 areas and such a measure is expected to prevent heat from being stored in building facades and pavements and to reduce anthropogenic waste heat from buildings and surrounding context (GHICM, 2005). Scale is being addressed from the very local or human scale to that of the neighborhood and region.



Figure 3: Living Wall urban development in Shibuya district. Both small cafe scale (a) and future large development(b) have expectations of inclusion of greenery. Source: © WhitPrestonPhotography 2016.

4. PRECEDENCE OF LIVING WALLS IN JAPAN

The proliferation of living walls internationally demonstrates an acceptance and certainty of their sustainability (Van Uffelen: 2011). Similarly, those found in Tokyo rely no doubt on the history of ‘nature in architecture’ and has been most likely further influenced by the 2005 World Expo *Biolung* pavilion, an important Japanese precedent that implied combining “life” (bio-) and “lung” as the pulmonary function of plants in an urban environment. The (now disassembled) 150 x 12-meter wall of plants claimed to be the world’s largest green wall at the time and was essentially the first infrastructural investigation using a living wall. In a timely manner, it coincided with the introduction of the GHICM policy.

Some fifteen companies shared the construction of *Biolung*, each using its latest wall-greening technology in a portion of the wall (<http://www.expo2005.or.jp/en/eco/bio-lung.html>). In hindsight, Expo coordinators note that various methodologies were tried from installation, operation and removal and there was much to be learned from this research and development. In a Letter of Appreciation from the Aichi Expo Bio Lung Executive Committee, it was stated that the techniques of

making greening walls in Japan not only improved dramatically in the Expo process but for many visitors, it was inspirational as the first living wall many of them had ever seen (<http://www.greenwall.jp/bio.html>).



Figure 4: Biolung project in 2005 World Expo Aichi Japan. *Source: Manuel Derra*

Conceptually, the grand wall was divided into three parts, with plants to suit each theme: village - garden, field side, and *sato-yama* (managed woodland), and *okuyama* (wild forest). Plant selections (where roughly 200 kinds of plants were introduced), such as pansies, olive apples, honeysuckle and strawberries, were intended to enhance the sensory experience of the wall to expo visitors. At both ends of the central large screen, plants were held in pockets of the canvas made from kenaf (a type of hemp commonly cultivated in Southeast Asia) and coated with photo-catalyst. Other state-of-the-art greening technologies included sedum vegetation mats pasted over foam resin materials, vines planted over vegetation boards made of peat moss, and wild flowers planted on bog moss. The *Biolung* wall was sprayed with mist of active water generated by ceramics which had the effect of cooling the temperature in the expo area as a cooling effect in the summer months. Bio-lung was designed to absorb carbon dioxide and supply oxygen at the Expo Plaza (www.expo2005.or.jp/en/eco/bio-lung.html). It was thus presented as a model for future environmental equipment that could improve the urban environment and reduce environmental impact.

5. CASE STUDIES

The selected case studies demonstrate a variety of scale, typology and proximity to a transportation hub. In each case, a living wall as a sustainable technique has been implemented as a result of the GHICM initiative or perhaps a trend to the comforts that this implementation has achieved. This on-site research inquiry evaluates each system’s relationship to transportation rail-related centers, their application of a living wall as a Heat Island Control Measure (HICM) and the specific benefits of each. Ultimately, this comparative research facilitates transportation infrastructure optimization, novel implementation of green building techniques and heat-island reduction through physical and cultural potentials. The critical factors in evaluating the proposals, such as soil volume, specific plant and soil selections, water usage, maintenance and bio-habitat considerations, could not be attained in the limited field research, but are ones to further determine value in the future.

Table 1: Case Study Comparisons

Station	Year	Name	Architect	Area (sqm)	Typology	HICM	Plant types
Tokyo	2013	Rainbow Wall	GP Plants/ Jardin	300	thoroughfare	pixel	<i>Heuchera</i>
Ookayama	2007	Tokyu Hospital	Yasuda Koichi/ Hiraga Tatsuya	4,682	streetscape	strand	<i>ivy</i>
Ginza	2016	Kiriko terrace	Nikken Sekkei	3,500	plaza	trough/ pixel	<i>tropical</i>

Source: Briscoe (2016)

5.1 JR Tokyo Train Station thoroughfare

On one side, the JR Tokyo Station holds an iconic 1914 brick facade building. On the other, its own identity and place have been transformed with extensive, all-encompassing living walls. From smaller walls at the bike zone, stairs to upper levels (see figure 2) to the turnaround for taxis, pauses of greenery act as a buffer to heat and congestion.



Figure 5: (a) Steps leading to (b) upper thoroughfare/terrace. Source: WhitPrestonPhotography (2016)

In particular, the upper floor to Yaesu Terminal displays the *Heuchera Rainbow Wall* under a Grand Roof, with its greatest length of measuring approximately 100meters on. This area acts as an elevated intimate, yet urban space that seems almost a destination rather than a thoroughfare, meaning the train station is no longer simply a means to get from A to B, but instead a place to seek recluse, where to meet friends and when to simply take a moment to marvel. Integrated seating in the elevated area suggests such accommodation. This zone of the station is recognizably cooler offering a sense of qualitative effectiveness both visually and perceptively.

In addition, an overhead screen canopy defines the terrace and also protects plants and users from the sun and rain and allows hot air to continue its path up and out of the station. In speaking with Yuk Matsuzaki on site (Briscoe, 2016), the plants require a part-time maintenance team every week even though they are primarily a genus of evergreen, herbaceous perennial plants in the *Saxifragaceae* family. As native to North America and coming from a nursery in Oregon, USA (Vaughan:1). The top rail of the system design allows for a well-integrated maintenance system to occur so regularly without disturbing the thoroughfare.

5.2 Tokyu Hospital Facade

Coming up and out of the Ookayama Station feels much like any other in Tokyo. Until the building that sits on top of the station, is the sense of urban streetscape enhanced.



Figure 6: Street view of Tokyu Hospital. Source: WhitPrestonPhotography (2016)

Not only is the building unusual in its mixed typologies (as the only hospital in world built above a train station), but also in that its facade is covered in planting. Mitigation of excess heat generated by the station gives justification to the living wall, along with its benefit to street conditioning or better yet the patients inside (Largo-Wight, 2011). Fortunately for patients at Tokyu Hospital, each patient also has access to balcony space, garden courtyards, and a public plaza. These items give patients the opportunity to come into direct contact with plants and sunlight, which has been shown to have the strongest association with stress reduction and improved health.

The considerable solar exposure of this location is strategized through the shading effect of the living trellis design. Its two large facades are covered with vines another side has deep balconies that are lushly planted. Vines climb the height of the building on tension wires (Braiterman: 2010) and offer an amount of density for qualitative effectiveness offered by the selected species to reflect radiation without totally blocking natural light to the indoors. Along this busy street, the living system also acts as a noise buffer. Additionally, the living wall in this case is used as a passive technique to improve building energy performance. With green facades, a significant amount of heat can be prevented from entering and being trapped, resulting in the reduction of energy for cooling or heating. Also, plants and substrate can be used as the source for carbon sequestration (Charoenkit, 2016).

5.3 Tokyu Plaza Ginza Shopping Mall - Kiriko terrace (rooftop)

The Kiriko Terrace sits at the confluence of several rail stations: 1 min. walk from Ginza Station, 2-minute walk from Hibiya Station, and a 2-minute walk from Yurakucho Station. To suggest a commercial building which interacts with the city, this façade is mainly composed of finely crafted, faceted glass as metaphor to the active nature of the city-- a three-dimensional composition that reflects sunlight which only adds to the business of the street. While attractive as a symbolic form, true reflection of surrounding cityscape and climate occurs on the rooftop terrace and urban green space. This facade inversion on the rooftop, situated about 56 meters above the ground, creates an open-air urban “living room” – a public amenity in the sense that seating and lounge space are free and lush greenery forms a three-tiered living wall surrounding the observation space and café. It is open and at the same time intimate with a sense of recluse from the urban bustle and heat below. By internalizing the event, this shopping complex draws people up through the entire building to its rooftop (see figure 7). The project additionally uses a common solution to UHI is to incorporate high albedo surface materials which are capable of bouncing solar radiation back into space before it transforms into heat. This strategy is used by the so-called cool roofs, which are highly reflective finishing surfaces that keep roof’s temperature low



Figure 7: Tokyu Plaza Ginza - Kiriko rooftop terrace. Night view. Source: Ana D'Apuzzo (2016)

(Victorero:3417). The project utilizes a component system filled with a variety of sedums and tropical ferns. The grid disappears by the qualitative effectiveness of planting control and maintenance. A tree is also incorporated into the scheme which implies the plaza’s purpose as alternative ground condition. With the preciousness of real estate and inability to introduce new green space at the ground level, as is the case in Tokyo and every other major city, this rooftop solution forms beneficial urban space as well as a heat island solution to the busy Ginza station.

6. CONCLUSION

These projects (and basic analysis of their intentions) essentially serve as the first documentation specifically focused on transportation infrastructural use of living walls. Their manifestation and dissemination are critical to then register these metrics and methodology for future car park development. This concise study identifies a plausible path for supplementing the development of transportation infrastructure by augmenting their exterior applications of living wall systems. This proposal challenges the current assumptions of transportation infrastructure design as well as the standard practices of living wall application and purpose to either architecture or landscape disciplines. Rail-related transportation stations, like Shin-Yamaguchi Station and Kyoto station, are now other examples in Japan being affected by this policy and use of living wall benefits. Policies such as the Guidelines for Heat Island Control Measures (GHICM) demonstrate how Tokyo Metropolis along with many other cities, both large and small can develop urban strategies for reducing heat island effects by incorporating living wall systems into the program and interests.

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