Chapter 15

Toward Holistic Urban Green Infrastructure Implementation

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Abstract This article aims to reexamine green infrastructure (GI) visions and frameworks and site-scale GI implementation toward holistic urban GI implementation. For GI visions and frameworks, both City of Philadelphia and Singapore have demonstrated progressive approaches to weave different divisions and planning, accomplishing holistic frameworks as well as enhancing GI implementation at site-scale level. Through three site-scale GI implementation case studies, the creative solutions have been demonstrated how streets, retention ponds, and the existing urban fabric were to transform into GI open spaces. This article suggests the way how GI could be interwoven into visions, planning, and design to create places for people.

Keywords Urban green infrastructure · Visions and framework · GI implementation · Open space

15.1 Toward Holistic Urban Green Infrastructure Implementation

Green infrastructure (GI) implementation needs to integrate visions and frameworks of the city scale with the ones of the site scale. In recent years, many practices have demonstrated good GI implementation; however, there are gaps between city-scale GI visions and site-scale GI implementation. Like many other concepts, the term GI often creates the confusion of its definition. As per Environmental Protection Agency (EPA) in the USA, GI is defined as “systems and practices that use mimic natural process such as infiltration and evapotranspiration.”

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Section 502 of the Clean Water Act defines green infrastructure as “the range of measures that use plant or soil systems, permeable pavement or other permeable surfaces or substrates, stormwater harvest and reuse, or landscaping to store, infiltrate, or evapotranspire stormwater and reduce flows to sewer systems or to surface waters” (United States Environmental Protection Agency [n.d.](#)).

This sustainable stormwater management system has become a big trend since the early 2000s, and this system is introduced in the form of bioswales, green roofs, rain gardens, and such small implementation. On the other hand, the European Commission defines GI as “a strategically planned network of natural and semi-natural areas with other environmental features that was designed and managed to deliver a wide range of ecosystem services. It incorporates open spaces and other physical features in terrestrial and marine areas. On land, GI is present in rural and urban settings” (European Commission [2013](#)). Though these two perspectives indicate principles of GI, it is not clear how both concepts can be applied for GI implementation. In other words, EPA expects GI put focus on solution, and performance of urban ecological system, especially for stormwater. EU covers much broader open spaces and natural systems as its framework. How can we implement these perspectives on the ground? This section aims to reexamine “visions and approaches” toward holistic urban green infrastructure implementation with reference to some project case studies.

15.2 GI Visions and Frameworks: “Green City, Clean Water” Citywide Green Infrastructure Implementation Frameworks in the City of Philadelphia

City of Philadelphia, USA, challenged on creating a new type of the holistic framework toward strategic GI planning and implementation. Through a literature review and the interviews with the City of Philadelphia Water Department GI group, and by consulting “Green City, Clean Waters (GCCW)” to understand the development and framework of GI planning, three phases of GI planning and implementation were identified through the analysis of selected GI planning and policy (Fukuoka et al. [\(2020\)](#)). The first phase (1990s–2008) can be described as “Water quality control period.” Combined sewer overflow (CSO) was a big problem in Philadelphia. Polluted water would be released directly to the river system after extensive storm event. CSO Control Policy was implemented in 1994, and the long term Control Plan by Water Department was released in 1997. In this phase, GI was implemented as a site-scale project within Watershed Planning (Office of Watershed). The other approach was a grassroot West Philadelphia project directed by Anne Spirn, professor at the University of Pennsylvania. West Philadelphia project demonstrates very progressive approaches which cover stormwater management for social issues and food production. Prof. Spirn collaborated with PWD (Philadelphia

Water Department) and advocated GI at early stage (West Philadelphia Landscape Project [n.d.](#)).

The second phase (2008–2012) can be described as “GI planning development period.” Mayor Nutter (2008–2016) started it in 2008, and orchestrated very powerful leadership in creating sustainable cities. Multiple Policies and Guidelines such as Green Works (Sustainability Vision by Office of Sustainability), GCCW (GI Plan by PWD), and Green Philadelphia (Open Space Plan by Park and Recreation) are enforced from one after another.

The third phase (2012–) can be described as “GI implementation acceleration period.” City of Philadelphia joined a partnership with EPA in 2012 to implement GI further. Contents of GI partnership include GI model project implementation, GI engineering development, and water quality research and communication. For organizational structure, GI Planning group was created in 2017.

City of Philadelphia shifted GI implementation unit from watershed-based implementation to district-scale implementation which is more effective to create synergy between city planning and GI implementation. In addition, Green Street Design Manual (PWD and Transportation), Stormwater Design Manual (PWD), and Planning and Design Manual (PWD) had been issued in 2018. Now, cities challenge to accelerate GI implementation further. GCCW performed key roles in setting GI goals, visions, and frameworks.

As a summary, Philadelphia developed the holistic framework toward strategic GI implementation. GI visions and frameworks set the big pictures and the essential structures for diverse governmental divisions in order to move forward with GI concepts. Those frameworks also help build up and activate a wide range of site-scale GI projects from green streets, open spaces to urban redevelopment. Especially, shifting GI framework scale from watershed-based one to district scale helped to create a synergetic effort with city planning work (Fig. 15.1). It was rather solo frame work before. The next phase for challenges aims to make this vision and framework much broader so that it will include new types of GI such as vacant lots or brownfields that are significantly increasing around the city periphery areas.

15.3 National-Scale Holistic GI Visions and Approaches: “ABC Water Design Guidelines in Singapore”

In contrast to GI implementation in Philadelphia, Singapore challenged to create national-scale holistic GI visions and frameworks with Design Guidelines. This case study is an excellent example of sustainable stormwater management at a national scale and may be applicable in other cities and nations in the similar monsoon climate. Singapore is located at the heart of Southeast Asia, and is comprised of 63 islands. Singapore Island is 42 km long from east to west and 23 km from north

Fig. 15.1 GI implementation in the City of Philadelphia in 2019. *GSI indicates green stormwater infrastructure (Fukuoka et al. (2020) created it by using open Data PHL map Green Stormwater Infrastructure Public Projects Points/Street data set)

to south. Historically, Singapore has relied on Malaysia for 40% of its drinking water resource coming through pipelines. However, due to uncertain future with water problems, Singapore government made a decision to become self-sufficient of water by applying watershed-based management system. Especially, annual rainfall (around 2340 mm) is targeted as the major water resource to be wisely used together with gray water and the water stored in reservoirs. Public Utilities Board (PUB), Singapore’s national water agency, has embarked on water management using the

3P (People, Public, and Private) approach to take joint ownership of Singapore's water resource management.

This is embodied in PUB's tagline – Water for All: Conserve, Value, Enjoy (Public Utilities Board 2016a).

The Active, Beautiful, Clean Waters (ABC Waters) Program, launched by PUB in 2006, is the cornerstone of the 3P approach. The program intends to transform Singapore's extensive network of reservoirs and water bodies into beautiful and clean streams, rivers, and lakes, creating a vibrant City of Gardens and Water. More than 100 potential locations will be identified as the site for the implementation of the program by 2030 (Public Utilities Board 2016b). As of June 2014, 23 projects had been completed (Public Utilities Board 2014).

The first edition of the ABC Waters Design Guidelines was launched in 2009 and the second edition in 2011. In June 2014, PUB upgraded the guidelines for locally built examples to the ones for the showcase developers, architects, and engineers who have incorporated the ABC Waters concept in their developments (Public Utilities Board 2016c). ABC Waters Program helps implement ABC Waters Design Guidelines and function based on GI as a hinge between visions and site-scale projects. This new set of reference material aims to meet the industry's needs better and continue building up technical expertise in the industry (Kato and Fukuoka 2016). First, the ABC Waters Design Guidelines provide actual stormwater design tools for three different stages which are applicable to various types of green infrastructure project scale. These stormwater design tools are categorized into (1) catchment elements, (2) treatment elements, and (3) conveyance and storage elements. First, catchment elements aim to collect water based on land use typologies such as road, canal, water bodies, pedestrian walkways, public open spaces, plazas, and buildings. For different surface conditions, appropriate stormwater planning and design methodologies are shown with a clear illustration. At the stage of project planning, research and concept were made based on the ABC Waters, and location and volume of buildings were to meet ABC Waters' goals, and applicable green infrastructure implementation methodologies were introduced at catchment stage. For example, building was divided into various catchment elements such as green roofs, terraced green balconies at multi levels, and ground level elements such as planted areas and water features. The ABC Waters Design Guidelines provided engineering and design procedures so that the basic knowledge and methodologies could be easily integrated into projects. Second, methodologies how to implement treatment elements such as swales, bioretention pond, detention pond, stormwater planter, rain garden, and cleaning biotope are explained through visual information. Water treatment part covers a wide range of methods, and this provides concept, benefits, and design methodologies for management issues. Third, conveyance and storage elements focus on large water bodies and provide methodologies such as bioengineering, erosion control, and water quality control.

Second, in order to realize ABC Waters concept, ABC Waters Certification and ABC Waters Professional Program were created to make loop of projects be recognized and adopted by people (Kato and Fukuoka 2016). The ABC Waters Certification launched by PUB on 1 July 2010 is a scheme to provide a recognition to public agencies and private developers who embrace the ABC Waters concept and incorporate ABC Waters Design Features in their developments (Public Utilities Board 2016d). Besides providing the recognition, the scheme also aims to ensure that the design features incorporated within the developments meet the minimum design standard. Since 2010, 62 projects have been certified by the ABC Waters Certification. Certification is judged in four categories: Active, Beautiful, Clean, and Innovative. Out of total 110 possible points, for a project to be certified, it needs to receive a minimum of 45 points with at least 5 points in each of the first three categories. ABC Waters Professional Program is supported by multiple institutions such as Institution of Engineers Singapore (IES) with the support of the Singapore Institute of Architects (SIA) and Singapore Institute of Landscape Architects (SILA) (Public Utilities Board 2016e).

As a summary, Singapore put force on setting nationwide Water Design Guidelines and provided both urban green infrastructure visions and frameworks at a national scale. Singapore's case study demonstrates "top-down" approaches and sets effective schemes to translate GI visions to real projects by creating multiple programs. Both Certificate and ABC Waters Professional Program help accelerate GI implementation. As described above, two cases demonstrated differently, but both are powerful in GI visions and frameworks toward implementation. In the next section, three cases of site-scale GI implementation in urban settings have been examined.

15.4 GI Approaches: Site-Scale GI Implementation

In this section, site-scale GI implementation project cases are introduced. GI visions and frameworks often express broader ideas but remain vague. At the same time, site-scale GI implementation tends to split into single bits of spaces such as bioswales, green roof, and rain garden. As shown in Fig. 15.2, toward urban GI implementation, each project still needs to contain a big picture about how each piece fits to create the whole GI. Site-scale GI's function is also difficult in setting a good balance among multiple choices such as stormwater management, biodiversity, heat mitigation, and others. Figure 15.3 illustrates GI goals with an envision. It varies from "disaster reduction," "healthy city" to "soft infrastructure, community." How can we set appropriate GI goals and clarify the function of GI required? In this section, three site-scale GI projects are introduced to describe its character and functionality.

Fig. 15.2 GI implementation in city scale

15.5 Street as GI: “City of Copenhagen’s New GI Street Approaches”

City of Copenhagen, Denmark, illustrates an excellent GI street project adapting to the climate change. In July 2011, cloudburst, heavy stormwater event, caused a significant damage to the city. Extensive 150 mm of rainfall in 2 h left major part of the old city area under 1 m of water, and the damage caused by that was approximately 1 billion Euro worth (Fig. 15.4). Based on the research, the expected flood damage caused by both cloudburst and expected sea level rise forced City of Copenhagen to work on cloudburst master plan with blue-green infrastructure in order to reduce the future risk of disaster (ASLA 2016). Existing historic old city has no further spaces left without implementing GI to solve problems. In this master plan, strategic approach such as utilizing road as GI street was taken specifically for Copenhagen. Cloudburst master plan created frameworks to accelerate GI implementation and there are three essential points. First, precautions against cloudburst are developed based on “research.” The City of Copenhagen worked on investigating multiple sets of data and identified high-risk areas. In addition, they model and map the large-scale catchment base of stormwater and

Fig. 15.3 GI goals with an envision

visualize vulnerable areas as well as their risks. Second, GI function and GI implemented places bridge over cloudburst by creating “Cloudburst Toolkit.” This toolkit touches “design and quality” of spaces and aims to provide human-scale experiences to the place. Hot spots for future GI implementation projects are identified and rough images of designed places are illustrated according to the typologies based on the toolkit. Third, socioeconomic cost-benefit analysis was conducted, and it clarified that GI solutions have 50% of potential in saving over conventional gray infrastructure or piped solutions. As explained above, these three points helped utilize GI visions and frameworks for site-scale GI implementation.

Fig. 15.4 Cloudburst caused significant damages to Copenhagen (Ramboll Studio Dreiseitl)

Figure 15.5 illustrates a basic concept for transforming road into GI street. Two lanes 16 m wide road would be reduced into one lane road, and the rest of the space was converted into planted areas and pedestrian walkways. Inner 11 m space has a preventive function as a floodwater storage area to tackle once in 100-year storm event. Planted area has the function to store stormwater underground and to provide green and spaces for people. All GI streets had a plan to connect the stormwater flow and projected frameworks to reduce the flood risk. Similar to Singapore's ABC Water Design Guidelines, future site-scale GI projects were identified, and would be gradually implemented. As a summary, the cloudburst project suggests one possibility to implement GI into existing city fabric by transforming existing roads to GI. In 2018, City of Copenhagen selected 50 GI projects planned to be built, and 5 projects already completed. The speed of GI implementation is slower than expected due to the complicated coordination with existing underground infrastructure. The other raised issue is how cloudburst can be evaluated as a climate change adaptation project (Nakajima and Hoshino 2017). Especially, water quality control is yet unsolved to meet with EU water quality framework. Lessons learned from the cloudburst are how to set GI goals as well as evaluation framework to create multifunctional space in the urban settings.

Fig. 15.5 GI implementation proposals in cloudburst master plan (Ramboll Studio Dreiseitl)

15.6 Kashiwanoha Aqua Terrace: “Closed Retention Pond to GI Open Space”

Kashiwanoha Aqua Terrace is the place that was redeveloped from flood control pond into multifunctional GI open space. It is located in Kashiwa, northeast of Tokyo, where 273 ha smart city is being developed. Aqua Terrace is a part of phase 2 developments with the concept of “Innovation Campus.” The retention pond was formerly fenced around and had no access to the public and purely functioned as a flood control pond. Site area is about 2.4 ha big and retention capacity is approximately 73,720 m³. Within 25 ha of phase 2 development, there was no central open space but the existing retention pond (Fig. 15.6). Thus, the idea of renovating closed retention pond to GI open space was strategically proposed.

To realize Kashiwanoha Aqua Terrace, the public-private partnership was formed by Kashiwa City, Kashiwanoha Urban Design Center (UDCK) and Mitsui Fudosan, a private developer. Prior to GI open space implementation, the master plan of vigorous “Innovation Campus” was issued in 2008 to illustrate “District of Mixed Usage” and “Walkable Street and Public Open Space Network” at the conceptual level. In 2015, the landscape design for Aqua Terrace started to connect the existing streets and the pond through applying seamless circulation loop, and multilevel seating on the retention pond slope. 800-m-long jogging loop around the pond provides a place for walking and jogging, while permeable paving provides cooling surface in a hot summer time. Multilevel seating on slope provides places of diverse

Fig. 15.6 Retention pond prior to redesign (Nikken Sekkei Ltd.)

activities for people and helps connect people and water. The challenge of Aqua Terrace design was to control the fluctuating water levels. The water level is usually kept at 40–80 cm; however, maximum of 4 m water level could be expected at once in 50-year storm event around this designed area. Trees and site elements were set carefully, and the lighting can endure against the floodwater. Instead of installing physical fences or gates against the dangerous water level after the storm event, lighting pole would blink red light when the water level has risen more than 1 m (Fig. 15.7). GI discussion tends to set aside the power of design; however, Kashiwanoha Aqua Terrace demonstrates an excellent design to weave GI's function and character into the place designed for people.

Regarding management of Kashiwanoha Aqua Terrace, UDCK plays a central role to bring all players and volunteers together. Volunteers help with planting management as well as cleaning up the walkway after the high water overflow. Events vary from “Outdoor Movie Night” to natural environment observation event for local children. Toward sustainable GI implementation, it is important to set organizational structures in order to manage GI properly. Lastly, Kashiwanoha Aqua Terrace represents a good GI open space model and illustrates the possibility of public open space in the era of mature society.

Fig. 15.7 Kashiwanoha Aqua Terrace as GI open space (Forward Stroke Inc.)

15.7 Minami-Machida Grandberry Park: Creating Livable, Sustainable City with Open Spaces

15.7.1 GI Visions and Frameworks

The Minami-machida Grandberry Park is a complex project in Machida city, southwest Tokyo. The train station, shopping mall, urban sports park, and Sakai River waterfront were integrated under the concept of “park life.” The plan was to create a walkable community with seamless connections between the station, commercial facilities, parks, and the Sakai River. The inviting design starting from the station through the mall up to the sports park promotes “active lifestyle.” This complex is located in the suburban residential area that was developed about 40 years ago with the station placed in the south and a semi-industrial area in the north. The urban redevelopment builds open spaces at its core. There are three major sites. Grandberry Park (shopping mall, privately owned, 8.3 ha), park life site (privately owned and operated facilities on former roads and public land, 0.5 ha), and Tsuruma Urban Sports Park (publicly owned, 7.1 ha), and a necklace of 14 open spaces in three large areas (Fig. 15.8). As illustrated, seven open spaces colored in blue are privately owned open spaces, and the other seven open spaces colored in green are publicly owned. In addition, yellow-green colored “park life site” is built by public-private partnership. Each of the 14 plazas has a variety of designs and unique atmosphere. For example, in the large Oasis Plaza, children can play on a

Fig. 15.8 Minami-machida Grandberry Park illustrative plan (Machida-Shi, Tokyo)

100-meter-long water carpet in summer, and in winter a skating rink is set up for multifunctional use.

How does this Minami-machida Grandberry Park function as GI? GI is strategically conceptualized in its vision and frameworks as networked open spaces. Formerly, the site was divided by the river, roads, urban sports park, shopping mall, and station. City of Machida (public) and Tokyu Corporation (private) formed public-private partnership in order to create a livable and sustainable city with open spaces. The following are the key frameworks related to GI. First, “Walkable City Network” is proposed from creating seamless connection of spaces through the district. A big decision was made to close the existing city road and create a 6-m-wide pedestrian street, which enhanced the physical integrity of Grandberry Park (shopping mall) and Tsuruma City Sports Park. In addition, fluid pedestrian circulation allows to connect the north and the south district that were formerly divided by railroad. Second, “Open Space Network” in both public and private land was created by proposing 14 open spaces. This necklace like open space structure allowed to promote not only walkability but lively urban lives. Third, “Sustainable Development Goals” raised by challenging to obtain “LEED-ND Gold” as common goals for all stakeholders. This vision helped implement sustainable stormwater management and other site-scale GI later on (Fukuoka 2020).

15.7.2 *Design of Places and Public Engagement*

By using visions and frameworks as guidelines, series of open spaces are designed to enhance its concept and character. “Walkable City” visions are developed for the broader “Active Design” concept. Active Design is a concept to support development or design for creating healthy cities (Osamura and Fukuoka 2020). In terms of health, when walkability improved, Tsuruma Park (Urban Sports Park) would function as the core site where people can participate in sports and become healthier. The 7.1 ha sports park provides diverse places for sports and the healthy activities. This park has tennis courts (three omni courts), artificial turf pitches (equivalent to three futsal pitches), athletic open space with playground (0.65 ha), clubhouse (studio, café, lockers, and showers), and parking lot for 133 cars. Active Design for promoting physical activities was implemented all over the park for the purpose of running, muscle training, jumping, etc. and yoga, dance, karate, etc., and classes are also open regularly at the studio (Fig. 15.9).

“Open Space Network” was implemented in various forms with unique character. For example, in the large Oasis Plaza, children can play on a 100-meter-long water carpet in summer, and in winter a skating rink is set up for multifunctional use. On the line of flow from the station to the park, plants of mainly native species are planted in connection with Tsuruma Park and Sakai River. Besides planting, there are many ideas worked out to allow comfortable usage of outdoor spaces. Various type of seating, shades, paving, and surrounding shops and façade create a setting for “park life” for all generations.

Regarding the aspect of sustainability, sustainable rainwater management was implemented as a part of Open Space Network. All rainwater at the station building is stored underground for reuse, and a permeable pavement has been installed on the site. The retention basin under the park is approximately 24,600 m³. Sustainable stormwater management was implemented throughout the project by installing rain gardens and bioswales which promote temporary storage and infiltration.

Fig. 15.9 Tsuruma Urban Sports Park in Minami-machida Grandberry Park (left, before park renovation; right: after park renovation)

In the process of public engagement and participation, numerous workshops and activities were held for the citizen during the planning and design phase. Interestingly, citizen participation workshop was transformed into “Park School” where citizens themselves plan and implement temporal events working with other citizens of similar interests. In autumn, “Park School Festival” was successfully held a few times, and the participation of the citizen transformed it into more active, motivated activities in the park. In 2021, “Minami-machida-wo-minnnano-machie foundation” (Creating Minami-machida Town for All) was founded by public-private partnership in order to proceed the city to the next stage. As a summary, the Minami-machida Grandberry Park demonstrates how big their visions and frameworks are and that the site-scale project was indeed integrated into a whole GI open space network. In this case, both city and developer envisioned big pictures such as “creating healthy, active cities” and “sustainable cities,” and those visions realized the interconnected open spaces. In terms of public engagement, this case illustrates how participation and engagement process was integrated into the part of GI implementation in order to achieve a long term, sustainable management.

15.8 Toward Urban Green Infrastructure Implementation: Open Space as GI

Through examination of “visions and approaches” (15.1–3) and “site-scale GI project case studies” (15.4–7), the following are to recommend toward urban GI Implementation. Firstly, GI visions and frameworks need to provide broader perspectives from the heat mitigation in urban areas, reduction of water disaster to a healthy and walkable city. Frameworks also need to illustrate rough spatial images as well as functions of those spaces. City of Philadelphia demonstrated strategically implemented GI visions and frameworks and activated multiple planning and guidelines to accelerate GI implementation under very powerful leadership. On the other hand, Singapore developed nation-scale, top-down GI visions and frameworks in ABC Waters Design Guidelines. ABC Waters Design Guidelines set clear goals and provide typological GI approaches as well as demonstrate GI with actual model projects. Other good finding was circulative system of ABC Waters Design Guidelines with “ABC Waters Certification” and “ABC Waters Professional Program.” This framework allows sustainable GI implementation over time.

Secondly, site-scale GI implementation needs to create places for multifunction and for people. The site-scale GI often tends to focus too much on monolithic function related to the stormwater management such as rain garden and bioswale. In Chap. 2, three GI implementation projects were introduced. Copenhagen’s cloudburst demonstrates how “the strategies of climate change adaptation” were introduced into the current urban fabrics through transforming roads into multifunctional streets for all. Kashiwanoha Aqua Terrace developed interesting scheme to renovate closed, monofunctional retention pond into GI open space for diverse users.

At Minami-machida Grandberry Park, GI visions and frameworks can be seen in creating “Open Space Network,” “Walkable City,” and “Sustainable Development.” At site scale, GI open space is created to achieve both GI function and its character as a place for people.

Lastly, this article tried to depict how GI visions and frameworks are translated into the site scale and physical GI implementation through various case studies. This article indicates how GI needs to be interwoven into vision, planning, and design, and creates places for people. As stated above, strategic GI visions and frameworks can catalyze a change to our city through physical manifestation of GI implementation.

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