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Green Infrastructure Gauge: A tool for evaluating green infrastructure inclusion in existing and future urban areas

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Abstract

In the current global momentum of Eco and Smart Growth, Green Infrastructure (GI) concept is proving a popular means to accomplish sustainable development. This study's aim was to develop a Green Infrastructure Gauge (GIG), whose goal was to maximize presence of GI elements and functions in future urban master plans, and gauge GI status in existing urban areas. We derived relative value for each GI function through a questionnaire survey to public workers in 41 Japanese municipalities. It highlights the most valuable GI elements and functions future towns and cities can incorporate, to realize ecosystems and environment wellbeing, and herald sustainable future communities.

Keywords: Green Infrastructure (GI); Green Infrastructure Gauge (GIG); green infrastrucutre functions and elements; ecosystem and environment wellbeing

1. Introduction

Many cities are facing challenges emanating from lack of essential environmental support systems. This translates to low livability index among the communities found there in, and lack of healthy ecosystems, bio diversity, and environment. Some of the cities are responding with proposals to establish Satellite New Towns, or urban redevelopment programs to establish new communities and remedy status quo shortcomings. However, importance of urban biophysical networks – what would be termed as 'green assets' are largely overlooked (Schaffer and Swilling, 2012). Planning tends to focus on the so called 'grey infrastructure' networks of energy and material supply system (Weisz and Steinberger, 2010). There is a need to study and plan for these New Towns and new communities, to guide them from

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conceptualization, planning, implementation, and management to achieve sustainable and liveable future communities. One such strategy involves Eco, Green, or Smart Growth that is shaping future cities, towns, and communities, providing a paradigm shift in urbanization. In its current global momentum, Green Infrastructure (GI) concept is proving popular as one of the means to accomplish such sustainable developments. Though GI is ambiguous in interpretation and implementation, the ecological, environmental, and societal benefits it affords where practiced cannot be disputed. Wright (2011) expresses this ambiguity and argues that a single and precise meaning of "green infrastructure" is problematic because it is an evolving concept, divided between environmental theory and socio-economic policy.

GI encompass connected networks of multifunctional, predominantly unbuilt, space that supports both ecological and social activities and processes (Kambites and Owen, 2006). In this study, we have described GI as, "natural or built ecosystems, elements, and concepts that encourage land-use planning and practices that focus on interconnectivity to support sustainability and confer life support benefits to nature and people". GI can improve ecological processes, enhance food production, create employment, and promote the use of renewable energy. It entails establishment of green networks and green ways, enhance disaster prevention and mitigation, as well as storm water management. It also promotes green architecture, enhance community, family, and interpersonal bonding, as well as give identity and pride to residents. In the UK, guide to GI planning (Natural England, 2009) promotes the importance of GI in "Place Making". It should be designed and managed as a multifunctional resource, capable of delivering those ecological services and quality of life benefits required by the communities it serves, and needed to underpin sustainability (Natural England, 2009). In the USA, Environmental Protection Agency (EPA) and partner organizations manage GI programs, focusing mainly to improve water quality and storm water runoff management (US EPA, 2012).

It is an adaptable term used to describe an array of products, technologies, and practices that use natural systems, or engineered systems that mimic natural processes (US EPA, 2012). It includes Low Impact Development (LID), Smart growth and smart conservation strategies, green/ grey interface, conservation developments and Urban Green Best Management Practices (BMPS). At all its levels, GI can utilize Ian McHarg's (1969) idea of 'physiographic determinism', which claims that natural process should be the basis for determining development (or non development priorities). This idea calls for environmental conscious approach to land use, a concept that resonates well with GI.

GI can be implemented at any scale; individual plot, local community, regional, national, or even multinational levels (Benedict and McMahon, 2006). As an evolving concept (Wright, 2011), new tools for planning, developing, managing and evaluating GI in future towns and cities are thus necessary. This is to ensure its optimum inclusion for the benefits of host communities. Rudolf et.al (2002) conceptualized a framework and typology, but this only focuses on natural ecosystems, which are only, one of the components of GI. Green Infrastructure Assessment (GIA) focuses on hub and corridor selection at regional level (Weber et.al, 2006). Green Factor Score Sheet or Seattle Green Factor aims to increase the quantity and quality of planted areas (Seattle City, 2010). This applies to an individual plot hence unsuitable in addressing GI holistically and at a larger scale. City Biodiversity Index (CBI) or Singapore Index (CBD, 2010) also tackles urban biodiversity conservation, planning, and evaluation, and is not inclusive of GI elements. More research is needed on the way in which ecosystem services are being, or ought to be valued in cities, with a focus on how they might conceivably be incorporated into spatial planning and urban design (Schaffer and Swilling, 2012).

To seal the above gaps, we focused at developing a Green Infrastructure Gauge (GIG). We have defined GIG in this study as "a method of analyzing and evaluating the level of Green Infrastructure presence in an existing urban area, OR its level of inclusion in a Green / Environmental Master Plan for an existing or a proposed new urban area". The aims of this GIG are to maximize presence of GI elements in the future urban master plans and gauge GI status in existing urban areas. Such a gauge can be useful in assessing existing GI or guide future land use planning and developments. This would ensure sufficient inclusion of GI elements, and their multi-functions, essential in conferring ecological wellbeing and quality of life to the population. It can be applied in the case of development of satellite new towns, development of new neighbourhoods within boundaries of existing urban areas, rejuvenation projects of old towns, and even during city compaction in case of depopulation.

We have described GI elements as Physical or conceptual tools, systems, products and technologies that contains, promotes and makes available benefits, goods and services of Green Infrastructure. These include but not limited to; nature reserves and ecological networks, working lands, facilities and plans for renewable energy generation and use, greenways and green networks, facilities for rain water harvesting, storage and use. Others are facilities and plans for disaster prevention and mitigation, waterways and water features, green architecture, cycling, walking, and hiking trails, among others. These GI elements afford GI functions, which are benefits, goods and services that Green Infrastructure elements in part or holistically give to nature, environment, and people. We can classify these functions as ecological functions (ensures continued ecosystem functions, goods and services provisioning) (Rudolf et.al, 2002), physical and natural environmental functions, and socio-economic functions.

The main objectives of this study were: (1) to identify various GI elements and functions they can afford. (2) To formulate a Green Infrastructure Gauge (GIG). (3) To generate GI functions relative values through a questionnaire survey and (4) to test the completed GIG practicability through application in Koshigaya Lake Town. The study area comprised of two levels: (1) Tokyo 23 Special Wards (independent functioning municipalities) abbreviated as 'Tokyo 23 SW', and their neighbouring contiguous suburban cities. (2) In Koshigaya Lake Town, a new town located within Koshigaya City in Saitama Prefecture, Japan. Tokyo area is one of the most urbanized and densely populated spots on earth. As such, municipalities in its core and suburbia are always grappling with challenges arising from this intense urbanism, and are constantly strategizing for their counter. Municipal workers spearhead these efforts hence suitable as respondents to the survey. On the other hand, Koshigaya Lake Town is a new projected curved out of land formally dominated by rice paddies. It has been constructed in the 'ECO era' and primarily established with its core as Osagami flood control reservoir. There are many GI elements, technologies, and concepts showcased, making it a suitable subject to test GIG after completion.

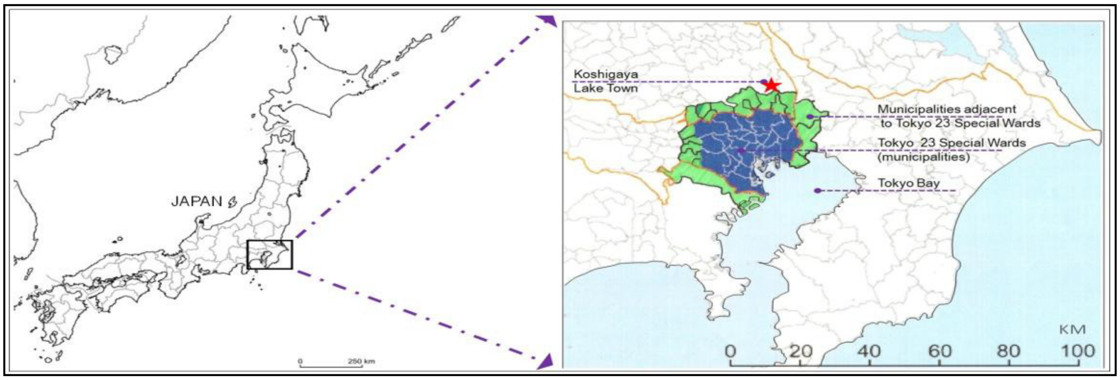

Fig. 1. Map showing the study areas and their location

2. Methodology

Through literature review, and review of Green Master Plans (GMP) by Japanese municipalities in the Tokyo region, we identified 13 GI elements and 21 GI functions and described them. They are broad and inclusive in their definitions and scope, to cover as many GI aspects as possible, and have universality in application. We designed a matrix with the 13 GI elements on the left end column and the 21 GI functions on the top row. We examined each GI element for any of the GI functions it afforded, and accorded the value of that or those functions it dispensed. We repeated this for all the GI elements, with a view to establish cumulative level of GI at the planning stage, or as existing in the subject area. We derived relative value for each of the 21 GI functions through a questionnaire survey to public workers in 41 municipalities within and around Tokyo. We targeted three departments that deal with spatial, environmental and land use planning and management within these municipalities. These included the department of urban planning and development, department of parks and green Space, and the department of environment. Individual workers provided the GI functions relative value based on their training, experience and personal opinion rather than their departments or municipality policy.

The questionnaire included definition of Keywords such as Green Infrastructure (GI), Green Infrastructure Gauge (GIG), GI elements and GI functions. We made a reference also to the Green Master Plan (GMP) already prepared by many Japanese municipalities, to elicit familiarity by the municipal workers. We did this to prepare the respondents psychologically, create personal awareness, as well as have background knowledge on Green Infrastructure. The GI functions were listed in alphabetical order, to avoid any assumption of author's preference by the respondents. We gave descriptions to ensure all the respondents had a common understanding of each GI function. Each respondent was to award a score or weight to each function as follows; 5 = very strong, 4 = strong, 3 = Fair, 2 = weak and 1 = very weak. We calculated average relative value for each of the GI functions, based on the scores or weights awarded by all the respondents. Relative value for each GI function was weighted as follows; '0' for absence of the function, '0.4' of the relative value where the elements and their functions are included in planning documents pending implementation. '1' (full relative value) where the elements have been physically implemented, and their function(s) confirmed through field survey.

We completed the final GIG with the inclusion of GI functions relative values (FRV) and provision for cumulative GIG, scores and a legend. The scoring for subject urban area is 'Points' and 'Class' based (SCORING AND CLASS: (0 ~ 1.99 Points = Poor, 2 ~ 3.99 Points = Fair, 4 ~ 5.99 Points = Good, 6 ~ 10 Points = Excellent). We tested its applicability in Koshigaya Lake Town, where we had carried out a field survey to record GI elements and their functions.

3. Results

The 23 GI functions identified are as shown and described in table 1. They are within three broad classifications of ecological functions, physical and natural environmental functions, and socio-economic functions.

Out of the 123 questionnaires distributed in 41 municipalities, 91 (73.98%) were filled up and mailed back from 40 municipalities. In the first categorization by area, 54 were from Tokyo 23 SW and 37 from the suburban Cities neighbouring Tokyo 23 SW. In the second categorization, by municipality departments, the valid responses were as follows; Urban Planning Departments (N = 31), Parks and Green Space Departments (N = 35), and Environments Departments (N = 25). The mean relative values for the GI functions were as shown in figure 2.

Table 1. 21 GI functions and their descriptions

	GI function	Description
1.	Biodiversity promotion	Vital habitat for wild species, vast genetic bank, harbour plants pollination and dispersal, and migration of wildlife among others.
2.	Cultural and historical identity	Has the following value: heritage, worship, fashion, folklore, music, dance, language, film, landmarks, architecture, historical, and traditional practices among others.
3.	Disaster prevention and mitigation	Protecting an area against floods, storm damage, landslides, earthquakes, fires, droughts, and mitigation of disaster impact, among others.
4.	Energy saving	Reduces energy use, demand, and cost.
5.	Economic activities support	Provide marketable goods (such as fish, raw materials, recreation and services), avoided cost, willingness to pay, and hedonic pricing among others.
6.	Environmental education	Providing opportunities for cognitive development, awareness, school excursions, and scientific research among others.
7.	Food / resource production	Source of food, natural raw materials, biomass, fodder, fish, game, and minerals among others.
8.	Good aesthetics	Provide attractive sceneries, decorations, and views among others.
9.	Improvement of local climate	Cooling effects to buildings and spaces, mitigation of urban heat island, air circulation, humidity regulation, and wind effect among others.
10.	Nature conservation	Maintenance of flora and fauna (such as native species in natural land), and promote natural systems (such as hydrological and nutrients cycles among others).
11.	Noise reduction	Buffers and attenuates noise from static or mobile sources before reaching possible disturbance areas.
12.	Part of larger green network	A hub, a link, or a site (Benedict and McMahon, 2006) in larger interconnected green spaces and elements.
13.	Planning structure	Part of the planning components used in the area overall master plan, either as a physical or philosophical element.
14.	Pollutants filtration	Water filtration, air cleaning, trapping of dust, breakdown and removal of toxic nutrients and compounds among others.
15.	Promotes communal activities	Provides venues and avenues for community activities and participation, such as festivals and social events among others.
16.	Public health promotion	Encourage physical exercises, jogging, walking cycling, therapy, clean environment, elimination of vermin and parasites among others.
17.	Rain water harvesting	Capacity to trap, store and use rain water especially for irrigation, and cleaning.
18.	Recreation opportunity	Provides a chance for travel to natural ecosystems, ecotourism, outdoor sports, play and relaxation.
19.	Reduction of green house gases	Sequestering carbon, reduction in or alternatives to green house gases emitters.
20.	Reduce public infrastructure cost	Replaces or reduces public works, alternative transport and communication means among others.
21.	Storm water management	Reduction of runoff via increased infiltration, temporary holding before release, evapotranspiration and or re-use among others.

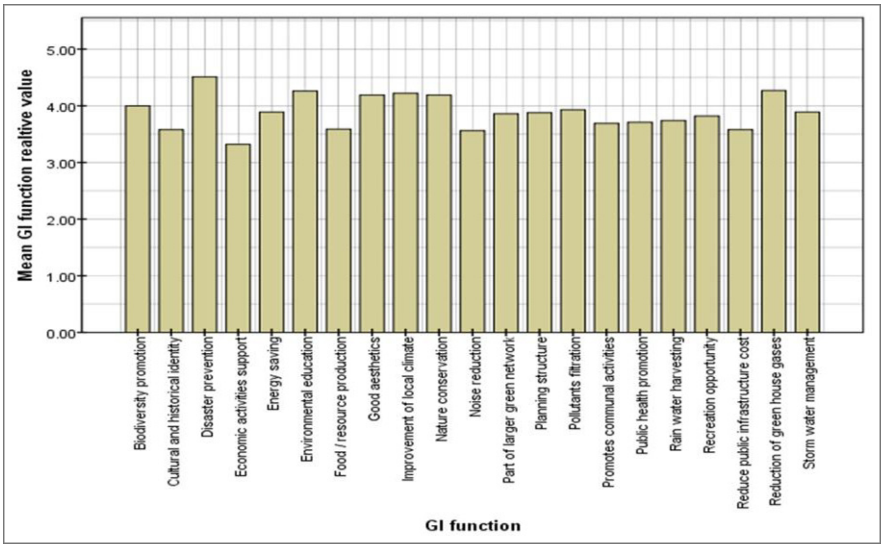

Fig. 2. Mean relative values for GI functions from all the respondents

Respondents identified disaster prevention and mitigation as the most valuable function of GI with a relative value of 4.51 out of 5. Economic activities generation emerged with the least value among the 21 GI functions with 3.32 out of 5. Other GI functions with relative high values include reduction of green house gases (4.27), environmental education (4.26), and improvement of local climate (4.22). Those others with relative lower values were noise reduction (3.56), reduction of public infrastructure cost (3.58), and cultural and historical identity (3.58). The mean cumulative value for all the GI functions from all respondents was 3.89. The results based on the two categories were as shown on figures 3 and 4.

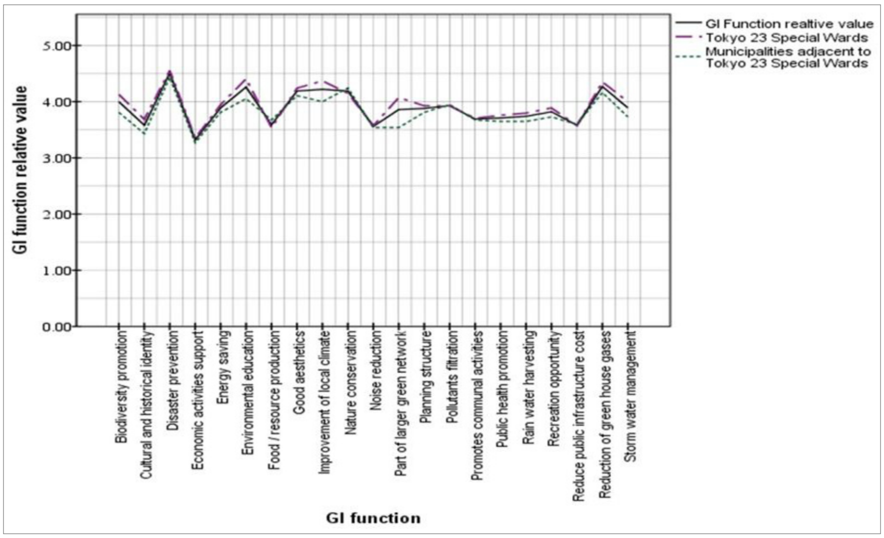

Fig. 3. Mean relative values for GI functions based on area categorization

Public municipal workers in the Tokyo 23 SW also indicated disaster prevention and mitigation function to have the highest value (4.50). Economic support services too came last with 3.35. However, they indicated food and resource production to have the second least value at 3.54. The mean cumulative value for all the GI functions from all the respondents in this category was 3.95 out of 5. From the suburban cities neighbouring Tokyo 23 SW, nature conservation was the second highest valued GI function after disaster prevention and mitigation. Unlike in the Tokyo 23 SW, workers in this category valued food and resource production much higher as the eight least valuable at 3.68. The mean cumulative value for this category was 3.80 out of 5.

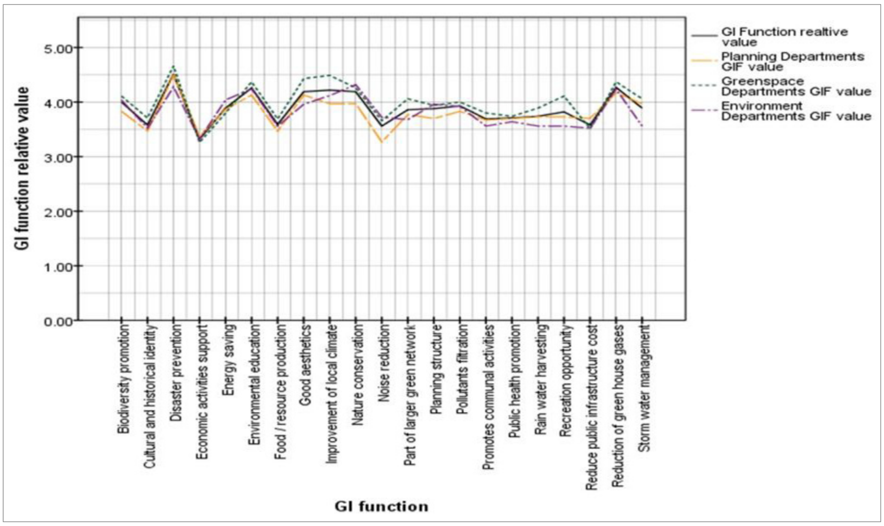

Fig. 4. Mean relative values for GI functions based on departments' categorization

In the second categorization by municipalities' departments (Fig. 4), disaster prevention and mitigation function was the highest valued. It had 4.50, 4.66, and 4.28 in the departments of planning, parks and green space, and environment respectively. Economic support function scored the least in the departments of parks and green space (3.26) and environment (3.32), whereas noise reduction (3.27) was the least valued by workers in the departments of planning. Parks and green space departments' workers rated good aesthetics (4.43), improvement of local climate (4.49), part of larger green network (4.06) and recreation opportunity (4.11) much higher than the average mean. The mean cumulative values for all the GI functions per category were; 3.81 for planning departments, 4.00 for parks and green space departments, and 3.83 for environment departments. After GIG design completion and inclusion of GI functions' relative values, results from evaluation of Koshigaya Lake Town were as shown on table 2. The gauge (GIG) revealed that reduction of green house gases was the most prevalent and valuable function with a function total score (FTS) of 38.43. Environmental education was second with 38.34 FTS, followed by improvement of local climate with 33.76. Those with the least FTS were food / resource production (2.88), cultural and historical identity (3.58), and economic activities support (3.99).

On the other hand, we also assessed elements for their element total score (ETS). Both disaster prevention and mitigation elements and water ways and water features had an (ETS) of 70.40. Rain water harvesting, storage, use, and infiltration elements followed with an ETS of 63.77.

Table 2. Complete Green Infrastructure Gauge (GIG) with results from application in Koshigaya Lake Town

GREEN INFRASTRUCTURE GAUGE (GIG).

GI ELEMENTS \ GI FUNCTIONS	1. Biodiversity promotion.	2. Cultural and historical identity.	3. Disaster prevention.	4. Energy saving.	5. Economic activities support.	6. Environmental education.	7. Food / resource production.	8. Good aesthetics.	9. Improvement of local climate.	10. Nature conservation.	11. Noise reduction.	12. Part of larger green network.	13. Planning structure.	14. Pollutants filtration.	15. Promotes communal activities.	16. Public health promotion.	17. Rain water harvesting.	18. Recreation opportunity.	19. Reduction of green house gases.	20. Reduce public infrastructure cost.	21. Storm water management.	E.T.S
F.R.V	4.00	3.58	4.51	3.89	3.32	4.26	3.59	4.19	4.22	4.19	3.56	3.86	3.88	3.93	3.69	3.71	3.74	3.82	4.27	3.58	3.89	
1. Cycling route/ Walking route/ Trail/ Promenade.	0.00	0.00	0.00	3.89	0.00	4.26	0.00	4.19	4.22	0.00	0.00	0.00	3.88	0.00	3.69	3.71	0.00	3.82	4.27	3.58	0.00	39.51
2. Green buffer/ Green belt.	4.00	0.00	0.00	0.00	0.00	4.26	0.00	4.19	4.22	4.19	3.56	0.00	0.00	3.93	3.69	3.71	0.00	0.00	4.27	0.00	3.89	43.91
3. Green network/ Greenway.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4. Green roofs/ Green walls/ Green curtains.	4.00	0.00	0.00	3.89	0.00	4.26	0.00	4.19	4.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.27	0.00	0.00	24.83
5. Landscaping plants (trees, shrubs, groundcovers, lawn).	4.00	0.00	0.00	3.89	0.00	4.26	0.00	4.19	4.22	0.00	3.56	0.00	0.00	3.93	3.69	3.71	0.00	3.82	4.27	3.58	3.89	51.01
6. Renewable energy harvesting and use/ Energy saving facilities.	0.00	0.00	0.00	3.89	1.33	4.26	0.00	0.00	0.00	0.00	0.00	0.00	3.88	0.00	0.00	3.71	0.00	0.00	4.27	3.58	0.00	24.92
7. Nature reserve/ Woods/ Forest/ Grasslands.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8. Parks/ Gardens/ Squares/ Beach/ River front	4.00	3.58	0.00	0.00	0.00	4.26	0.00	4.19	4.22	4.19	0.00	0.00	3.88	3.93	3.69	3.71	0.00	3.82	4.27	0.00	3.89	51.63
9. Rain water harvesting, storage, use, and infiltration facilities.	4.00	0.00	4.51	3.89	0.00	4.26	0.00	4.19	4.22	4.19	0.00	0.00	3.88	3.93	3.69	3.71	3.74	3.82	4.27	3.58	3.89	63.77
10. Disaster prevention/ mitigation elements	4.00	0.00	4.51	3.89	1.33	4.26	1.44	4.19	4.22	4.19	0.00	3.86	3.88	3.93	3.69	3.71	3.74	3.82	4.27	3.58	3.89	70.40
11. Water ways/ Water features	4.00	0.00	4.51	3.89	1.33	4.26	1.44	4.19	4.22	4.19	0.00	3.86	3.88	3.93	3.69	3.71	3.74	3.82	4.27	3.58	3.89	70.40
12. Wetlands/ Bogs/ Peat land	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13. Working lands (Farming, natural resource extraction, etc).	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
F.T.S	28.00	3.58	13.53	27.23	3.99	38.34	2.88	33.52	33.76	20.95	7.12	7.72	23.28	23.58	25.83	29.68	11.22	22.92	38.43	21.48	23.34	440.38

SCORE: 440.38/1061.84 41.47 % **4.15** Points CLASS: **Good**

LEGEND:

- WEIGHTED VALUES: (**0** = Not present, **0.4** = Planned for, **1** = Present).
- SCORING AND CLASS: (0 ~ 1.99 Points = **Poor**, 2 ~ 3.99 Points = **Fair**, 4 ~ 5.99 Points = **Good**, 6 ~ 10 Points = **Excellent**).
- F.R.V = Function Relative Value from **0** to **5**.
- E.T.S = Element Total Score.
- F.T.S = Function Total Score.

The GIG revealed that there were no elements for green network/ greenway (0.00), wetlands/ bogs/ peat land (0.00), and working lands (farming or natural resource extraction) (0.00). Overall, Koshigaya Lake Town gauge was a score of 4.15 points out of maximum 10 and classified as 'Good' in a scale of 'Poor' to 'Excellent'.

4. Discussion

Trough this study, we have established that disaster prevention and mitigation is the most valuable GI function by the Japanese municipalities' workers. We can attribute this to the fact that Japan Archipelago is always experiencing many natural disasters such as the recent March 11 2011 earthquake and Tsunami. Volcanic eruptions and strong typhoons that trigger flooding and landslides are frequent, hence the high awareness and valuation of this GI function. Japan, having one of the lowest unemployment rates and diverse work opportunities may have led municipal workers to attach less value to economic activities support GI function. This could be a different case in countries where unemployment levels are high and opportunities low. It should still be strongly considered for inclusion in future GI planning to lessen the burden of unemployment, and promote economic health and sustainable communities.

The ongoing global debate on climate change seems to work in sensitizing public workers on environmental matters. This might have increased their cognitive consciousness hence the high valuation of reduction of green house gases, environmental education, and improvement of local climate GI functions. The high values attached to these functions give them impetus for inclusion in planning and management of current and future urban areas. This can necessitate avoidance of future consequences of climate and environmental change that could plague future communities.

After categorization of the respondents based on areas and departments, there was no significant deviation from the mean. This shows that the values attached to the GI functions have universality among all the respondents. There were only minor variations across the categories. In Tokyo 23 SW, food and resource production had a much lower value, as opposed to the neighbouring suburban cities that accorded it higher value. Tokyo 23 SW forms the core of the City, with very high population density, and very expensive and scarce land. This reduces the amount of land available for farming and resource production; hence workers in these municipalities may have fewer opportunities to engage in planning and management of such functions. This is in contrast with those in the suburban municipalities with lower population densities, much open and cheaper land that includes urban farms. Another variation was in the suburban cities where natural conservation was second highest valued GI function. These areas could be having more natural environments with GI elements like forests, woods, riparian ecosystems, and Satoyama (Japanese rural landscape) than in central Tokyo.

In case of categorization by municipalities departments, workers in the department of planning valued noise reduction as having the least value. This could be due to their perceived competition from artificial noise reduction elements. Noise shields such as those installed in major highways around Tokyo could have perceived or real effectiveness, over GI elements like earth mounds and green buffers that require time and space to install. Workers in the parks and green space departments emphasized good aesthetics, improvement of local climate, part of a larger green network, and recreation opportunities GI functions. Their importance in improving urban environments and communities' wellbeing saw those awarded higher values than the mean. We must amplify such functions when planning for the future communities, in order to make them liveable and healthy.

Cumulative value of all the GI functions shows that parks and green space departments' workers attach the greatest value (4.00) to GI. This could be due to their daily engagement in planning and management of vital GI elements such as parks and green networks among others. Those in urban planning departments across the study area attach the least value (3.81) to GI. Being the main contributors to technical aspects relating to land use planning and management, they ought to be more sensitized on the value of GI so as not to overlook it in their daily work engagements. Workers in Tokyo 23 SW also seem to have a higher appreciation of the value of GI than those from the suburb cities. They work in municipalities with land constraints and high population densities hence higher value attachment for the limited GI elements and functions within their jurisdiction.

Koshigaya Lake Town having been built around a flood control reservoir, had its best performing GI elements and highest function total score (FTS) based on this central main feature. Despite the fact that it was curved from rice farming land, it was found to lack working lands (farming and resource extraction) among other essential GI elements. Such a paradox should be resolved through planning and application of reference tools such as GIG, to ensure optimum inclusivity and sustainability. The New Town as existing scored 4.15 points out of 10, and classified as 'Good' since it has many GI elements dispensing numerous GI functions. With complete obliteration of the hitherto existing farmland and farming culture, the project lost essential points based on GIG. It mirrors the architectural phenomenon of scrap and build common in Japan, leading to loss of local identity (Kinoshita et. al, 2012) and heritage. However, if the missing GI elements were to be included, the project could achieve 'Excellent' status, and become a perfect case for sustainable future communities.

5. Conclusion

We conclude that; Green Infrastructure functions do not poses uniform or equal values. They afford varying levels of ecological, environmental and socio-economic goods and services. Some GI functions have relatively high values and others relatively lower value attachments. Local conditions in different municipalities influence the workers value attachment to GI functions. As such, we find it necessary that a future study should test the GI functions relative values in different parts of the world. This is in order to find out if there are any variations in their values across environmental, cultural, social, and economic backgrounds to enhance GIG universality. As for the response of the municipalities' workers within the study area, we conclude that their understanding of the GI functions is relatively high and universal. Their response pattern had minimal variation across the categories hence reliability of the results. However, we need more training and sensitization of public municipal workers on GI especially in the departments of planning and environment. This is to ensure all the workers contributing in land use, spatial planning, policy formulation, management, and enforcement of aspects touching on GI understand its concept and value. Their lower valuation of GI functions can lead to the exclusion of GI in future urban development or redevelopment. This absence of its benefits could expose future communities to ecological, environmental, and socio-economic challenges. Disaster prevention and mitigation may have a higher value attachment than other functions in the context of workers from disaster prone Japanese municipalities. This does not negate its value in countries less prone to disasters. Disasters either manmade or natural are never anticipated and occur without warning and in unpredictable randomness across the world. We can reduce their probability of occurrence, and mitigate their impact if they do. Thus, this GI function should be embraced globally to avoid loss of lives, environmental degradation and ecological disturbances all of which are detrimental to the future communities well being. We have confirmed that the Green Infrastructure Gauge (GIG) we formulated is practical as a Green Infrastructure (GI) evaluation tool after application in Koshigaya Lake Town. Its application in such existing urban or planned areas can highlight their GI strengths and weaknesses, and point out possible improvement areas. Finally, we conclude that as part of possible weakness, this tool (GIG) cannot claim to include all the elements and functions of the ambiguous and fast evolving Green Infrastructure (Wright, 2011). It highlights valuable GI elements and functions future towns and cities can incorporate, to realize ecosystems and environment wellbeing, and herald sustainable future communities.

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References

Convention on biodiversity (2010). *City Biodiversity Index* (or Singapore Index) (online). Retrieved, 1st May 2012, from: http://www.cbd.int/authorities/gettinginvolved/cbi.shtml

Environmental Protection Agency (EPA) (Online). *Green infrastructure*. Retrieved, 20th August 2012, from: http://water.epa.gov/infrastructure/greeninfrastructure/index.cfm

Kambites, C. and Owen, S. (2006). *Renewed prospects for green infrastructure planning in the UK*, *Planning Practice and Research*, 21(4), 483-496, Routledge.

Kinoshita, I., Binder, H., Okabe, A. (2012). *Identity and Sustainability*. Hobunsya Publisher Inc. Tokyo.

Benedict, M., A., McMahon, E., T. (2006). *Green infrastructure: Linking landscapes and communities*. Island Press, Washington.

McHarg, I. L. (1969). *Design with Nature*. Reprint, John Wiley & Sons, 1995.

Natural England, (2009). *Natural England's Green Infrastructure Guidance* (NE176) (Online). http://publications.naturalengland.org.uk/publication/35033?category=49002 (Accessed 15th February 2012).

Rudolf, S. de G., Mathew, A. W., Roelof, M. J. B. (2002). *A Typology for the Classification, Description and Valuation of Ecosystem Functions, Goods and Services*. *Ecological Economics*, 41, 393-408, Elsevier.

Seattle City (Online). *Seattle Green Factor*. Department of Planning and Development. Retrieved, 3rd May 2012, from: http://www.seattle.gov/dpd/Permits/GreenFactor/Overview/

Schaffler, A., Swilling, M. (2012). *Valuing green infrastructure in an urban environment under pressure* - The Johannesburg case. *Ecological Economics*, In Press.

Weber, T., Sloan, A., Wolf, J. (2006). *Maryland's Green Infrastructure Assessment: Development of a comprehensive approach to land conservation*. *Landscape and Urban Planning*, 77, 94-110, Elsevier.

Weisz, H., Steinberger, J. (2010). *Reducing energy and material flow in cities*. Current opinion in material *sustainability*, 2(3), 185 – 192, Elsevier.

Wright, H. (2011). *Understanding green infrastructure: the development of a contested concept in England*. *Local Environment* 16(10), 1003–1019, Routledge.