Journal of Architecture and Construction
Volume 3, Issue 1, 2020, PP 23-36
ISSN 2637-5796

Comparison of Five Green Roof Treatments in Flint Michigan with Freidman's Two-Way Analysis of Variance by Ranks

Wing Chi VincyTam[1], Dr. Jon Bryan Burley*[2], Dr. D. Bradley Rowe[3], Dr. Trisha Machemer[4],

[1]*Environmental Design, School of Planning, Design, and Construction, Michigan State University, E. Lansing Michigan, USA*
[2]*FASLA, Associate Professor, Landscape Architecture, School of Planning, Design, and Construction, Michigan State University, E. Lansing, Michigan, USA*
[3]*Professor, Department of Horticulture, Michigan State University, E. Lansing, Michigan, USA*
[4]*Associate Professor, Urban and Regional Planning and Landscape Architecture, School of Planning, Design, and Construction, Michigan State University, E. Lansing, USA*

***Corresponding Author:** Dr. Jon Bryan Burley, FASLA, Associate Professor, Landscape Architecture, School of Planning, Design, and Construction, Michigan State University, E. Lansing, Michigan, USA 48824; E-mail: burleyj@msu.edu*

ABSTRACT

Planners and designers are interested in evaluating the metrics and statistical differences between design treatments. This study addresses categories of design treatments for a rooftop at The Sylvester Broome Empowerment Village, located in Flint, Michigan. Five design treatments: flat roof, self-design roof, extensive green roof, semi-intensive green roof, and intensive green roof, were evaluated by 36 variables chosen by the investigators. The Friedman's Two-way Analysis of Variance by Ranks statistical test was applied to examine significant differences between the five treatments ($p \leq 0.05$). The Friedman's multiple comparison test revealed the treatment of the flat roof performed the poorest. There was no significant difference to demonstrate that the other four design treatments perform better than the other with the exception that the intensive green roof treatment was predicted to be significantly better than self-design rooftop ($p \leq 0.05$).

Keywords: *landscape architecture, environmental design, sustainability, green architecture*

INTRODUCTION

Interest is green roofs and roof tops has been of interest to planners, designers, concerned citizens, government officials, and clients (Osmundson 1999). Utilizing the rooftop is often a method of creating an inner-city alternative social space (Pomeroy, 2012), and part of a response in response to climate change (Peck, 2008). Whittinghill and Rowe (2012) describe some of the benefits associated with green roofs. This is especially true in developed, highly populated, dense cities. However, this practice of building on rooftops in cities like Hong Kong must first receive government authorization. Prior studies have shown the benefits of urban green space. First, people are more likely to visit an urban green space than a native green area (Peters, Elands and Buijs, 2010). Secondly, people have a better sense of the neighborhood and better relationship with their neighbors if there are green spaces nearby (Kuo *et al.*1998). Research also shows that having more trees and plants in an area is a better place-making strategy for social connection purposes than leaving the place abandoned (Kuo *et al.* 1998). Moreover, green roofs can boost worker creativity and help provide different perspectives for work (Loder, 2014). In addition, a close proximity to a green space is a positive factor for people to observe; but the designer should still design urban green space for people who are lacking in mobility (Schipperjin *et al*., 2010). Nevertheless, studies had found that vegetated rooftops are helpful on reducing urban heat island effect (Sanchez and Reames 2019, Sutton 2015), promote urban ecosystem (Sutton, 2015), reduce storm water runoff (Peck, 2008), and increase water and air quality (Peck, 2008).With numerous ecological and social benefits of green roofs and urban green space, research concerning the specific evaluation of various rooftop designs approach lacking. The study addresses the different categories (convention rooftop, self-design rooftop, extensive green roof, semi-intensive green roof, and intensive green roof) of rooftop design treatments to determine to statistically access the differences between design treatments.

Green spaces and green infrastructures play important roles in social activities and environment events. While they promote social cohesion, it is also important to look into social interaction and place attachment (Peters Elands and Buijs 2010). Instead of leaving rooftops abandoned, the idea of having a social space within a community would make the rooftop accessible to the local neighborhood and could become a functional park in densely built areas. This idea provides restoration opportunities to the neighborhood and improves residents' sense of well-being (Mesimaki *et al*. 2017). Research suggests that green common space is beneficial to individuals and the community because it attracts people to be out in a social common space and increases opportunities for casual social contact (Kuo *et al*. 1998). Neighborhood social ties are positively affected by the amount of common space vegetation; there is a linear correlation for the growth of neighborhood ties near a common space as more vegetation takes place (Kuo *et al*. 1998). Compared to people living near a barren space, people living near green infrastructures are more willing to help and support their neighbors and have a stronger feeling of belongings (Kuo *et al*., 1998). These communities also have more social activities and visitors (Kuo *et al*., 1998). Also, as vegetated rooftops are one the best management practice for storm water runoff (Weiler and Scholz-Barth, 2009). Researchers found that its efficiency on lengthen the time of concentration, increase infiltration, resulting in reduced workloads for existing sewer systems and decreasing risk of watershed safety by decentralizing storm water, which green roofs keep storm water on site to reuse and recycle it (Weiler and Scholz-Barth, 2009). It was determined vegetation roofs, especially an extensive green roof, could hold reduce around 85% to 90% annual rainfall addressing on one inch falling event (Weiler and Scholz-Barth, 2009). These prior studies support the positive correlation between neighborhood connections to green spaces/rooftops and the positive attributes of vegetated roofs in the environment. This proposed study focuses specifically on comparing various rooftop design treatments.

Understanding if one rooftop design approach is better concerning design, maintenance, social, and environmental issues, is important for landscape architects, urban planners, policymakers, architects, and building owner. It may be possible to convert flat-topped barren rooftops into something more beneficial. It is important to understand and compare conventional rooftops, self-use rooftops, extensive green roofs, semi-intensive green roofs, and intensive green roofs. This research focuses on accessing these different design approaches.

Rooftops are often referred as the forgotten "fifth façade" that are ugly, barren, where people refuse to visit, and dispose elements that are unpleasant to watch, such as heating and cooling equipment and telecommunications towers (Peck, 2008). There are approximately 40% of impervious paving is composed by rooftops (Shafique Kim and Kyung-Ho, 2018).With the large amounts of rooftop spaces in a cities, and known environmental and social benefits of green roofs, there is an opportunity for building owners, developers, urban planners, and governments to develop and utilize them in order to create an inner-city, alternative social spaces (Pomeroy 2012), tools to alleviate urban heat island effects (Sanchez and Reames 2019), and to create and improve urban ecosystems (Sutton,2015).

Green roofs are not a new phenomenon. They have been constructed for thousands of years to protect people from arduous weather (Peck, 2008). The history of green roofs is presented by Peck (2008). Jim 2017).Subsequently, the era of modern green roof began around 1960sGermany, Switzerland, Austria, and Norway, since there were growing concerns about rapidly grown cities and towns, and intensive urbanization that qualities of livings were degrading and chances of being involve in the nature were declining(Peck 2008, Jim 2017). Reinhard Bornkamm, a botanist, who conducted research at University of Berlin, helped in developed a green roof system which we now known as the extensive green roof system, which is a green roof system with 6 inches or less growing media (Peck, 2008), which composed by relatively thin and light growing media profile (Forschungsgesellschaft Landschaftsentwicklung--Landschaftsbau 2018). Then, the system had been heavily studied by German institutions and found numbers of positive attributes in storm water management, plant survivability, fire retardation, and energy conservation (Peck, 2008).Green Roof Guidelines- Guidelines for the Planning, Construction and Maintenance of Green Roofs (Forschungsgesellschaft Landschaftsentwicklung—Landschaftsbau 2018), is a non-profit research society aimed at conduct researches about green roofs and set standards and guidelines for German landscaping industry (Peck, 2008). German then continue to emerge as the world leader on green roofs technologies, legislations, and economics incentives (Snodgrass, & Snodgrass, 2006). Snodgrass and McIntyre (2010) describe contemporary issues and best practices to construct green roofs.

Green roofs are still an on-going movement. Currently, the potential of retrofitting flat-topped rooftop has gained public policy support in over 75 jurisdictions resulting in green roof explosion in Germany, Austria, Switzerland, and Europe (Peck, 2008). Canada and the United States have begun to follow the European model concerning green roofs, to encourage and reward practice green roofs in their lands (Snodgrass and Snodgrass 2006). For example, green roofs are installed on city halls of Chicago and Toronto (Snodgrass and Snodgrass 2006). Leadership in Energy and Environmental Design (LEED), a green building certification program developed by the U.S. Green Building Council, had included green roof as one of the sustainable practices to obtain a higher reward (Snodgrass and Snodgrass 2006).Recent studies to address the benefits of green roofs include: reduce storm water runoff (Feitosa Wilkinson, 2016, Whittinghill Rowe Andresen and Cregg 2015Kroguleck 2014,Cronk 2012, Berndtsson 2010, Weiler and Scholz-Barth, 2009, Bliss Neufeld Ries 2008, Getter Rowe Andersen, 2007, Teemusk andMander 2007, Mentens, Raes Hermy 2006), green roofs as tools to alleviate global warming(Matlock and Rowe 2016, Whittinghill Rowe Schutzki and Cregg 2014, Rowe 2010, Getter*et al*. 2009 , Sailor, 2008), green roofs in noise reduction(Pittaluga, 2012, Van Renterghem and Botteldooren 2009,Van Renterghem and Botteldooren 2008, Öhrström, 1991), wildlife habitat and biodiversity enhancement (Partridge and Clark 2018, Rumble Finch andGange2018; Washburn *et al.* 2016,Cook-Patton 2015, Eakin, Campa, Linden, Roloff, Rowe, & Westphal, 2015,Sutton 2015, Maclvor, and Lundholm 2011,Monsma, 2011, Burghardt Tallamy Philips and Shropshire, 2010, Lundholm *et al.*2010, Nagase and Dunnett 2010,Wilsey e*t al*. 2009, Spehn*et al.* 2000, Yachi and Loreau, 1999), and green roofs as urban parks benefiting social connections (Mesimakiet al. 2017, Kazmierczak, 2013, Arnberger and Eder, 2012aPeters Elands and Buijs 2010, Peck 2002, Kuo et al. 1998,).

While there has been much interest in the properties of green roofs, very little effort has been focused upon assessing statistically the differences in various treatments from a multi-variate perspective. This study investigates a set of these treatments.

METHODOLOGY

The experimental design for this study is to develop 5 design scenarios with different rooftop design approaches using the rooftop on an existing infrastructure at The Sylvester Broome Empowerment Village, located in Flint, Michigan. The site is located at 4119 Saginaw St., Flint, MI. Flint has the 7-th highest population density in Michigan, laying on M-475, M-69, and M-75.

The building itself is owned by The Sylvester Broome Empowerment Village. This two-story structure is nearly a hundred years old. It is open to the public. The building has four rooftop levels (Figure 1) of which the bottom three are considered for a green roof. The low three levels comprise0.84 acres, this undeveloped roof is the first treatment, Currently the accessibility to the rooftop is through some classroom windows (Figure 2). A second treatment is a client-based design with a teaching greenhouse and plaza space on the lowest roof level with access to the roof from the ground floor to the greenhouse (Figures 3 and 4).

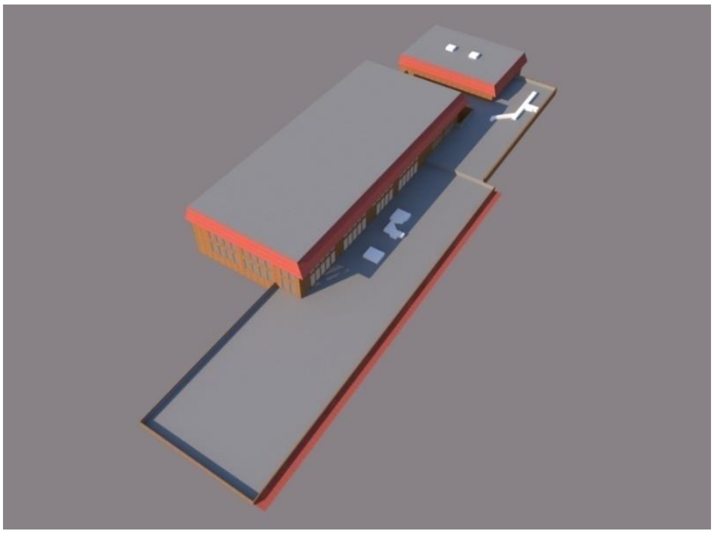

Figure1. *Birdseye view of a conventional rooftop (treatment 1), the existing condition where the lower three levels are further examined with green roof treatments. (Copyright © 2019 Wing Chi Vincy Tam all right reserved used by permission).*

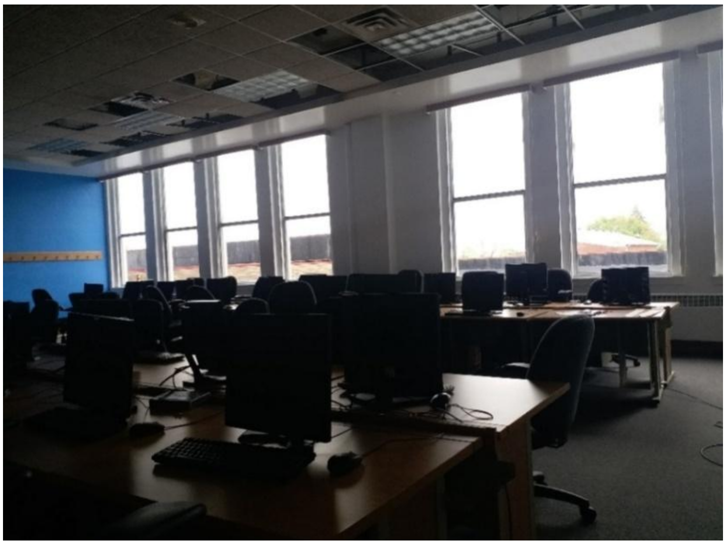

Figure2. *There is an accessibility challengeon accessing to the rooftop through some classroom windows. (Copyright © 2019 Wing Chi Vincy Tam all right reserved used by permission).*

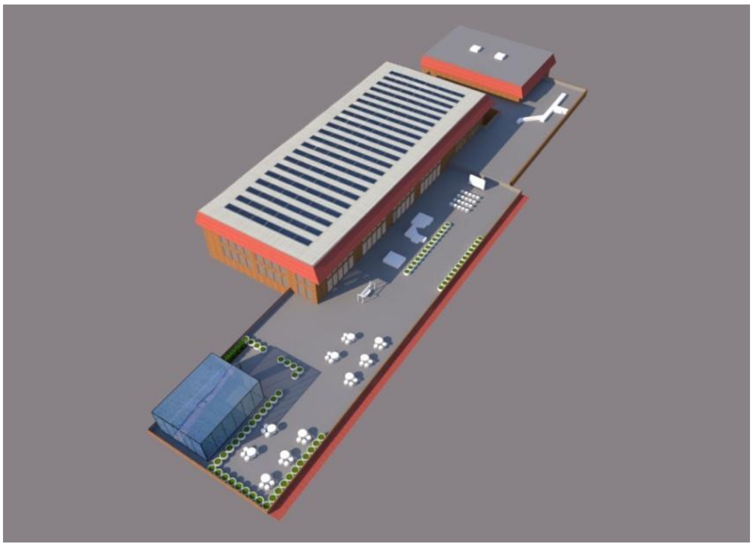

Figure3. *Birdseye view of a client-self-designed rooftop (treatment 2). (Copyright © 2019 Wing Chi Vincy Tam all right reserved used by permission).*

Figure4. *An outdoor teaching area for maximum 20 students. (Copyright © 2019 Wing Chi Vincy Tam all right reserved used by permission).*

Figure 5 presents an extensive green roof treatment (treatment 3). Such treatments are usually not open to public (Peck, 2008), so it would not have the designer features in treatment 2, but rather the treatment contains planting with extensive greening. Goals of this design approach are:

- Reduce storm water runoff, heat island effect, pollutant loading, carbon footprint, noise pollution
- Provide habitat for wildlife
- Improve surrounding human mental health by providing meadow view for people within the building; and
- Increase longevity of roofing membranes

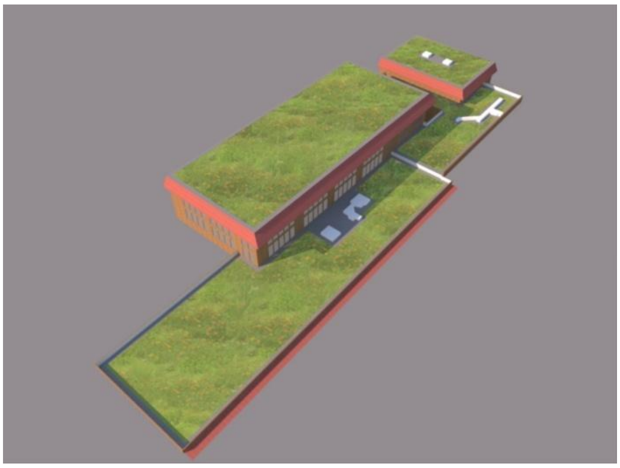

Figure5. *Birdseye view of an extensive green roof (treatment 3). (Copyright © 2019 Wing Chi Vincy Tam all right reserved used by permission).*

Treatment 4 is a semi-intensive green roof (Figure 5). This design approach attempts to create a social space and encourage engagement with the outside. The goals of this design approach are:

- Improving accessible challenge by designing ADA path from first level rooftop to second level rooftop
- Generate renewable energy by applying solar panels
- Addressing accessibility issue by having proper door entrance
- Encourage social interaction by having gathering space
- Allowing group activity or outdoor classroom by having plaza space
- Family friendly by having children entertaining facilities

This semi-intensive green roof is divided into two parts: quiet area, and active area. The reading area, as shown in figure 14, is the quiet area that is partly enclosed by walls and a foot-tall fence to create a quiet, and enclosed feeling. Flower plots in are employed to sit in the reading area to create an inclusive atmosphere and to emphasize on spatial relationship. Active area includes interactive children entertaining equipment a viewing bar, a multi-purpose area, a flower bed, a dry garden, and a fire pit with sofa

Figure5. *Birdseye view of a semi-intensive green roof (treatment 4). (Copyright © 2019 Wing Chi Vincy Tam all right reserved used by permission).*

The fifth treatment is an extensive green roof design (Figure 6). This design approach intends to create an alternative of urban park, and a multi-functional space provides social, educational, and environmental value, which is also hoping to be influential to surrounding encouraging other building owners to utilize their rooftop and invest in green roof. The design criteria are:

- Generate renewable energy by applying solar panels;
- Reduce storm water runoff by building it with special soil profile;
- Provide social opportunities by provide gathering space and seats;
- Provide educational opportunities by provide real time footage of butterfly garden with monitors and monitoring cameras;
- Encourage nature preservation by creating a man-made habitat for butterflies and provide educational programs about renewable energy and preservation of nature to visitors; and
- Improving accessible challenge by designing ADA path from first level rooftop to second level rooftop.

Nature preservation, storm water management, and energy efficiency are the three concepts that had been applied to the design. The site becomes not only a gathering site for youths and their families, but a biological spot for natural species (butterfly) and an educational spot for the community to have a better understanding about storm water management, clean energy, and ecology.

Figure6. *Top view of an intensive green roof. (Copyright © 2019 Wing Chi Vincy Tam all right reserved used by permission).*

To evaluate the 5 treatments, a list of 36 variables ranging across 7 aspects, including accessibility, plant, function, habitat value, active maintenance, water efficiency, and program are presented in Table 1.The variables are assessed with Friedman's Two-Way Analysis of Variance by Ranks to compare all treatments across multiple variables. This experimental design had been used on several past landscape studies, including: Feng *et al.* (2018), Feng *et al.* (2017),Lin *et al.* (2017), Burley *et al.* (2016), *et al.* (2016),Wang *et al.* (2015), Wang Burley and Partin (2013) Hallsaxton and Burley, 2011; Hallsaxton and Burley; 2010, Keefe and Burley 1998; Burley 1996, and Burley *et al.* (1988). Burley, Li, and He (2020) published a technical report concerning this methodology. The treatments are assessed in the flowing steps

1. All treatments across blocks are going to rank from smallest to largest by the author by observation (Daniel, 1978). Treatments would receive same ranking it the author thinks they rank the same. For example, the author found the best and the worst treatments rank 1 and 5 accordingly, the other three treatment would all rank 3;
2. Sum up within each treatment;
3. Apply $x_r{}^2 = (\frac{12}{bk(k+1)} \sum_{i=1}^{k} R_i{}^2) - 3b(k+1)$ (1)

Where:

b equals blocks

K equals numbers of treatments

R equals sum for ranks in each treatment

4. Since there are ties, apply $1 - \sum_{i=1}^{b} R_i{}^2 T_i \,/\, bk(k^2-1)$ to justify $x_r{}^2$ (2)

Where:

$T_i = \sum t_i{}^3 - \sum t_i$

t_i = the number of observations tied for a given rank in the ith block.

5. Apply $|R_i - R_{i'}| \geq z\sqrt{\frac{bk(k+1)}{6}}$ to determine which scenarios is better than the other, where,

R_i and $R_{i'}$ are the ith and i'th treatment rank totals

z is the value from a table provided in Daniel's book, corresponding to $\propto/k(k-1)$ (Daniel, 1978);

6. Find z score from Daniel's book (Daniel, 1978)
7. Calculate differences between each scenario; and
8. Compare results from step 5 and step 7, if the result from step 7 is larger than result from step 5, there is enough different showing these two scenarios have nonidentical effects.

The p-value is set at 0.05. The null hypothesis of this study is all design approach scenarios have identical effect (Daniel, 1978); the research hypothesis is at least one scenario have larger value then at least one scenario (Daniel, 1978).

Table1. *The list of variables employed in assessing the treatments.*

Aspect	No.	Variable
Accessibility	1	Entrance
	2	ADA accessible
	3	Safety
Plant	4	Shading
	5	Diversity of plants
	6	Present of plant in number
Function	7	Reduce storm water runoff
	8	Renewable energy production
	9	Conserve energy
	10	Reduce heat island effect
	11	Promote water infiltration
	12	Reduce pollutant loading
	13	Rainwater recycle
	14	Increase longevity of roofing membranes
	15	Reduce carbon footprint
	16	Reduce noise pollution
	17	Provide on-site education
	18	Provide on-site research value

Habitat value	19	Provide habitat for wildlife
	20	Promote biodiversity
Active maintenance	21	Minimal or no irrigation
	22	Do not require chemical inputs, such as fertilizers, pesticides, or herbicides
Water efficiency	23	No permanent irrigation
Program	24	Seating
	25	Table
	26	Gathering space
	27	Viewpoint/ observation deck
	28	Children playing equipment
	29	Encourage social interaction
	30	Improve public health
	31	Encourage volunteerism
	32	Promote neighborliness and social inclusion
	33	Provide views for people within the building
	34	Encourage for outdoor activities
	35	Improve surrounding human mental health
	36	Being influential and encouraging for having green infrastructure

RESULTS

Table 2 presents the ranks of the five treatments; while Table 3 presents the sum of the rankings for each treatment. The results from equations 3,4, and 5 suggest that at least one treatment is significantly different than at least one other treatment ($p \leq 0.05$). In the multiple compassion test, the results suggest a difference between treatments larger than 37.7001 are significant. The self-design rooftops, extensive green roofs, semi-intensive green roofs, and intensive green roofs are statistically significantly better than conventional rooftops ($p \leq 0.05$). In Addition, the intensive green roof is statistically significantly better than self-design rooftopp ≤ 0.05).

Table2. *Variables in rankings*

Aspect	No.	Variable	Conventional	Self-Design	Extensive	Semi-intensive	Intensive
Accessibility	1	Entrance	4.5	2	4.5	2	2
	2	ADA accessible	4.5	3	4.5	1.5	1.5
	3	Safety	3	3	3	3	3
Plant	4	Shading	4.5	4.5	3	2	1
	5	Diversity of plants	5	4	1	3	2
	6	Present of plant in number	5	4	1.5	3	1.5
Function	7	Reduce storm water runoff	4.5	4.5	1	3	2
	8	Renewable energy production	4.5	2	4.5	2	2
	9	Conserve energy	4.5	4.5	1.5	3	1.5
	10	Reduce heat island effect	5	4	1.5	3	1.5
	11	Promote water infiltration	4.5	4.5	1	3	2
	12	Reduce pollutant loading	5	4	1.5	3	1.5
	13	Rainwater recycle	5	1	3	3	3
	14	Increase longevity of roofing membranes	4.5	4.5	2	2	2
	15	Reduce carbon footprint	5	4	1.5	3	1.5
	16	Reduce noise pollution	4.5	4.5	1.5	3	1.5

	17	Provide on-site education	5	2	4	3	1
	18	Provide on-site research value	5	3	2	4	1
Habitat value	19	Provide habitat for wildlife	5	4	1	3	2
	20	Promote biodiversity	5	4	1	3	2
Active maintenance	21	Minimal or no irrigation	2	2	2	4	5
	22	Do not require chemical inputs, such as fertilizers, pesticides, or herbicides	2	2	2	4	5
Water efficiency	23	No permanent irrigation	2	2	2	4.5	4.5
Program	24	Seating	4.5	3	4.5	1.5	1.5
	25	Table	4.5	1	4.5	2	3
	26	Gathering space	4.5	3	4.5	1.5	1.5
	27	Viewpoint/ observation deck	4.5	3	4.5	2	1
	28	Children playing equipment	4	2	4	1	4
	29	Encourage social interaction	5	3	4	1.5	1.5
	30	Improve public health	5	4	2	2	2
	31	Encourage volunteerism	5	4	3	1.5	1.5
	32	Promote neighborliness and social inclusion	5	3	4	1.5	1.5
	33	Provide views for people within the building	5	4	2	2	2
	34	Encourage for outdoor activities	5	3	4	1.5	1.5
	35	Improve surrounding human mental health	5	4	2	2	2
	36	Being influential and encouraging for having green infrastructure	5	4	2	2	2

Table3. *Sum in ranking of each scenario*

	Conventional	Self-design	Extensive	Semi-intensive	Intensive
Sums	161.5	118	95.5	90	75

$x_r{}^2 = (\frac{12}{36\times5\times(5+1)} \times (161.5^2 + 118^2 + 95.5^2 +$
902+752−3× 36× 5+1=50.35 (3)

Since there are ties occurs, text statistic has been justified by dividing $x_r{}^2$, by

$1 - \sum_{i=1}^{b} R_i{}^2\, T_i\, /bk(k^2 - 1)$

where,

- $T_i = \sum t_i{}^3 - \sum t_i$
- t_i = the number of observations tied for a given rank in the ith block.

There are 27 two-way ties, 12 three-way ties, and one five-way ties, therefore,

$$1 - \frac{(2^3-2)\times27+(3^3-3)\times12+(5^3-5)\times1}{36\times5\times(5^2-1)} = 0.868056 \qquad (4)$$

Then, we calculate adjusted x^2 value by,

$$x^2 = 50.35 \div 0.868056 = 58.003 \qquad (5)$$

Then, the ${x_r}^2$ adjusted for ties is 58.0032.

A numerical value for assessing the null hypothesis is needed and is determined by using a table that contain chi-square value of $x2\ (1-\alpha)$ with k-1 degree of freedom, provided by Daniel (Daniel, 1978). If ${x_r}^2$ is greater or equal than the determined value, the null hypothesis will be rejected (Daniel, 1978). In this study, the experiment-wise error rate of α equal to 0.05 and k equal to 5. The value of ${x^2}_{0.99}$ with 35 degrees of freedom is 57.342. Since 58.0032 is greater than 57.342, at least one treatment is significantly different than another treatment.

In order to determine which scenario is better than the other, multiple-comparison procedure for use with Friedman test apply (Daniel, 1978). The equation is (Daniel, 1978);

$$|R_i - R_{i'}| \geq z\sqrt{\frac{bk\,(k+1)}{6}} \quad (6)$$

Where,

- R_i and $R_{i'}$ are the ith and i'th treatment rank totals
- z is the value from a table provided in Daniel's book, corresponding to $\propto/k(k-1)$ (Daniel, 1978).

In this study, experiment wise error rate of α equal to 0.05, which

$z = \alpha \div k(k-1)$

$z = 0.05 \div 5(5-1) = 0.0025$ z -score for 0.0025 is 2.81, found in a table in Daniel book.

Therefore, after applied multiple comparison procedure for use with Friedman test apply,

$$2.81\sqrt{\frac{36\times5\times(5+1)}{6}} = 37.7001 \quad (7)$$

Table4. *Design Scenarios Difference*

Combinations of Design Scenarios	Difference
Conventional & Self-design	43.5
Conventional & Extensive	66
Conventional & Semi-intensive	71.5
Convention & Intensive	86.5
Self-design & extensive	22.5
Self-design & Semi-intensive	28
Self-design & Intensive	43
Extensive & Semi-intensive	5.5
Extensive & Intensive	20.5
Semi-intensive & Intensive	15

Discussion/Conclusion

Based upon the sum of the rankings, intensive green roof scenario performs the best, then the semi-intensive green roof, the extensive green roof, and the self-design rooftop. This is the typical approach when designers often evaluate projects; yet the statistical approach reveal different insights. As might be suspected, the conventional rooftop scenario ranked the least; however statistically some of the designs are not significantly different. The result of Friedman's Two-Way Analysis of Variance by Ranks test supported the notion that the self-design rooftop, the extensive green roof, the semi-intensive green roof, and the intensive green roof scenarios are statistically better than the conventional roof top scenario. In contrast the test did not confirm that the self-design roof top, the extensive green roofs, the semi-intensive green roofs, and the intensive green roofs are different on their performance. They had not shown remarkable statistical difference. Under this circumstance, one could still confirm intensive green roofs are statistically better than self-design roof tops. This result is slightly differed from might be expected. Designers often observe much in the differences between various design treatments and may interpret the treatments with more separation and distinction between each other; yet statistically, they are somewhat equal. Each treatment offers something different. Statistically there is no best design; but statistically, there is a least preferred design. From the better performing green roof treatments there is not enough separation to identify statistically the best treatment.

This study has a limited sampling size; it is just one green roof study, with five treatments. Each rooftop design approach has only one design provided for comparison. These designs are quite subjective. Even though there are 36 variables selected from 7 aspects, which where chosen by the study team, and it may be a personal perspective with bias, not being as comprehensive or as thoughtful as it could be with the input of other scholars. In addition, the error rate is set at 5%, which if it is set at a different rate, the results might be different. Future study is recommended to have a larger sample size and to have more samples come from reality to let this study become more comprehensive.

For building owners, urban planners/designers, developers, and government officials, it is beneficial to appreciate underused spaces, such as rooftop environments. Rooftops can be retrofitted, re-designed, and adjusted. The variables presented in Table 1, can provide an initial program list to assess design alternatives.

There could be many possibilities toward rooftops, which could bring many attributes to the societies and natural environment. This study focusses on comparing five rooftop design approach scenarios: conventional rooftops, self-design rooftops, extensive green roofs, semi-intensive green roofs, and extensive green roofs, with the quantitative method. The result shows that conventional rooftops are the poorest environments in these five scenarios. Intensive green roofs are better than self-design rooftops. However, there are insufficient statistically results to confirm if self-design rooftops, extensive green roofs, semi-intensive green roofs, and extensive green roofs are different from each other.

Bibliography

[1] Arnberger A, Eder R. The influence of green space on community attachment of urban and suburban residents. Urban Forestry & Urban Greening. 2012;11(1),41-49. Available from: doi:10.1016/j.ufug. 2011.11.003.

[2] Berndtsson JC. Green roof performance towards management of runoff water quantity and quality: A review. Ecological Engineering. 2010;36(4),351-360. Available from: doi:10.1016/j.ecoleng.2009.12.014

[3] Bliss DJ, Neufeld RD, Ries RJ. Storm water runoff mitigation using a green roof. Environmental Engineering Science. 2009; 26(2), 407-418. Available from: doi:10.1089/ ees.2007.0186.

[4] Burghardt K T, Tallamy D W, Philips C, Shropshire KJ. Non-native plants reduce abundance, richness, and host specialization in lepidopteran communities. Ecosphere. 2010; 1(5),1-22. Available from: doi:10.1890/ ES10-00032.1.

[5] Burley JB. Designing to preserve wildlife. Landscape Design. 1996;9(10):16-23.

[6] Burley JB, Johnson, S, Larson P. Pecka B.Big Stone granite quarry habitat design: HSI reclamation application. ASSMR Conference Proceedings, PA. Pittsburgh, Pennsylvania: ASSMR, 1998. p.161-169.

[7] Burley JB, Li X, He S. Metrics Evaluating Multivariate Design Alternatives: Application of the Friedman's Two-way Analysis of Variance by Ranks: A Personal Reflection. White mud Academics: 2020.

[8] Burley JB, Li N, Ying J, Tian H, Troost S.2016.Chapter 3: Metrics in master planning low impact development for Grand Rapids, Michigan. In: Egren M.(ed.) Sustainable Urbanization. Rijeka, Croatia: Intech, 2016. p.61- 86.

[9] Cook-Patton, S. C. Plant Biodiversity on Green Roofs. In: Sutton R. (ed.). Green roof ecology. New York, NY: Springer; 2015. p.193-210.

[10] Cronk E. Storm water Retention Capabilities of Steep Sloped, Extensive Green Roof Systems. M.A. Thesis Environmental Design, Michigan State University; 2012.

[11] Daniel, WW. Applied nonparametric statistics. Boston: Houghton Mifflin; 1978.

[12] Eakin CJ, Campa H, Linden DW, Roloff GJ, Rowe DB, Westphal J. (2015). Avian response to green roofs in urban landscapes in the midwestern USA. Wildlife Society Bulletin. 2015;39 (3):574-582. Available from: doi:10. 1002/wsb.566

[13] Feitosa RC, Wilkinson S. (2016). Modelling green roof storm water response for different soil depths. Landscape and Urban Planning. 2016;153:170-179. Available from: doi:10. 1016/j.landurbplan.2016. 05.007.

[14] Feng M, BurleyJB, Machemer T, Korkmaz A, Villanueva MR.2018. Earthquake spatial mitigation: Wenchuan China and Los Banos, Philippines Case Studies. GSTF Journal of Engineering Technology (JET). 2018; 5(2).

[15] Feng, M, Burley JB, Machemer T, Armagan Korkmaz A.2017. Spatial mitigation treatments: Wenchuan earthquake case study. 3rd Annual International Conference on Urban Planning and Property Development (UPPD 2017). Global Science & Technology Forum (GSFT); 2017. p.68-75.

[16] ForschungsgesellschaftLandschaftsentwicklung --Landschaftsbau. Green Roof Guidelines-Guidelines for the Planning, Construction and Maintenance of Green Roofs. Bonn, Germany: ForschungsgesellschaftLandschaftsentwicklung Landschaftsbaue.V./Landscape Development and Landscaping Research Society e. V. (FLL); 2018.

[17] Getter KL, Rowe DB, Andresen JA. Quantifying the effect of slope on extensive green roof storm water retention. Ecological Engineering. 2007;31(4):225-231. Available from: doi:10.1016/j.ecoleng.2007.06.004

[18] Getter K L, Rowe, DB, Robertson GP, Cregg BM, Andresen JA. Carbon sequestration potential of extensive green roofs. Environmental Science & Technology. 2009; 43(19):7564-7570. Available from: doi:10. 1021/es901539x

[19] Hallsaxton M, and Burley JB. Residential interior occupant health criteria review and assessment in Holland, Michigan. International Journal of Energy and Environment. 2011: 5(5):704-713.

[20] Hallsaxton M, Burley JB.2010. Residential interior occupant health criteria in West Michigan. In: Panagopoulos, T., T. Noronha, and J. Beltrao, (eds.) Advances In Urban Rehabilitation and Sustainability 3rd WSEAS International Conference on Urban Rehabilitation And Sustainability (URES '10). Faro. Portugal: University of Algarve; Faro, 2010.p.42-48.

[21] Jim, CY. An archaeological and historical exploration of the origins of green roofs. Urban Forestry & Urban Greening, 2017;28,32-42. Available from: doi:10 1016/j.ufug. 2017. 06 .014.

[22] Kazmierczak,A. The contribution of local parks to neighborhood social ties. Landscape and Urban Planning. 2013;109(1):31-44. Available from: doi:10.1016/j.landurbplan.2012.05.0076.

[23] Keefe PS, BurleyJB. Post-mining predictive visual quality assessment: a methodology. In: Throgmorton, D., J. Nawrot, J. Mead, J. Galetovic, and W. Joseph (eds.) Proceedings Fifteenth Annual Meeting American Society for Surface Mining and Reclamation: Mining--Gateway to the Future! May 17-21, 1998, St. Louis, Missouri, The American Society for Surface Mining and Reclamation; 1998.p.752-760.

[24] Krogulecki KS. Effects of green roof plant selection on enhancing storm water quality under steep sloped roof conditions. M.A. Thesis Environmental Design, Michigan State University; 2014.

[25] Kuo FE, Sullivan WC, Coley RL, Brunson L. Fertile ground for community: Inner-city neighborhood common spaces. American Journal of Community Psychology. 1998; 26(6):823-851. Available from: doi:10.1023/ A:1022294028903.

[26] Lin W, Burley JB,Nieratko P, Machemer T.Railroad station arrival cognition: way-finding at the East Lansing train station.3rd Annual International Conference on Urban Planning and Property Development (UPPD 2017). Global Science & Technology Forum (GSFT); 2017. p.91-97.

[27] Loder, A. 'There's a meadow outside my workplace': A phenomenological exploration of aesthetics and green roofs in Chicago and Toronto. Landscape and Urban Planning. 2014; 126:94-106. Available from: doi:10. 1016/j. landurbplan.2014.01.008

[28] Lundholm J, Macivor JS, Macdougall Z, Ranalli M. Plant species and functional group combinations affect green roof ecosystem functions. PloS One. 2010;5(3), e9677. doi:10.1371/journal.pone.0009677.

[29] MatlockJM, Rowe DB. The suitability of crushed porcelain and foamed glass as alternatives to heat-expanded shale in green roof substrates: An assessment of plant growth, substrate moisture, and thermal regulation. Ecological Engineering. 2016;94:244–254.

[30] MacIvor JS, Lundholm J. Performance evaluation of native plants suited to extensive green roof conditions in a maritime climate. Ecological Engineering. 2011;37(3):407-417. Available from: doi:10.1016/ j.ecoleng. 2010. 10.004.

[31] Mentens J, Raes D, Hermy M. (2006). Green roofs as a tool for solving the rainwater runoff problem in the urbanized 21st century? Landscape and Urban Planning. 2006; 77(3): 217-226. doi:10.1016/j.landurbplan. 2005. 02. 010.

[32] Mesimäki M, Hauru K, Kotze DJ, Lehvävirta S. Neo-spaces for urban livability? urbanites' versatile mental images of green roofs in the Helsinki metropolitan area, Finland. Land use Policy. 2017;61:587-600. Available from: doi:10.1016/j.landusepol.2016.11.021.

[33] Monsma, JL. A Comparison of Insect and Spider Species Presence and Composition Across Multiple Vegetated Roof Systems. M.A. Thesis Environmental Design, Michigan State University; 2011.

[34] Nagase A, and Dunnett N. Drought tolerance in different vegetation types for extensive green roofs: Effects of watering and diversity. Landscape and Urban Planning. 2010; 97(4) : 318-327. Available from: doi:10.1016/j. landurbplan.2010.07.005.

[35] Öhrström E. Psycho-social effects of traffic noise exposure. Journal of Sound and Vibration. 1991;151(3):513-517. Available from: doi:10.1016/0022-460X(91)90551-T/

[36] Osmundson T. Roof Gardens: History, Design, and Construction. New York: W.W. Norton and Company; 1991.

[37] Partridge DR, Clark JA. Urban green roofs provide habitat for migrating and breeding birds and their arthropod prey. PloS One. 2018;13(8):e0202298. Available from: doi:10. 1371/journal.pone.0202298

[38] Peck SW. Award-winning green roof designs: Green roofs for healthy cities. Atglen, PA: Schiffer Pub.; 2008.

[39] Peters K, Elands B, Buijs A. Social interactions in urban parks: Stimulating social cohesion? Urban Forestry & Urban Greening. 2010;9(2): 93-100. Available from: doi:10.1016/ j.ufug. 2009.11.003.

[40] Pittaluga I, Schenone C, Borelli D. Sound absorption of different green roof systems. Proceedings of Meetings on Acoustics. 2012;14(1).Available from: doi:10. 1121/1. 3685875

[41] Pomeroy J. Room at the top-the roof as an alternative habitable / social space in the Singapore context. Journal of Urban Design. 2012;17(3):413-424. Available from: doi:10. 1080/13574809.2012.666176.

[42] Rowe DB. Green roofs as a means of pollution abatement. Environmental Pollution. 2011;159 (8):2100-2110. Available from:doi:10.1016/j. envpol.2010.10.029.

[43] Rumble H, Finch P,Gange AC. Green roof soil organisms: Anthropogenic assemblages or natural communities? Applied Soil Ecology. 2018;126:11-20. Available from: doi:10.1016/j. apsoil.2018.01.010.

[44] Sailor DJ. A green roof model for building energy simulation programs. Energy & Buildings. 2008; 40(8):1466-1478. Available from: doi:10.1016/j.enbuild.2008.02.001.

[45] SanchezL, ReamesTG. Cooling Detroit: A socio-spatial analysis of equity in green roofs as an urban heat island mitigation strategy. Urban Forestry & Urban Greening. 2019;44:126331. Available from: doi:10.1016/ j.ufug. 2019. 04. 014.

[46] Schipperijn J, Ekholm O, Stigsdotter UK, Toftager M, BentsenP, Kamper-JørgensenF, RandrupTB. Factors influencing the use of green space: Results from a Danish national representative survey. Landscape and Urban Planning. 2010;95(3):130-137. Available from: doi:10.1016/j.landurbplan.2009.12.010.

[47] Shafique M, Kim R, Kyung-Ho K. Green roof for storm water management in a highly urbanized area: The case of Seoul, Korea. Sustainability. 2018;10(3):584: doi:10.3390/ su10030584.

[48] Snodgrass EC, McIntyre L. The green roof manual: A professional guide to design, installation, and maintenance. Portland: Timber Press; 2010.

[49] Snodgrass EC, Snodgrass LL. Green roof plants: A resource and planting guide. Portland, Oregon: Timber Press; 2006.

[50] Spehn EM, Joshi J, Schmid B, Diemer M, Korner C. Above-ground resource use increases with plant species richness in experimental grassland ecosystems. Functional Ecology. 2000;14(3):326-337. Available from: doi:10. 1046/j.1365-2435.2000.00437.x.

[51] Sutton, R. K. Introduction to Green Roof Ecosystems. In: R. Sutton (ed.). Green Roof Ecology. NewYork, NY: Springer; 2015, p.1-26.

[52] Teemusk A, Mander Ü. (2007). Rainwater runoff quantity and quality performance from a greenroof: The effects of short-term events. Ecological Engineering. 2007;30 (3);271-277. doi:10.1016/j.ecoleng.2007. 01.009.

[53] Van Renterghem T, Botteldooren D. Numerical evaluation of sound propagating over green roofs. Journal of Sound and Vibration. 2008; 317 (3):781-799. Available from: doi:10. 1016 / j.jsv.2008.03.025.

[54] Van Renterghem T, Botteldooren D. Reducing the acoustical façade load from road traffic with green roofs. Building and Environment. 2009; 44(5):1081-1087. Available from doi:10.1016 /j.buildenv. 2008.07. 013.

[55] Wang M, HydeRQ, Burley JB, Allen A, Machemer T.Low-impact housing: River Rouge, Michigan. Housing and Society. 2015; 1-14.

[56] Wang Y, Burley JB, Partin S. Case study: post-mining and lands-use planning and design: an overview. Journal of Mining Reclamation. 2013;2(1):114-135.

[57] Washburn BE, Swearingin RM, Pullins, CK, Rice, ME. Composition and diversity of avian communities using a new urban habitat: Green roofs. Environmental Management. 2016;57(6): 1230-1239. Available from: doi:10.1007/ s0026 7-016-0687-1.

[58] Weiler SK, Scholz-Barth K. Green Roof Systems: A Guide to the Planning, Design, and Construction of Landscapes Over Structure. Hoboken, N.J: John Wiley & Sons; 2009.

[59] Whittinghill LJ, RoweDB. The role of green roof technology in urban agriculture. Renewable Agriculture and Food Systems. 2012:27(4):1-9. Available from: doi:10.1017/ S1742170 5110 0038X.

[60] Whittinghill LJ, Rowe DB, Andresen JA, Cregg BM. Comparison of storm water runoff from sedum, native prairie, and vegetable producing green roofs. Urban Ecosystems. 2015;18(1):13-29. Available from: doi:http://dx.doi.org. pro xy2.cl.msu.edu/10.1007/s11252-014-0386-8.

[61] Whittinghill LJ, Rowe DB, SchutzkiR, Cregg BM. Quantifying carbon sequestration of

various green roof and ornamental landscape systems. Landscape and Urban Planning. 2014;123:41-48. Available from: doi:10.1016/ j.landurbplan.2013.11.015.

[62] Wilsey BJ, Teaschner TB, Daneshgar PP, Isbell FI, PolleyHW. Biodiversity maintenance mechanisms differ between native and novel exotic-dominated communities. Ecology Letters. 2009; 12(5):432-442. Available from: doi:10.1111/j.1461-0248.2009.01298.x.

[63] Yachi S, Loreau M. Biodiversity and ecosystem productivity in a fluctuating environment: The insurance hypothesis. Proceedings of the National Academy of Sciences of the United States of America. 1999:96(4):1463-1468. Available from: doi:10.1073/pnas.96.4.1463.

Citation: *Wing Chi VincyTam et.al, "Comparison of Five Green Roof Treatments in Flint Michigan with Freidman's Two-Way Analysis of Variance by Ranks", Journal of Architecture and Construction, 2020, 3(1), pp. 23-36.*