"PARK SEVENTEEN" RESIDENTIAL ROOF GARDEN: LANDSCAPE PERFORMANCE AND LESSONS LEARNED

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1 ABSTRACT

The purpose of this study is to present the results of landscape performance investigations and lessons learned from quantifying benefits of the Park Seventeen project, a ¾ acre residential roof garden in uptown Dallas, Texas. Park Seventeen is the residential component (25-story tower) of an urban mixed-use development completed in March 2011. It is complemented by a 19-story office tower that sits to the immediate east of Park Seventeen. The research team was formed to quantify their landscape performance benefits during the summer of 2012 and sponsored by Landscape Architecture Foundation's Case Study Investigation Program. Because of limited resources (funding and time), the research team identified simple environmental, economic and social metrics that could effectively provide meaningful performance information. Metrics were used to investigate urban heat island mitigation qualities of the roof garden, stormwater detention characteristics, residents' satisfaction and sense of community, and cost comparison between a conventional rooftop and the project. By measuring the air temperature on ground and roof surfaces, researchers found that the roof garden mitigated urban heat island effect by reducing the average air temperature by 1.3 °F, and the average surface temperature by 15.9 °F. The growth media used on the roof garden could hold the equivalent of 2.5-inch rainfall. For the cost comparison analysis, the cost for constructing a park on the ground within the uptown Dallas of the same size would be much higher than that for the Park Seventeen project. As for the social benefits, 78% of residential and commercial tenants who regularly used the roof garden felt the sense of the community through socializing with others. The researchers documented the lessons learned related to material selection and wind/heat effects on user's comfort and safety during the summer. Elements that are deemed sustainable are also compiled as a guide for designing future urban roof garden projects in hot climate areas.

1.1 Keywords

sustainability, stormwater, green roof, urban heat island

2 INTRODUCTION

Landscape Architecture Foundation (LAF) has been promoting landscape performance research since 2010 through a series of calls for Case Study Investigations (CSI). LAF's intent is to fill a critical gap in the marketplace and make the concept of landscape performance and its contribution to sustainability as well-known as other discipline such as building performance is (LAF, 2014). This effort has been producing case study briefs that document built projects' benefits and has been published by LAF on its web site. The intent is to provide "an online interactive set of resources to show value and provide tools for designers, agencies and advocates to evaluate performance and make the case for sustainable landscape solutions. (LAF, 2014)" Its theoretical framework is built upon the sustainability triad: environment, economy and society (Li et al., 2013). Through the quantification of environmental, economic and social benefits of a built landscape, its performance can be determined (Figure 1).

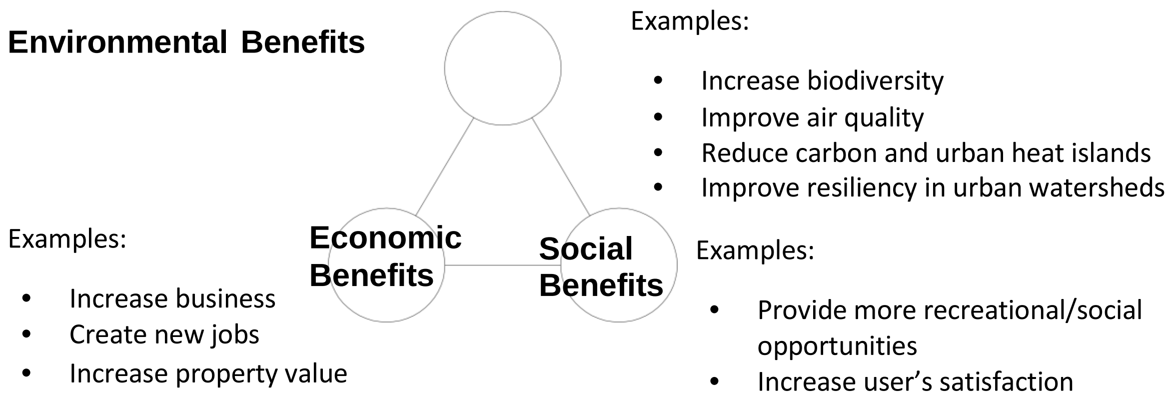

Figure 1. Landscape Performance Benefit Framework

The use of rooftops as usable space has a long history in Western culture from the Hanging Gardens in Babylon to the many elevated gardens and terraces (Osmundson, 1999) built during the Renaissance. At the turn of the Twentieth Century, building construction techniques changed radically with a shift of structural loads from thick walls with short roof spans to concrete and steel post and beam construction which allowed longer spans and cheaper materials. This radically changed building construction so that rooftops could be constructed with ample structural loads without significant costs or the constraints of wall placement (Werthmann, 2007). The modern building techniques spawned a radical change in building programming where many buildings in the late 1800's and early 1900's now had rooftop playgrounds, restaurants, theaters, private gardens, swimming pools and gardens (Jarger, 2008). The United States was a world leader with rooftop garden construction in the early 1900's until the invention of air-conditioning. Prior to the application of mechanical air- conditioning, the rooftop was a novel and cool environment to hang out during the summer. With the advancement of air-conditioning technology, rooftop gardens became less popular and faded from American skylines (Jarger, 2008). Today, with the advancement of lightweight construction materials and a desire by people to reconnect with nature, rooftop gardens are becoming more popular, especially in dense cities. North America has experienced significant growth of green roofs in many forms including residential and mixed use developments (Green Roofs for Healthy Cities, 2010). The United States is lagging behind parts of Europe and Asia in terms of new rooftop construction, but it is emerging as a leader in research about the performance of green roofs (Blank, et al., 2013). Traditional research often evaluates a single topic of study. Thus a full spectrum of the performance of green roofs is often difficult to assess. This study evaluates environmental, social and economic outcomes of a constructed rooftop garden in Dallas, Texas.

Park Seventeen is the residential component (25-story tower) of an urban mixed-use development in the uptown district of Dallas completed in March 2011. It is complemented by the 1717 McKinney project, a 19-story office tower that sits to the immediate east of Park Seventeen. Both towers sit atop and share a common 7-story parking structure. The top of the structure has been developed as a roof garden for the overall development and occupies approximately ¾ acre between the two towers (Figure 2). This seventh floor park provides both visual and physical amenities such as a swimming pool, fireplace, and sitting and gathering spaces for residents and office tenants alike (Figures 3 and 4).

Figure 2. Photograph of the Park Seventeen Roof Garden. (Source: TBG Partners)

Figure 3. Site Plan of the Park Seventeen Roof Garden. (Source: TBG Partners)

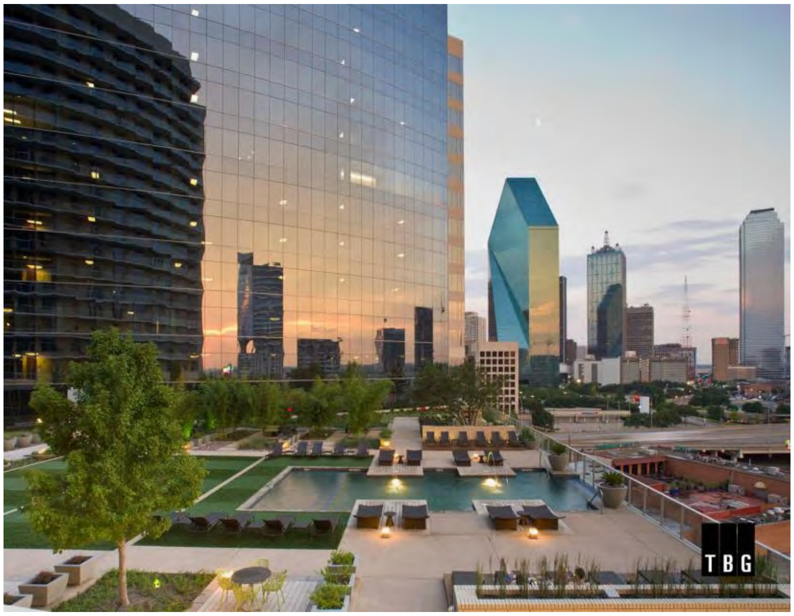

Figure 4. View to Uptown Dallas from Park Seventeen. (Source: TBG Partners)

In 2012, LAF selected the research team composed of Texas A&M University and TBG Partners to investigate the landscape performance benefits of Park Seventeen. Specific expertise represented by the researchers includes green roof, stormwater management and urban design. LAF required that the landscape performance benefits must be quantified in three aspects: environmental, economic and social. A minimum of five benefits should be documented. The timeframe of the study began in May 2012 and ended in August 2012.

The purpose of this paper is to present the results of landscape performance benefit testing, as well as lessons learned from the designer's perspective. The lessons learned can help designers, practicing educators and students revisit design strategies when designing similar urban roof gardens surrounded by high rise residence buildings.

3 METHODS

3.1 Environmental Benefits

The research team faced the constraints of time (less than four months) and budget and determined that a snapshot cross-sectional method be used to quantify the environmental performance benefits. Therefore, the research team focused on the urban heat island effect mitigation by the roof garden and stormwater detention because these were the team's expertise and relevant to the project. For the cross-sectional comparison purpose, air and surface temperatures were measured on the Park Seventeen roof garden and the parking lot below the roof garden. Readings were taken on July 11, 2012 between 2:31 PM and 3:10 PM. The weather prior to and during the temperature readings was partly cloudy with maximum temperatures for the day at 96 degrees at 3:50 in the afternoon, with average wind speeds of 8.4 MPH and relative humidity of 35 percent (NOAA, Climate Report).

Surface temperatures were measured with an Extech IR thermometer. Figure 5 shows the researcher taking the temperate reading of the synthetic turf on the roof deck by using the thermometer. Several readings were averaged to represent the recorded temperatures. The IR thermometer was held approximately three feet above the surfaces. Air temperatures were taken with a Radio Shack® digital Indoor/outdoor thermometer. Air temperatures were taken at approximately chest height. The air temperature thermometer was allowed to rest in place from location to location until the readings stabilized. Although it was a partly cloudy day, temperatures (air and surface) were taken only during sunny conditions.

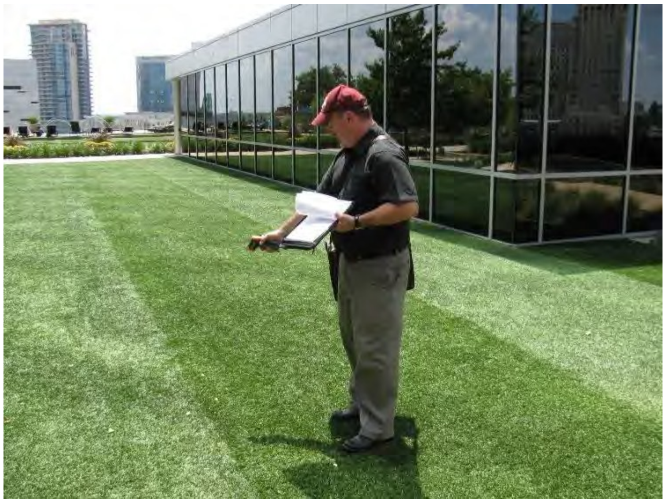

Figure 5. Extech IR Thermometer Reading Surface Temperatures of Synthetic Turf

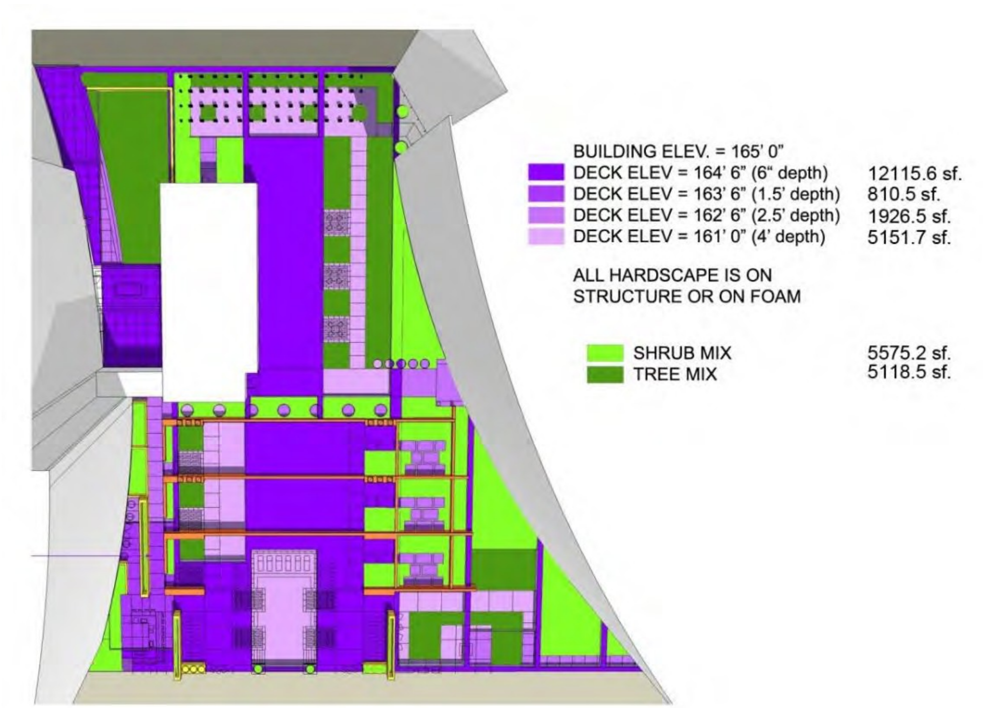

Figure 6. Growing Media Plan of Park Seventeen. (Source: TBG Partners)

The research team also estimated the potential quantity of stormwater runoff that could be detained by the growing media installed on the roof garden. Figure 6 shows the growing media plan of Park Seventeen that details the depth and area of different planting zones.

3.2 Economic and Social Benefits

Economic benefits were estimated by comparing the difference between the costs of a conventional structural garage deck versus the improved garden terrace condition presented herein. The research team used the typical land cost in uptown Dallas area around 2012 for estimation.

Social benefits were measured by three metrics: the resident's sense of place, social events held per year, and educational activities occurred per year. From July 6th to July 10th, 2012, a survey about residents' perception of the roof garden was conducted through SurveyMonkey.

Table 1. Surface and air temperatures of the roof garden and parking lot below on a 96°F day

Location	Materials	Air Temperature (ºF)	Range (ºF)	Surface Temperature (ºF)	Range (ºF)
Parking lot (Sun)	Pavement	97.2	97.0 - 97.4	145.8	142.7 - 150.0
Parking lot (Shade)	Pavement	94.8	95.0 - 97.4	96.8	96.5 - 97.0
Roof garden (Sun)	Average of all surfaces	95.9	93.8 - 97.0	129.8	114.0 - 158.0
Roof garden (Shade)	Average of all surfaces	92.2	92.0 - 93.0	90.5	85.4 - 96.4

The survey was composed of 7 multi- choice questions and 2 open questions. The multi- choice questions were about the frequency and typical time that respondents use the garden, the social value generated by the garden, how much the respondents enjoy using the garden and also the respondents gender and age range, while the two open questions were about the microclimate condition on the roof garden, and general comments.

4 RESULTS

4.1 Environmental Benefits

Overall, the parking lot air and surface temperatures were greater than the roof garden (Table 1). The average parking lot air temperature was 97.2 °F and ranged from 97.0 to 97.4 °F. The average surface temperature was 145.8 °F and ranged from 142.7 to 150.0 °F. In the shade, the average parking lot air temperature was 94.8 °F with a range of 95.0 to 97.4 °F and the average surface temperature was 96.8 °F with a range of 96.5 to 97.0 °F. The average roof garden air temperature was 95.9 °F in areas open to the sky and ranged from 93.8 to 97.0 °F. The average surface temperature was 129.8 °F and ranged from 114.0 to 158.0 °F. It is interesting to note that the synthetic turf measured the highest surface temperature of all the surfaces recorded including the dark colored parking lot below. The coolest surface temperatures open to the sky were the white concrete roof tiles. In the shade, the average air temperature was 92.2 °F with a range of 92.0 to 93.0 °F and the average surface temperature was 90.5 °F with a range of 85.4 to 96.4 °F.

For the estimation of detained stormwater runoff, TBG Partners provided the Green Roof Growing Media Analysis on the water holding capacity for the intensive mix and extensive mix. The water holding capacity of the intensive mix and extensive mix is 482 cubic inches of water per cubic foot of soil and 354 cubic inches of water per cubic foot of soil, respectively. The intensive mix of 3 feet in depth was used at tree areas and the extensive mix of 1.5 feet in depth was used at shrub areas. The calculation procedure is presented below.

Water holding volume by intensive mix:
Area of the intensive soil is 5,118.5 square feet
$5{,}118.5 \times 3 = 15{,}355.5\ ft^3$
$15{,}355.5 \times 482 = 7{,}401{,}351\ in^3$

Water holding volume by extensive mix:
Area of the extensive soil is 5,575.2 square feet
$5{,}575.2 \times 1.5 = 8{,}362.8\ ft^3$
$8362.8 \times 354 = 2{,}960{,}431.2\ in^3$

By dividing the total water holding volume by the total roof area, an equivalent rainfall depth can be estimated. The total area of the roof garden is 32,670 square feet (= 4,704,480 square inches).

Water holding volume: $7{,}401{,}351 + 2{,}960{,}431.2 = 10{,}361{,}782.2\ in^3$

Water holding volume divided by the total roof deck area: 10,361,782.2 / 4,704,480 = 2.2 inches

The inference is that, for rainfalls of 2.2 inches or less, 100% of stormwater on the roof deck could be captured by the soil mixes, assuming that the drainage system would transport stormwater runoff to all soil areas. According to the Natural Resource Conservation Service, the 2-year, 24-hour rainfall in Dallas County is approximately 4 inches. Should a rainfall of such magnitude occur, 55% (2.2/4=0.55) of stormwater could be detained by the soil mixes.

4.2 Economic Benefits

As described, the research team evaluated the difference between the costs of a conventional structural garage deck versus the improved garden terrace condition presented herein. The total area of the deck is 32,670 square feet, and the cost to provide waterproofing, landscape, irrigation and pedestrian hardscape and amenities within this space was approximately $1,800,000. This equates to a premium cost per square foot of $63 for the roof garden. A traditional parking deck, without any waterproofing, landscape, hardscape or amenities would cost approximately $712,500 to build (assuming $7,500 per space and a total of 95 spaces would be built). This is the base cost of approximately $22 per square foot ($712,500 / 32,670 square feet) for a parking deck, as opposed to $85 per square foot for a roof garden ($22 base cost plus the roof garden premium cost at $63).

Further, a property searched online (reference accessed on July 25th, 2012) approximately 0.6 mile away from Park Seventeen would cost $63.54 per square foot indicating that building a park on the ground level within the uptown Dallas area would cost $2,075,851.80 in land acquisition ($63.54 x 32,670 = $2,075,851.80). Together with the cost of construction, landscape, irrigation, pedestrian hardscape and other amenities, the total cost is higher than the roof garden.

The resultant change represented by the roof garden improvements was identified in the early stages of design, in collaboration between consultants and the general contractor. This early evaluation was done to ensure a cost impact that was within financeable limits and that could legitimately be determined as “recoupable” within a pre-determined period of time, based upon leasing projections for both residential as well as office tenants.

4.3 Social Benefits

Based upon an on-site capture of 350 or so residents within 292 units and an approximate current office population of 325 tenants, about 44 resident socials are programmed per year with an average attendance of 15-18 people. It should be noted that approximately 50% (+/- 160) of the total office tenant population has been included in office tenant events such as receptions, open houses, and tenant parties.

According to TBG Partners, the total approximate number of students touring the project on an annual basis (2011) is 120, including ASLA student chapters, and program tours from Texas A&M, Texas Tech and UT Arlington; the total approximate number of professionals (real estate, design consultants) touring the project on an annual basis (2011) is 180, including USGBC tours (2), Institute of Real Estate Management, and CREW.

4.4 Limitations

With the three month timeframe for this study, two apparent limitations exist. Firstly, the research team only measured the temperatures on a typical summer day. A full-year temperature comparison would be of great interest to many if temperatures of other seasons were also measured. Secondly, the economic metric chosen and measured by the research team only represented a hypothetical cost comparison. Actual long-term property data can reflect the economic benefits of the project better and should be considered if the timeframe allows.

5 DISCUSSION: LESSONS LEARNED

LAF allows the research teams to select the metrics for measuring environmental, economic and social benefits but only gives approximately three months for research under its funded CSI Program. The positives of this arrangement include (1) the freedom of choosing the metrics may develop an original, innovative and effective method in measuring benefits; (2) the research team should choose “doable” metrics that represent the teams’ strength; and (3) the results using cross-sectional comparison become available in a timely fashion. The negatives may include (1) the research team may avoid measuring certain metrics that are more relevant but require significant efforts; and (2) since long-term monitoring was not possible, some ecosystem services, like health benefits, could not be used as metrics of landscape performance. For future CSI studies, the research team recommends these to be addressed for improvement.

The survey revealed how valuable the roof garden is for the residents as a place where a sense of community is maintained. Without the roof garden, residents said they would drive or walk to the nearest park. The residents use the roof garden on a regular basis on weekend (77%). Although there was frequent mention that the garden can be too windy or too hot, it still gets used on a consistent basis and provides a stable location for social events.

One interesting finding was the contribution of synthetic turf to increased temperatures on the roof garden. It was assumed that the roof garden would be cooler, especially in the shade, however, it was not anticipated that the synthetic turf would become a source of increased discomfort on the roof garden. The average mid-afternoon temperature of the synthetic turf in the sun was 151.0 degrees and air temperature was 95.9 degrees. These temperatures were equal to the parking lot temperatures. Since live turf was not allowed on the roof garden, perhaps the findings provide evidence for future allowance of code variances to allow real turf, especially drought tolerant varieties on roof gardens.

Microclimates on conventional roofs in Texas can reach extreme temperatures, but live plants on green roofs can create cooler microclimates(Dvorak, Bruce and Astrid Volder 2013). Therefore, material choice on rooftops is critical especially when occupied. According to the survey about residents' perception of the roof garden, conducted between July 6th and July 10th, 2012, many users' level of satisfaction with the roof garden was hindered by the high temperatures and wind. Therefore, roof garden designers should consider providing more opportunities for live vegetation, shade and wind breaks to create more pleasant and usable spaces on rooftops.

Stormwater retention was also investigated and found to be similar to other findings in Texas. Field studies in Texas found that stormwater retention from shallow green roofs can play an important role in managing runoff from rooftops. The 4.5 inch deep green roofs at Texas A&M University retained 78% average over the growing season (Volder, Astrid and Bruce Dvorak 2013). One inch storms were captured at near 100% retention; however, for the Park Seventeen roof garden, over two inch storms were estimated to be retained at the 100% level. The deep substrates allow for intense rainfall events to be retained on the roof for plants and evaporative cooling.

Many challenges exist with the development of a park of this magnitude atop a structure. At seven stories above street level, these challenges included wind load and load of landscape elements, including trees, paving and a pool (impacts upon both comfort and function). Load challenges were overcome through careful coordination with the design team to ensure adequate clearances in the parking structure below while accommodating the extensive package of amenities above. The solution included variable depths between beams to allow for placement of the pool and large specimen trees in deep areas and lighter loads in areas of turf and/or paving only.

For wind loading, which is exasperated by the "funnel" effect created by curving building facades, design solutions were proposed that included: canopy trees in areas where they could contribute to dissipation of force; special detailing to anchor vertical elements (including tree anchoring) to the structural slab below; selection of weighting furnishings and amenities; binding agents used within aggregate surfacing.

6 CONCLUSION

This paper presents the results of landscape performance investigations and lessons learned from quantifying benefits of the Park Seventeen project, a ¾ acre residential roof garden in uptown Dallas, Texas. The effort was part of the LAF's 2012 CSI Program. Documented benefits in this investigation are summarized below:

- Mitigates urban heat island effect by reducing the average air temperature by 1.26 °F, and the average surface temperature by 15.9 °F (based upon temperature readings taken on 7/11/2012).
- Holds a maximum stormwater volume equivalent to a 2.2 inch rainfall in the engineered soil mix.
- Provided a sense of place for 78% of tenants who regularly used the roof garden.
- Promotes social activities between neighbors; every year approximately 44 resident socials are programmed, and the average attendance is 15-18 people.
- Provided educational opportunities to approximately 120 university students and 180 professionals in real estate and architectural design, and from US Green Building Council in 2011.
- CSI's short timeframe and less stringent requirements for choosing metrics may be adjusted to address the issues raised in the Discussion section.

7 ACKNOWLEDGEMENTS

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