Living Wall: Digital Design and Implementation

Danelle Briscoe

University of Texas, Austin/USA ·briscoed@utexas.edu

Abstract: This paper documents a multi-disciplinary, research investigation and installation that contributes to knowledge in advanced BIM technique as applied to sustainable design. As a co-operative and academically funded project, the installation addresses the specific challenges of its hot and dry climate from the perspectives of architecture, ecology and landscape departments. The research conveys a multi-stakeholder workflow where BIM and other visual programming platforms support the design, fabrication, construction and metric of a customized, plant and eco-habitat façade.

Keywords: Living wall, BIM, simulation, ecology

1 Introduction

Since the early 2000s, Building Information Modelling (BIM) has become a necessary part of major building construction. Beyond the benefits of standard documentation agreeance and project management coordination, many architects and other design professionals express concern over the limitation this modelling process may have on the design process, or better yet social responsibility or ecological benefit. This research suggests BIM is arguably an effective tool to support innovation in the design process, as well as promote collaboration between ecology and architecture disciplines. Ecological measures and evidence further validates BIM procedural clarity and recognizes building façade exploration both technologically and environmentally.

Façade greenery, or more specifically a living wall – a vertical plant system rooted in growing media attached to a wall – is suggestive of an alternative landscape approach in service to ecological enhancement. Such views of landscape move away from those traditionally ascribed by the human contrived Anthropocene era: cultivation, reflection, utilitarian. Instead, living walls offer opportunities for the architecture discipline to serve as a connected, interdependent whole (ANDERSON 2017). In this manner, BIM technology assists in the appropriation of ecological benefits and furthermore, allows a post-construction actuality to negotiate a relationship between the built and natural world.

In May of 2016, a Living Wall pilot project was installed along the west façade of Goldsmith Hall, the primary building for the University of Texas at Austin's School of Architecture (UTSOA). Investigating the role of ecology in architecture, the structure is comprised of a patent-pending honeycomb design, patent-pending soil media, SkySystem™ and native flora specially selected to attract local fauna. Five years in the making, the project tests the limits of what is possible with living walls in central Texas through ongoing research, data collection and analysis. This paper documents a multi-disciplinary living wall project and its installation in the hot and dry climate of Austin, Texas.

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2 Project Background

2.1 Specifics

The project location (30°11'N. 97°52'W, elevation 247 m average annual precipitation 34.25 inch) is just blocks away from the State Capitol of Texas and is located within a dense urban campus. According to U.S. Climate Data the sub humid, subtropical Austin climate experiences a bimodal rainfall pattern that often peaks in spring (May-June) and fall (September-October). In the summer months, the average high temperatures range between 30.5 °C in May and 36 °C in August. Additionally, night time temperatures tend to remain high in the summer months (>23 °C) especially in the urban core. Central Texas also is prone to sporadic rainfall patterns and temperatures especially during periods of drought, where temperatures range even higher, precipitation levels fall, and the time between precipitation events increases. Warmer climates, such as Austin's pose a number of problems for living wall designs due to high ambient air and soil temperatures, varied rainfall patterns and high evapotranspiration rates. For this reason, the pilot project investigation contributes to knowledge in urban heat mitigation using an atypical BIM technique.

Fig. 1:
Living Wall pilot project in context

2.2 Objectives

The primary goals of the project include: observing and testing living wall technology at the University to evaluate future application to parking garages across this campus, city and region, providing a living laboratory to facilitate educational opportunity with students, faculty and staff, and contributing to the ongoing research on living wall systems around the world. The research conveys a multi-stakeholder workflow where BIM supports the design, fabrication, construction and metric of a customized, plant and eco-habitat façade. As a co-operative and academically funded project, the installation addresses the specific challenges of its regional climate from the perspectives of architecture, ecology and landscape departments. The design, installation and maintenance of the Living Wall is a collaborative effort between the School of Architecture and the Lady Bird Johnson Wildflower Center (Wildflower Center). Facilities Services and Landscape Services at the University oversees the irrigation system design and maintenance. The Jha Lab at the University of Texas at Austin's Department of Integrative Biology performs invertebrate sampling and analysis.

Although many commercial living wall products exist, none found were suitable for sustainability in an extremely hot and dry climate. Many successful applications are often in mild or temperate climates; interior climate controlled conditions or focused solely on plant graphics or aesthetics (VAN UFFELEN 2015). Other academic research precedents have noted the importance of factors such as material efficiency, energy demands and waste production for an environmental perspective in construction. Innovative processes and technologies recognize the importance of sustainable or environmentally driven design and overcome the inefficiency and lack of interoperability present in the technology sector of design. (ISOLDA & GUILLAME 2016). Live BIM processes, for design, education and post-installation evaluation, are becoming an integral part of modern product development (AL-QATTAN et al. 2016). Furthermore, walls modelled by computational design and constructed to reduce thermal gain on façades have improved thermal performance of the façade (ANDREANI & BECHT-HOLD 2014).

2.3 Methodologies

The key ecological innovations of this pilot project (relative to a standard living wall design and implementation) derives from the optimization of soil volume, the incorporation of biohabitats for beneficial fauna and post-construction analysis features. As a freestanding wall, its west-facing orientation challenges the maximum heat gain in this climate. The pilot project stands (609.6 cm length x 365.76 cm height x 30.48 cm deep (10’ × 20’ × 18”) in scale. Each of the 104 hexagonal CNC extruded cells are gravity supported in a steel, water-jet milled frame in order to support the load of flora and fauna integration. Larger soil volume per plant is necessary to reduce thermal load of plant root networks. Each standard size cell holds approximately 4 liter (1 gallon) of soil media. The cell size and capacity are sufficient for the eco-habit requirements and data capturing technologies.

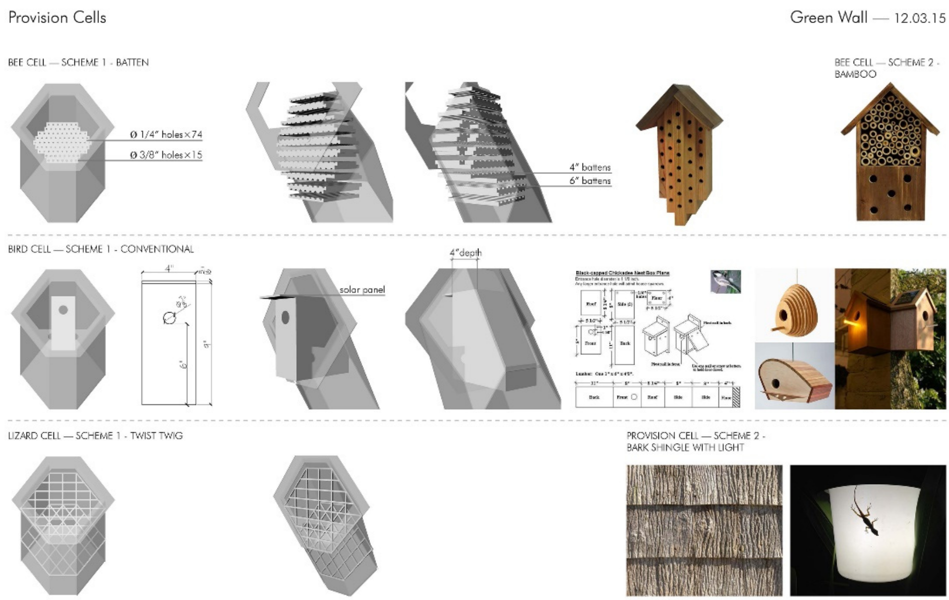

Fig. 2: Diagrams of each habitat type and its requirements

Ecological design specificity (embedded in several cells) targets the particular needs of pollinators (for hummingbirds and butterflies), songbirds and raptors (like owls or hawks), and arachnids and herbivores (or spiders and deer). One cell, for example, holds the birdhouse for the Carolina wren species. This bird is one of many from the Central Bird Flyway, a migration path that stretches along the entire length of the Americas and that uses this location as a stopping point along this long journey. Simple parameters set to the habitat's dimensional requirements allocate the placement of this habitat to 2 meters above ground. An intensive looping pattern to determine location and plant placement were created using Grasshopper for Rhino and recursion scripting plug-in, *Anemone*. The box dimensions of 12.7 cm × 16.51 cm an opening diameter of 2.85 cm deters non-native species such as starlings and house sparrows from entering. These plant and habitat combinations offer an inevitable natural and effective air purifying system, removing particulate matter (O^3, Volatile Organic Compounds and CO^2) as it passes through or across the wall. The potential ecological networks afforded by these plant to plant placements and plant to habitat combinations are intended to increase biodiversity and/or its rejuvenation (CANTRELL & HOLZMAN 2015).

BIM in this design scenario is the tool for synthesizing all other programs. BIM Material Editor Properties initially incorporated the ecologist's plant list and habitat characteristics into BIM. Later advanced use of material take-off for scheduling plants' and species' characteristics and requirements develops plant patterning through *Dynamo* visual programming and allows for quantification of plants to ecologists and the landscape maintenance team in charge of intelligent water system and monitoring. This information is colour coded for visual clarity and pattern testing. Likewise, specific plant parameters embedded within each BIM type property can then be scheduled as a material take-off quantity – each understood as a sum of plant and façade performance measures. The role of Revit's visual programming add-on, *Dynamo*, was to organize the plant list according to a Bitmap graphic. Several graphic patterns were extensively tested for pollinator applicability (BRISCOE 2014), however (for the purpose of this paper) a grey-scaled arrow was utilized to demonstrate grayscale range. This process would allow for any plant design layout, be it vertical on a living wall system or horizontal for a more typical landscape planting plan to be created and applied easily from the script. The schedule of this pattern gives the valued information from BIM of cost, quantity, type, and other identifying characteristics of each plant type.

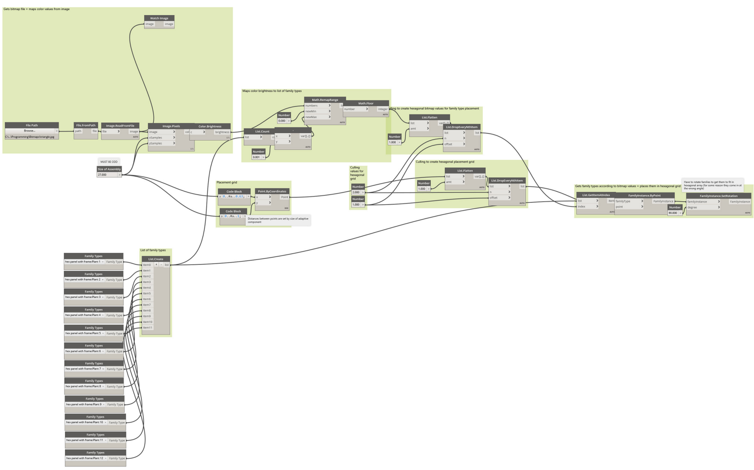

Fig. 3a: Revit/Dynamo script for organizing plant list to pattern creation

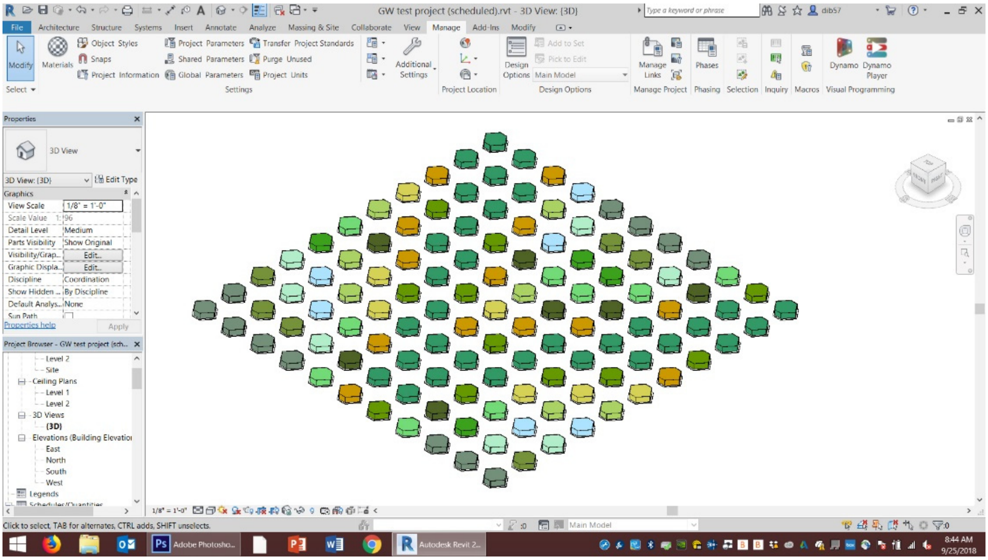

Fig. 3b: Each cell with differentiation of colour implies a different plant family type and registration

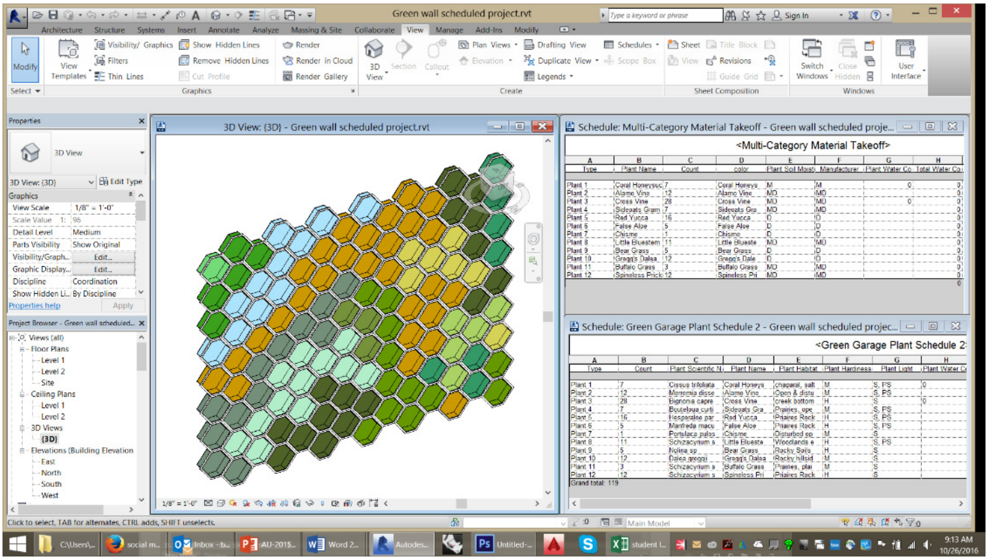

Fig. 4: BIM incorporation of scheduling as planting pattern progresses

3 Results

The post-installation BIM workflow allows for monitoring the biological species living in the wall; making maintenance and upkeep an interactive experience. Although the results are specific to this living wall pilot project, visual programming patterning of plants through BIM can indeed be extended to non-building, more land-based projects.

3.1 Analysis

Multiple, 3D printed custom sensors are placed within the living wall and used to track performance. This data records in real time using Arduino (the open-source electronic prototyping platform's) Photo Transistor, temperature-humidity sensor, Sound Detector and IR distance sensor. Grasshopper for Rhino and the Firefly plugin translate the temperature, light, and sound quantities, alongside proximity data into standard units such as thermal degrees, lux, decibels, and centimetres, respectively. These quantifiable values written into Excel sheets save at specified intervals, allowing the data to track over time for the preceding year.

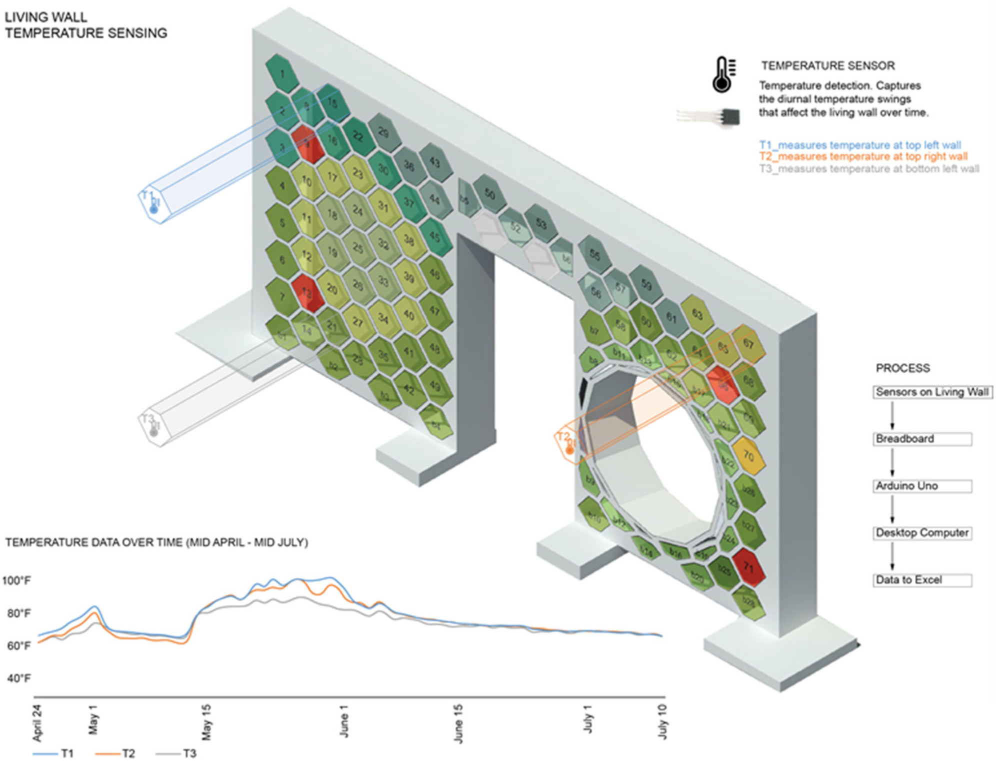

Fig. 5: Diagram displaying post-construction thermal analysis through sensors in wall

Monitors also track water usage for each plant cell through individually fed lines. The spreadsheet then imports the data back to the BIM model with an Import/Export Excel plug-in and the schedule updates the plant combination and water to soil performance. This then gives a ranking of which plants are using the most or least water in comparison to longevity. Analysis proves low water usage relative to other similarly scaled areas on campus. Overall, these data measurements are evaluating whether this green wall is cooling the west facade surface where it sits through the points of temperature sensing at three points in front of, within and behind the wall itself. Whether living wall reduces ambient air temperature around the building and thus ultimately helping to mitigate the urban heat-island effect is still under analysis.

Post-construction analysis of granular interactions between the living wall's surface, fauna habitats and specific plants, with reference to user proximity, daily water distribution and local temperature values give relevance to a live, interactive BIM platform. A highly coordinated water and data feed system is integral to the digitally fabricated cells. A digital dashboard co-exists with Arduino technology data sampling to fine-tune the BIM and analytical relationship and then disseminate metrics for educational purposes. The results establish the benefits and disadvantages to a comprehensive BIM for surface-plant-air interactions, ultimately to assess the effects of green architecture visions. The work concludes as potential to associating architecture and landscape. Through technological methodologies, such as a BIM workflow, prospective work is able to analyse human impact on biodiversity.

3.2 Maintenance

This aspect of any landscape project plays a critical part in its success and sustainability. The wall was initially monitored and recorded by the Wildflower Center collaborators for plant mortality every 3 months. After the third year, some plants that require more intensive trimming have been replaced with those native species that are evergreen. The water monitoring system has established that the amount needed to water the plants is so low that the quantity is almost negligible.

4 Conclusion and Outlook

The need to move towards the development of collaborative and comprehensive BIM processes requires facades to inform continuously post installation. The nature of this research truly requires a wide range of disciplines and coordination in order to understand and monitor the conditions affecting the range of biological species growing in or visiting the living wall and explore the possibilities of what this system offers to its environment. Indeed, the discipline needs a new type of construction process, one that utilizes technology to organize it (CHIEN et al. 2016). A BIM framework and workflow promotes the organization and innovation of this collaboration.

BIM needs only be moderately adapted to accommodate this living wall application, in that instead of scheduling building material, a user schedules plants. The visual, or node based, programming script makes it suitable for those not used to working with software and systems of this kind. This pilot project example focussed on here could be extended to non-building, landscape related projects.

Such application (if aggregated across a city) holds the potential to leave a lasting, "human induced" improvement to the planet. The intended application of the research addresses a university owned parking structure, but its scalability warrants the foundation for a more industrialized approach than this pilot or single typology. In this regard, technologists can turn their call for radical austerity into a renewed push for ecological incubation (YANG 2017). The architecture discipline, more climatically motivated than ever and furthermore driven by an advanced computational substrate, gives relevance to BIM as a collaborative focus in the industry and in architecture.

Acknowledgements

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