GREEN BUILDING AND BIODIVERSITY: FACILITATING BIRD FRIENDLY DESIGN WITH BUILDING INFORMATION MODELS

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ABSTRACT

Green buildings should respect nature and endeavor to mitigate harmful effects to the environment and occupants. This is often interpreted as creating sustainable sites, consuming less energy and water, reusing materials, and providing excellent indoor environmental quality. Environmentally friendly buildings should also consider literally the impact that they have on birds, millions of them. A major factor in bird collisions with buildings is the choice of building materials. These choices are usually made by the architect who may not be aware of the issue or may be looking for guidance from certification programs such as LEED. As a proof of concept for an educational tool, we developed a software-assisted approach to characterize whether a proposed building design would earn a point for the *LEED Pilot Credit 55: Avoiding Bird Collisions.* Using the visual programming language Dynamo with the common building information modeling software Revit, we automated the assessment of designs. The approach depends on parameters that incorporate assessments of bird threat for façade materials, analyzes building geometry relative to materials, and processes user input on building operation to produce the assessment.

KEYWORDS

bird collisions, bird avoidance, building information modeling, BIM, Dynamo, visual programming language

1. INTRODUCTION

Green building design and practice is often focused on issues of energy efficiency, toxic reduction, daylighting, and other issues that affect the human experience. Buildings of all sizes, however, cumulatively kill millions of birds each year in the United States (median estimate 599 million; Loss et al. 2014) and Canada (Machtans et al. 2013) through collisions with glass. Worldwide, avian mortality is estimated to be in the billions per year (Klem 2009).

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Reduction of bird–building collisions is a matter of sustainability and green building design, both because of the potential local and regional effects on birds (Longcore and Smith 2013) and because of the adverse emotional consequences of building occupants observing collisions and encountering dead birds. Green building has been criticized, rightly, for failing to consider biodiversity (Ogden 2014) and reduction in collisions is a straightforward way that designers can improve green building practice.

The most common victims of collisions with buildings are songbirds, many of which undertake long distance migrations each spring and fall (Arnold and Zink 2011, Hunsinger 2005). In North America, these species, which migrate at night, have long been known to be attracted to and to collide with tall lighted structures, including communication towers (Laskey 1956, Brewer and Ellis 1958, Cochran and Graber 1958) and tall buildings (Overing 1936, Overing 1938). Although the exact mechanism is unknown, nocturnally migrating birds are attracted to the vicinity of lighted structures and are unable to leave the area (Gauthreaux and Belser 2006, Longcore, Rich and Gauthreaux 2008). Often they then collide with glass during the following day.

Collisions with glass occur with most species of birds that are found around buildings, because birds behave as if glass were invisible to them (Klem 1989, Klem 1990). The particular species killed depends on the surrounding landscape and level of greenery around buildings (Cusa, Jackson and Mesure 2015). For larger buildings, effects of light emitted at night and glass are hard to distinguish from each other, but research is clear that more light and more glass means more birds colliding (Parkins, Elbin and Barnes 2015). Fortunately, windows can be made more visible to birds through use of mitigations such as fritting and films (Klem 2009, Klem and Saenger 2013).

Some debate exists over whether mortality from collisions with buildings affects populations of individual species of birds. Some have argued that it does not (Arnold and Zink 2011), with considerable disagreement (Klem 2014, Klem et al. 2012, Longcore and Smith 2013, Longcore et al. 2013). This may not, however, be the important question from a regulatory perspective. The Migratory Bird Treaty Act in the United States prohibits actions that kill migratory songbirds. Although this is not in practice enforced for building owners, actions that result in significant bird mortality do raise legal risks. Furthermore, Executive Order 13186 requires that federal agencies avoid or minimize the impacts of their actions on migratory birds, meaning that buildings designed for the federal government should consider the impacts of design on avian mortality. In Ontario, Canada, building owners have been found liable for avian mortality from building design or management that kills or injures birds; a result of legal action brought by the Fatal Light Awareness Project (see http://flap.org/law.php).

Given a need for designers to incorporate considerations about biodiversity into green building (Ogden 2014), and the specific opportunity to reduce bird mortality through design, architects are in need of tools that allow them to incorporate these concerns into a cost-effective workflow. Most architects are unaware of the specific techniques and approaches available to reduce avian collisions and have no way to assess potential designs for the risk they might pose to birds. The purpose of this paper, therefore, is to develop a semi-automated tool within a building information modeling (BIM) framework that can implement an assessment tool to evaluate compliance with a specific set of bird-friendly building guidelines.

2.0 BACKGROUND

2.1 LEED Pilot Credit 55

Bird-Friendly Building Design (Sheppard 2011), published by the New York Audubon Society and the American Bird Conservancy (ABC), helps designers understand the threats to bird lives posed by poor or unmindful design in building facades, landscaping, and urban planning and provides suggestions for improvements to lessen the number of bird collisions that occur each year. It includes an overview, discusses problems and solutions for choices of glass and lighting, provides information on legislation, and explains why the problems exist. It also discusses the ABC's role in advancing the *LEED Pilot Credit 55* (Sheppard 2011).

LEED (Leadership in Energy & Environmental Design) is a voluntary green building certification program that is administered by the US Green Building Council (USGBC). LEED certification is available at different levels (platinum, gold, silver) for different categories (building design and construction, interior design and construction, building operations and maintenance, neighborhood development, and homes). To achieve certification, specific prerequisites are met and then the level of certification is based on the number of additional points earned (LEED 2015). LEED also allows for innovation and pilot credits to test new point ideas.

LEED Pilot Credit 55 addresses bird collision deterrence. The intention of the LEED proposal is to reduce bird mortality from in-flight collisions with buildings. The full description of *LEED Pilot-Credits PC55: Bird Collision Deterrence* is not replicated here, but the key requirements are summarized (Table 1). It covers requirements that cover building façade

TABLE 1. Requirements for LEED Pilot-Credits PC55: Bird Collision Deterrence.

LEED BD+C: Core and Shell - LEED 2009 (One point)	
Building Facade Requirements	Option 1: All bird friendly materials (defined by the threat factor of all materials of 15 or below or a narrative explaining why the materials are bird-friendly)
	Option 2: Bird collision threat rating (BCTR) less than or equal to 25 (defined by the equations in a spreadsheet explained below)
Interior Lighting Requirements	Option 1: Manual shutoff of interior lights at night
	Option 2: Automatic shutoff of interior lights
Exterior lighting requirements	Option 1: Fixture shielding of exterior lights
	Option 2: Fulfillment of NC SSc8 requirements (*New Construction SS Credit, Light Pollution Reduction* –http://www.usgbc.org/node/2600382?return=/credits)
Post-construction monitoring plan	A three-year building facade monitoring plan to measure the effectiveness of the
LEED BD+C: Core and Shell - LEED 2009 (One point)	
requirements	solution

materials, interior lighting, exterior lighting and post-construction monitoring plan and has a 4-part evaluation process.

The first requirement, "building façade requirements," of the LEED Pilot Credit 55 deals specifically with the materials that the architects choose when specifying their building façades. Façades represent an important topic for education, because designers have near complete control over materials used yet rarely understand whether the choices they make have implications for the risk of bird collisions.

The pilot credit defines "All bird friendly materials" as materials having a threat factor of 15 or below. The threat factor is determined by looking its value up on a table supplied by the USGBC (USGBC 2011). It ranges from 0 (opaque material) to 100 (clear glass, single pane or insulated), with over 30 materials given threat factor values. Other examples are "glass: medium grey ceramic frit – 1/8" vertical lines spaced 1/2" apart, 20% coverage (Viracon) – 6" and "operable shutters external to glass: solid opaque hinged shutter – 10" and "Glass with continuous frit on interior (#2) surface, single pane or IGU – 25" (USGBC 2011). The designer would look up all the values, justify the use of numbers for those not explicitly defined, and determine if the goal is achieved of having all of the threat factor values under 15. If this is not the case, the designer will need to calculate the bird collision threat rating (BCTR) to determine if compliance is possible with that method.

USGBC supplies a spreadsheet that can be used to calculate the BCTR. There are two methods of calculation:

Hazardous Glass Area (HGA) has to be less than 15%.
Hazardous Glass Area (HGA) = amount of hazardous glass/total area
This was not used in this paper because an operational definition of "hazardous glass" was not found.

OR

Total Building BCTR is less than 25.

Total Building BCTR = ((Z1 BCTR * 2) + (Z2 BCTR)) / 3

The inputs are
All materials on the façade below the third floor (zone 1) and their threat factors
All materials on the façade on the third floor and above (zone 2) and their threat factors

The intermediary calculated values are
Factored area = material area * threat factor
Z1 factor area total = sum of all factored areas for zone 1
Z1 area total = sum of all material areas for zone 1
Z1 BCTR = Z1 factor area total / Z1 material area total
Z2 factor area total = sum of all factored areas for zone 2
Z2 area total = sum of all material areas for zone 2
Z1 BCTR = Z1 factor area total / Z1 material area total

Total Building BCTR = ((Z1 BCTR * 2) + (Z2 BCTR)) / 3

Z1 BCTR is multiplied by 2 to give more weight to the fact that the birds are more likely to collide with the lower part of the building.

Although LEED used a spreadsheet for its calculations of Total Building BCTR, the same calculations can be done in several different ways, one of which is to use a building information model (BIM) and a visual programming language (VPL).

2.2 Building Information Modeling (BIM)

Building information modeling is a method of 3D modeling used in the building industry for the design, documentation, and construction of buildings. "With BIM technology, an accurate virtual model of the building is constructed digitally. When completed, the computer-generated model contains precise geometry and relevant data needed to support the construction, fabrication, and procurement activities needed to realize the buildings" (Eastman et al. 2008). The intent is to create a virtual design and construction model that can be used throughout the life-cycle of a building from initial design, design development, construction, occupancy, and facilities management. The model can be used within simulation programs for construction phasing, cost estimating, and structural analysis. It can also be leveraged in several ways for assisting in designing sustainable buildings and has been used this way on many architecture projects (Krygiel and Nies 2008). Respondents (although a limited number) to a survey listed several uses of BIM-based performance used by their firm with energy analysis (83%), daylighting and solar (60%), building orientation studies (53%), and LEED documentation (50%) as the top replies (Azhar and Brown 2009). The market penetration of BIM therefore offers an opportunity to automate calculations assessing compliance with the LEED pilot credit for bird-friendly building.

BIM has several advantages over simpler CAD systems; one specifically is that the model is comprised of architecture components that have parameters. For example, a door is a component that has data about its width, cost, and fire rating. In our application, a glass curtain wall could be assigned a custom value for threat factor. It is also easy to calculate information about the building such as façade area or floor area or total cost. In Autodesk Revit, a popular BIM software program, these components (doors, windows, walls, floors, curtain walls, etc.) are called families, and the data are parameter values (width, cost, fire rating, threat factor, etc.).

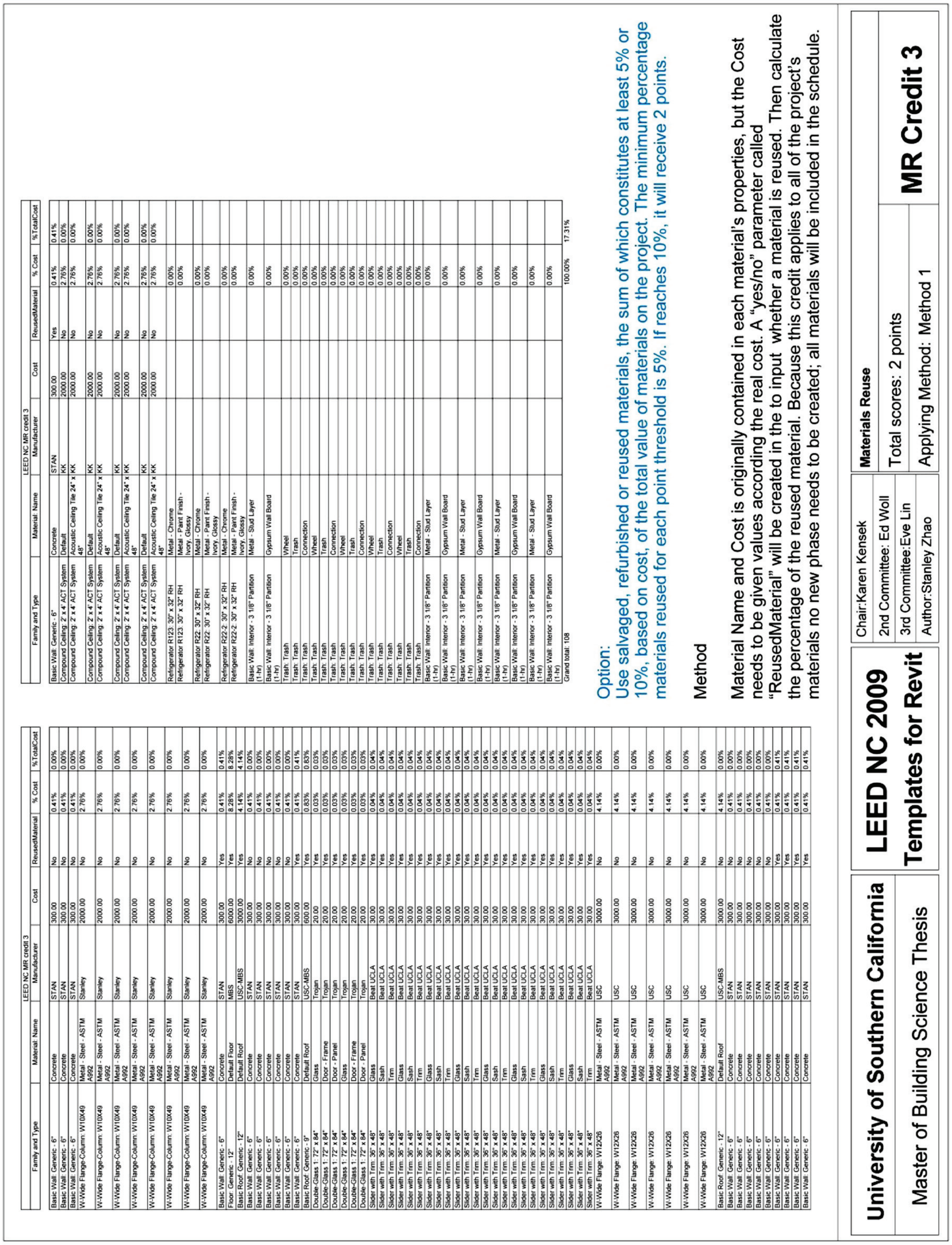
Families and their parameters are important for being able to enable the model to hold data about specific objects. Within Revit, the values in the material settings are used by Green Building Studio to calculate energy consumption for a detailed building model. The parameters can also be passed to other programs through the use of Industry Foundation Classes (IFC), a BIM interoperability file format. They can also be pulled from the model, manipulated in other software, and reinserted into the BIM (Aksamija et al. 2011). Parameters can also be employed in a BIM to LEED workflow.

2.3 Using BIM to calculate LEED points

Calculating LEED points with a BIM has four advantages:

- The architect and contractor probably already have a model.
- The model may contain data or data can be easily input that can be used for LEED point compliance.
- The software can do some calculations in a spreadsheet format using that data.
- The model can often be sent to third party software (such as an energy use simulation program) for more complex calculations.

FIGURE 1. Spreadsheet in Revit calculating the value of salvaged, refurbished, or re-used materials (Zhao 2011). (image courtesy of Xin Zhao)



We have previously explored the use of BIM in calculating and documenting LEED requirements. Looking over the requirements for *LEED 2009 for New Construction and Major Renovations*, Kensek and Zhao (2011) determined that a building information model could assist in the calculation or documentation of many points through the use of schedules and parameters, links to a third party software program, or by directly editing families. For example, existing parameters (Family and Type, Material:Name, and Cost), an additional custom parameter (ReusedMaterial), and calculated values can be used to determine if amount of material in a design was enough to achieve credit MR-3 requirements LEED 2009: *Material & Resources Credit 3 – Material Reuse* (Fig. 1).

Barnes and Castro-Lacouture (2009) also demonstrated the calculation of LEED information within a building information modeling software program. A framework was outlined for an implementation of BIM-LEED integration that could also perform a preliminary screening to determine the appropriateness of using BIM, what requirements and documentation are necessary, and tools that could be useful in implementation, especially with regards to external software interoperability such as the use of the application's programming interface (API), Industry Foundation Classes (IFC), or custom programs using eXtensible Markup Language (XML) (Wu and ISSA 2010). Several other researchers have commented on the usefulness of BIM to help in LEED certification (Alwan et al. 2014; Azhar et al. 2015; Biswas et al. 2013).

None of the previous research has shown an application of BIM to LEED using a visual programming language as an intermediary.

2.4 Visual Programming Language (VPL)

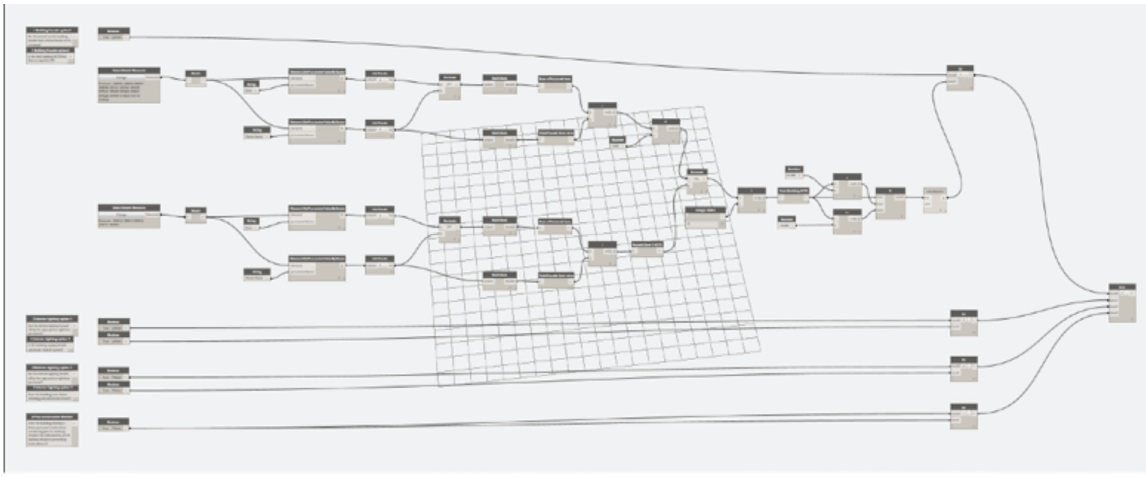
"Visual programming environments within CAD packages can be very effective for shape exploration, through real time generation of parametric variations. Most of these environments can be used without writing any code, although their capabilities can be extended with the use of scripting" (Celani and Vaz 2011). Complex form generators have been created with the use of VPL including panels for the design of an exterior of a stadium and roof structures. These have also been automatically linked to structural engineering software (Kensek 2014).

Visual programming languages (VPL) add a degree of control and customizability to 3D modeling programs without having to deal directly with the application programming interface or other text based coding. Autodesk Dynamo (http://dynamobim.com/) is one example of a VPL designed for use with Revit. It allows for the creation of nodes (numbers, value sliders, mathematical operators, functions, Boolean operations, etc.) that are connected with wires that establish the flow of the program (Fig. 2). Some nodes also allow for accessing of values of parameters in an associated Revit model. In this study, a Dynamo "graph" was created to evaluate if a building modeled in Revit would earn a point for the *LEED Pilot Credit 55: Avoiding Bird Collisions.*

3.0 METHODOLOGY

The resultant workflow has the designer create the building model in Revit using custom families that contain threat factor parameters and then run the Dynamo graph. Dynamo asks about the starting height of the third floor, accesses the wall and curtain wall parameters such as area and threat factor, and calculates the final threat factor of the whole facade system. While some questions still require yes or no answers, the tool provides output saying whether or not the design satisfies the LEED requirements using the bird collision threat rating.

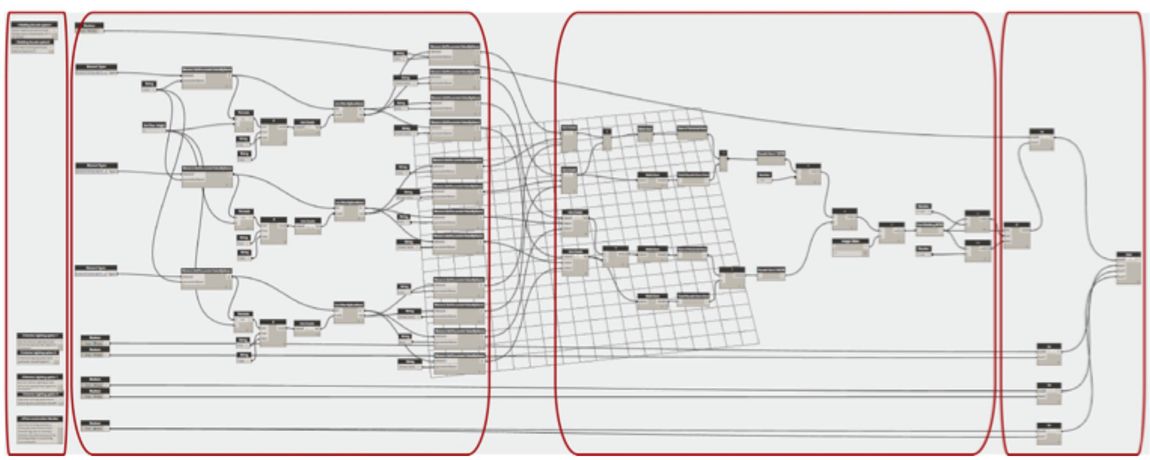
FIGURE 2. Nodes and wire connections in Dynamo. The graph is evaluated left to right.



3.1 Dynamo workflow

In the Dynamo graph there are four sections: initial questions, determining the zone for each component (zone 1 or zone 2), calculating the total building BCTR, and verifying that the other requirements are met (Fig. 3).

FIGURE 3. Dynamo graph of entire process: initial questions, determining which zone the component is in (zone 1 or zone 2), calculating the total building BCTR, and verifying that the other requirements are met.



The initial four requirements (with options) for LEED Pilot-Credits PC55: Bird Collision Deterrence are on the left side; the result of the four Booleans (True or False) are on the right (Fig. 4). Each option has a Boolean OR operator and each requirement has a Boolean AND operator to determine if all the conditions are met.

The components are separated into the two zones (Fig. 5) based on the user set third floor height.

FIGURE 4. Simplified diagram showing four initial conditions that must be met. .

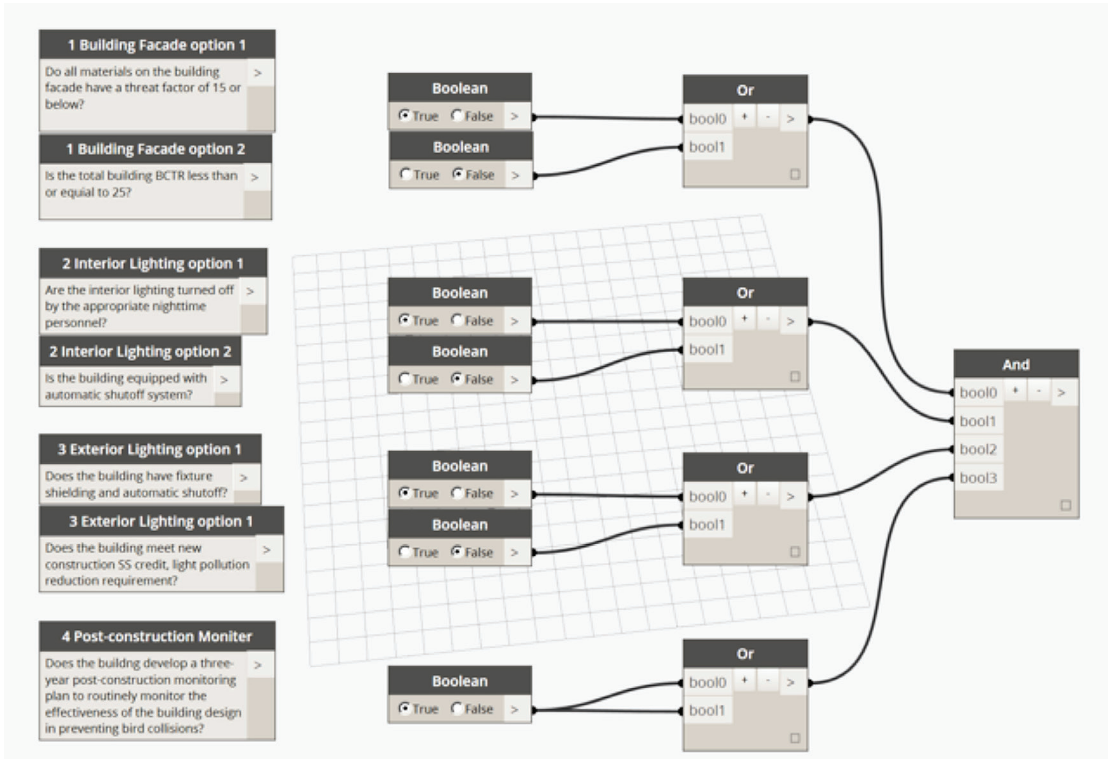
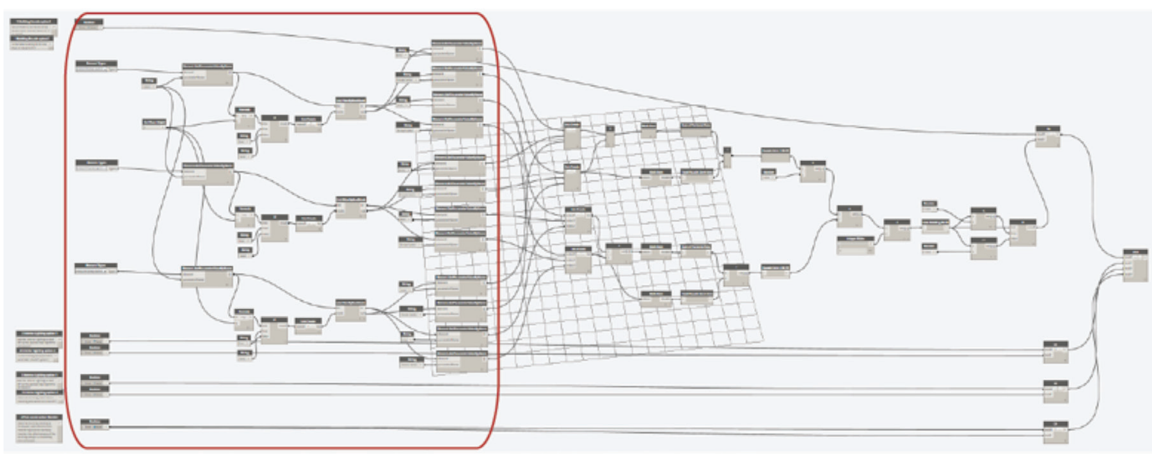


FIGURE 5. Data collection to determine which zone the element is in..



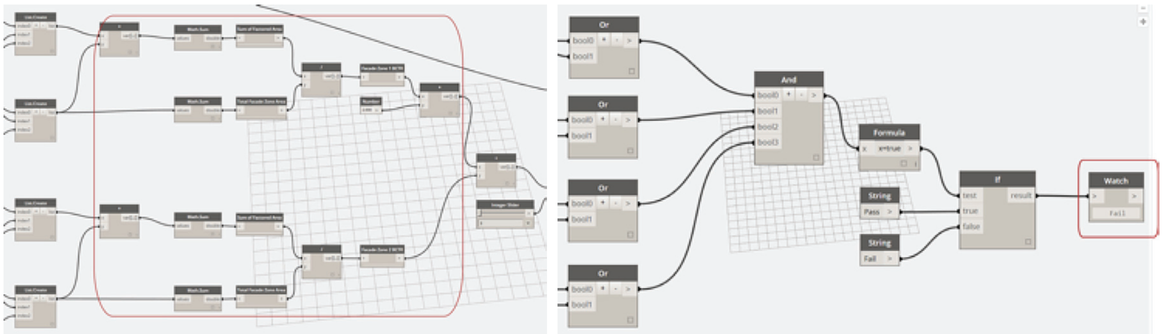
The Dynamo tool then calculates total building BCTR and determines for building façade, option 2: is the total building BCTR less than or equal to 25? (Fig. 6).

When run, the Dynamo tool extracts the necessary information from the Revit model and calculates a *Pass* or *Fail* for *LEED PC55: Pilot-Credits PC55: Bird Collision Deterrence*.

3.2 Custom families

As mentioned previously, designers have to create the models in Revit using custom families that contain threat factor parameters, so that the values are available for Dynamo to access.

FIGURE 6. Calculation nodes for building BCTR (left) and evaluation nodes for the four requirements (right).



To extract the threat factor parameters, they first had to be added as parameters to the components: walls, windows, and curtain walls. There are generally two ways of adding threat factors. One is adding them in the family property either as an instance or type parameter; in this case, a type parameter is applicable because it would be applied to all types of that component. The second method is to add the threat factor to the glass material (material element, material property). This is what was done. Thirty-five families were made for every glass type listed on the material threat factor table (e.g. opaque material- 0.rfa; clear glass, single pane or insulated-100.rfa; glass with continuous frit on interior (#2) surface; single pane or IGU-25.rfa; glass block, 8”x8”x4” deep with “wavy” translucent appearance and polished surface-20.rfa). The user must use these custom families when creating their building model or create their own with the threat factor parameter.

3.3 Zoning of building façade components

The areas of walls or curtain walls had to be classified into zone 1 or zone 2 based on whether the wall is above or below the third floor. The existing Revit parameters of base constraint and top constraint are used to recognize the zone in which a component is located. Users still must input the height of the third floor in Dynamo. From these three pieces of information, Dynamo classifies the wall as being in zone 1 or zone 2 and calculates the areas. This technique is not accurate for components that cross over two zones.

4.0 DISCUSSION

The prototype has shown that it is possible to use a building information model with a visual programming language to determine LEED requirement compliance. At its core, the provision of a BIM model to evaluate the *LEED Pilot Credit 55* is an educational effort that might result in more designers considering the credit. Implementing the model in its current state still requires considerable user interaction to establish key operational parameters for the building. In doing so, however, it guides the designer into thinking both about the design itself (e.g., the threat rating for façade materials) and about building operations that must be negotiated with future building users if the credit is to be obtained. Putting the pilot credit standards into a software environment where designers are comfortable should have benefits in terms of awareness about the underlying issue of bird collisions and educate them about potential design solutions.

Before the Dynamo/Revit tool can be released, several areas require improvement within the tool, and there are other fundamental issues to resolve beyond the scope of this tool.

4.1 Threat factor parameter

Three methods were tried for including the threat factor values. The first method of having the user specify them in Dynamo is not practical. The second method is to assign them in Revit manually adding a custom parameter to each element. This is also time-consuming. The method chosen was to create custom families with the threat factors already in them that must be used in the creation of the model. This works but is restrictive. A next step would be to have Dynamo access an outside database of threat factors and apply them to the components based on the materials selected. This is also complex because the materials have to also be created in advance, but it does allow for easier updating if the components change. There is still a major limitation that not all materials have an assigned threat factor by LEED and some judgment on assigning them has to take place. An important area of future work by USGBC and bird advocates would be to develop and make widely available downloadable sets of façade material definitions with bird hazard values for use in Revit.

4.2 Materials on the first and second floors and above

Currently the user must set what the height is of the base of the third floor to determine what are zones 1 and 2. It is difficult to extract this information from Revit because the definition of third floor is not exact and may change with each building studied. However, further work needs to be done to resolve the problem of walls and windows that cross over the two zones. This is possible to do in Dynamo, but difficult.

4.3 Other areas of improvement of the BIM tool

There are many places and other opportunities for improvement of the prototype. Three specific features would improve the tool for conceptual design:

- A report or color-coding of components that are the most "unfriendly" to birds so that designers can quickly understand the ramifications of their design decisions.
- Other knowledge about bird collision avoidance could be incorporated into the tool such as landscape locations or whether the project is in a migratory bird corridor (this might affect the height of the building).
- Incorporation of other bird friendly design guidelines in addition to the LEED credit requirements would provide designers different viewpoints into this complex problem.

4.4 Additional issues

It would be negligent to not mention other concerns that came up during the overall study of avian collisions that are out-of-scope of this research, but are related to it.

- The tool automates the formula calculation for compliance for LEED Pilot Credit 55: Avoiding Bird Collisions specifically for the bird collision threat rating (BCTR), which is based on glass area and glass type. Its ultimate success would depend on having accurate threat rating values for types of glass some of which is available, but not all.
- Further research needs to be done if the threat factor method proposed LEED Pilot Credit 55 actually is a suitable one for lessening the probability of bird collisions. Wood recommends that three other factors be added: glass type, window morphology

(“window morphology threat factor”), and proximity of bird habitat to the building (“site attribute threat factors”) (Wood 2014). Bird habitat, and landscaping, as key components came up in other studies also. The distance bird feeders are placed away from a glass surface affects window fatalities (Klem et al. 1989); “our findings suggest that strike rates are much higher where glass surfaces reflect nearby vegetation than where they do not (Gelb and Delacretaz 2006); and landscape context “had a slightly stronger relative influence than building variables” (Klem et al. 2009). It is apparent that the site context variables are as critical as the building itself to assessing and then mitigating avian strikes. Notwithstanding these factors, managing the amount of glass on the façade and the nighttime lighting of the building reduces avian mortality in all contexts (Collins and Horn 2008, Hager et al. 2008, 2013, Klem et al. 2009, Borden et al. 2010, Loss et al. 2014).

- LEED has proven relatively useful in raising architect’s, clients, and even the general public’s awareness about the issues that affect environmentally sensitive design. There is a worry that designers might just seek the credit point rather than understanding the overall issues of avoiding bird collisions, especially if a simple BIM tool is provided. Automation does not necessarily lead to a lack of consideration if used properly; it is hoped, instead, that in the early stages of design potential threats could be identified, leading to a better design.

5.0 CONCLUSION

Adoption of LEED credits depends on them being a useful addition to a description of a green building and that they are feasible to measure with a reasonable amount of effort. Bird collisions on building facades is an important environmental issue, and should the prototype Dynamo/Revit (VPL/BIM) tool be refined and released, it would present a standard way to assess compliance with *LEED Pilot Credit 55*. Although still requiring significant user inputs, a building information model to evaluate this credit has the advantage of working with software representations of proposed structures that are already created by designers and if used in the design process and would have the possibility of affecting design of facades, which are so important to mitigating risk of avian collisions with buildings. Market and regulatory forces may eventually require that certain sectors incorporate bird-friendly building design into new buildings and the ready availability of software tools to assess designs early in the process will aid compliance with such trends.

6.0 FINAL NOTE

Other local and landscape factors influence the degree to which buildings affect local biodiversity and minimizing bird collisions should not be interpreted as mitigating for other adverse impacts of a new structure in a sensitive environment. For buildings that are to be built, however, incorporating a bird-friendly design is a minimum element in developing a “green” building and could be combined with many other initiatives to better incorporate biodiversity into green building practice (Ogden 2014). “Members at all levels of interest and practice among the animal conservation and welfare community can contribute meaningfully to eliminating this lethal hazard by encouraging the U.S. Green Building Council to adopt their Pilot 55 Credit of their Leadership in Energy and Environment Design (LEED) evaluation system to include bird-safe windows and other protection measures as a permanent credit.

After all, 'green buildings' should not be considered 'green' if birds are dying after hitting their windows, no matter how high the LEED rating" (Klem 2015).

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