EXEGESIS

Design Companion

Designing with life on site

How can a building begin to earn its ecological footprint from the first design move?

Manu Molina
Student ID 20821456

ARCH6019
CTRL+Z Studio
Supervised by Justin Owen
Unit coordinator Urs Bette
Master of Architecture
School of Design and the Built Environment, Curtin University
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The project

No site is empty, even when the drawing is. It already has occupants that rarely appear in the brief; the plants, animals, soil and roots that live there, and the dependencies between them that keep each of them alive. Every architectural intervention carries an ecological responsibility. As designers, we must recognise that each decision we make has consequences beyond the physical boundaries of the project. These impacts are often the result of a series of seemingly minor design decisions and compromises which, accumulated over time, contribute to the ongoing loss of biodiversity.

And yet, when the design begins, almost none of this is on the screen. As professionals, we must be aware of the impact of the intervention being carried out. Around Perth, Banksia woodland has lost about half of its original extent, and the median patch has shrunk from about 146 hectares to 1.6 hectares (Threatened Species Scientific Committee 2016, 31, 97). We are responsible for making slow, poor decisions and reaching ineffective compromises; every delay means more natural habitat is lost for non-human species. When these consequences only become visible once the design is finished, ecology is often reduced to a few green gestures added at the end, which make a building look ecological without changing what it took from the site.

This thesis explores the need, the development and the use of "Design Companion", a tool that brings the life of a site into the design file. When a designer places walls, roofs or other assemblies, or changes a building, the tool shows what that move does and how it affects the plants, animals, soil and roots already on the site, using species data, and suggests alternative approaches, giving visual cues directly on the model. It works as a plugin for Rhino 8, the 3D software many architects already use, and as a standalone application, so that people outside the profession, from community members to anyone curious about a site, can open the same project.

Building Information Modeling (BIM) is the way architects attach information such as materials, quantities and cost to every part of a building, using software such as Revit; Design Companion attaches the life of the site. It can therefore be understood as a form of Ecological Building Information Modeling, which this thesis calls "eco-BIM", and the tool itself is the thesis. It was calibrated on Banksia woodland at Warwick Bushland (Perth), where the model holds 532 links between plants and animals; placing a test footprint there severs 40 of these links and puts 39 at risk. It was then applied at Leeuwin Barracks, a former Defence site on the Swan River (Derbarl Yerrigan), Whadjuk Noongar Country, where three versions of one building (careless, some care, designed with the tool) are a visual demonstration of the difference the tool makes.

Question and position

How can a building begin to earn its ecological footprint from the first design move?

A building cannot earn its footprint on its own; it begins to earn it through the decisions of the people who design it, and keeps earning it across its life. The research therefore moved from the building to the designer: how to enable users to negotiate and develop this sense of earning while the design can still change. Footprint here is not the area a building covers, which is just a number, but the ecological relationships and dependencies it affects, evaluated as a whole.

The central position of this research is that ecological responsibility should not be treated as an additional consideration or a corrective measure applied after a project has been designed. Instead, it should become an integral condition of the design process itself, from the first move. Building should not be considered an automatic right, but an intervention that must justify its presence in relation to the lives and systems that already inhabit a place.

Background: the gap

To earn place is to demonstrate, over time, that a building's presence contributes more than it takes, ecologically, socially and culturally. Till observes that architecture too often assumes the right to occupy a site, arriving with an authority it has not been granted (Till 2009, 48). Earning is therefore not a threshold crossed once at the start of a project, but a condition that must be maintained, tested and negotiated across the full life of a building. In this thesis it begins in the design tool, at the first move.

Negotiation is the ongoing, unresolved exchange between competing claims on a site, ecological, social, cultural and infrastructural, that cannot be settled by design but must be sustained across time. It is the condition in which multiple interests coexist without one overriding the others. Drawing on muf architecture/art, the architect's role is not to resolve competing interests but to make them legible, holding space for disagreement as a productive condition of public life (muf architecture/art 2001, 12). Design Companion extends this to the claims that cannot speak for themselves, the plants, animals, soil and roots already on a site.

This research builds on the understanding that digital tools are not neutral instruments. As Cardoso Llach (2015) argues, software actively shapes the conditions through which design knowledge is produced and architectural decisions are made. The way a digital environment structures information, establishes parameters, and enables certain operations inevitably influences what designers can perceive, consider, and ultimately design. Similarly, Zimmerman, Forlizzi and Evenson (2007), through the concept of preferred states, provide a framework for understanding design as a process that involves navigating between existing conditions and desired futures. This raises an important question. Whose preferred state is being considered when designing within an ecological context?

Contemporary architectural design relies heavily on digital modelling environments such as Revit and Rhino among others. These tools offer sophisticated possibilities for representing, developing, and documenting architectural proposals. However, they operate primarily within the logic of the designed object, rather than within the ecological context in which that object will exist.

Revit provides an extensive framework for documentation, construction information, and the organisation of building assemblies, while Rhino offers greater flexibility and freedom for geometric exploration and formal experimentation. Despite their different strengths, both share a fundamental limitation: the design environment is largely disconnected from the living systems surrounding the project. Designers typically begin with an empty digital file and proceed to draw, model, and modify their proposals without receiving continuous feedback from the specific ecological conditions of the site. Within these environments, design actions can be performed freely, while their consequences for the surrounding environment remain largely invisible.

Giraffe, a cloud-based platform developed by architects for early-stage urban design, goes further than either. It connects design to numbers from the first lines of a project, layering maps, Geographic Information Systems (GIS) data, solar, wind, cost and yield over a scheme so that it can be tested before it is drawn in detail (Day 2023). It shows that early, map-based feedback can change how a project is shaped. Yet the numbers it brings into design belong to the building and its feasibility; vegetation, animals and habitat are not among them. Design Companion takes the same principle, feedback from the first move, and applies it to the living systems of the site. A close precedent is Animal-Aided Design (Weisser and Hauck 2025), where target species set design limits at the start.

This separation reveals an important gap in current architectural software. Although building elements and construction assemblies can carry extensive information, the ecological systems affected by an intervention are rarely represented with the same level of detail, integration, or responsiveness. The site is often reduced to a static background, a collection of topographic data, or a set of environmental parameters, rather than understood as a living network of interdependent relationships.

The expansion of the built environment frequently involves the displacement, fragmentation, or destruction of existing habitats, affecting not only visible landscapes but also the complex relationships between the plants and animals that live there (Threatened Species Scientific Committee 2016, 30).

Flora and fauna, soil conditions, root networks, and subterranean relationships, such as mycorrhizal networks and associations are interconnected components of an environment that cannot be understood through isolated parameters alone. Their presence, interactions, and dependencies are essential to understanding what an intervention may disrupt, transform, or support. Many of these relationships remain invisible within conventional architectural representations, despite being fundamental to the functioning of an ecosystem.

Research into Building Information Modeling for green buildings already incorporates sustainability criteria directly into the architectural design process, enabling environmental impacts to be assessed and design decisions to be informed from the earliest stages of development (Chang and Hsieh 2020; Lu et al. 2017). Design Companion extends this to the plants, animals, soil and roots that the building affects.

The proposal seeks to move beyond the simple addition of environmental data to existing modelling software. Its purpose is to expand what architects are able to perceive and consider as part of the design process. This includes making visible not only the above-ground landscape but also the less visible ecological relationships that sustain it, particularly those involving soil, roots, and subterranean networks.

At the core of this proposal is the notion of negotiation. Negotiation is not understood merely as a means of reaching a final compromise between architectural requirements and ecological constraints, but as a fundamental part of the design process and an end in itself. It makes visible the interconnections between different living systems, bringing ecological relationships into the space of architectural decision-making. Through this process, each design move becomes an opportunity to question, reconsider, and negotiate the conditions under which an intervention can take place.

Ultimately, the aim is to shift ecological responsibility from a retrospective assessment to an active design practice: one in which the ecological footprint of a built intervention must be continuously questioned, negotiated, and earned. Architecture should not simply be designed within an environment, but negotiated with the living systems that constitute it.

Approach

This thesis is practice-based research: the tool is the main outcome, and the knowledge it offers is carried by the tool itself (Candy and Edmonds 2018). It follows research through design, where making an artefact is the way of asking the question (Zimmerman, Forlizzi and Evenson 2007). Gaver (2012) argues that what this kind of research produces is provisional and grounded in the things it makes. Design Companion is offered in that spirit, as a working proposal that others can open, use and question.

Design Companion grew through use rather than being designed once. Over eight months it morphed through cycles of building, testing and reflecting, close to what Schön (1983) calls a reflective conversation with the situation: each version was put in front of a site, a tutor or a test, and what came back changed the next one. The tool itself changed form several times, and each change came from frustration, trial and error, and a ceiling that stopped the experience from reaching its full potential. It began as a web app drawing live species data from the Atlas of Living Australia, but the data stayed on the screen, apart from the design. It then moved into Rhino, first as a node-based Grasshopper script and then, in June, as a plugin written in Python, so that the data sat inside the model being designed. In October it became a standalone application, so that people without a Rhino licence could open a project.

Testing used two sites with two roles; Warwick Bushland, a protected Banksia woodland, to calibrate the tool, and Leeuwin Barracks, a site facing redevelopment, to apply it where a real decision is coming. The same brief was designed three times, with and without the tool, to show its implications in real use.

Site

The site selection exercise was intended as a starting point for research rather than a comparative search for the optimal site. Ten remnant Banksia woodland sites across the Perth region were selected, from Herdsman Lake and Bold Park to Gwelup and Lake Goollelal, each written on a separate piece of paper and placed in a hat. One was then drawn at random, determining the site for this thesis: Warwick Bushland.

The exercise was not entirely arbitrary, as the ten sites had already been selected according to their ecological relevance. Rather, it surrendered personal preference while retaining the project's intellectual framework. The draw marked the moment when the site ceased to be a choice and became a given: a condition to respond to rather than a canvas onto which the project could impose its ideas. The project could not choose an easy ground to suit its argument; the argument had to answer to the ground.

Warwick Bushland is Bush Forever Site 202, about 58 hectares of Banksia, jarrah and tuart woodland on the Spearwood dunes in the City of Joondalup, on Whadjuk Noongar Country. More than 85 per cent of it is in very good to excellent condition. It holds a wide range of native plants, birds and reptiles, and it is a breeding site for several hollow-nesting birds (Government of Western Australia 2000). Warwick became the calibration site for Design Companion, the place where its species data, root systems and animal relationships were built and checked.

Warwick, however, is protected, and no one would ever be allowed to build there. A tool for negotiating new development needed a place where building was really going to happen, so I looked for a site that was about to change, and found Leeuwin Barracks. It is a former Defence site of 14.3 hectares on the Derbarl Yerrigan (Swan River) in East Fremantle, and in 2026 the Defence Estate Audit confirmed that its personnel would relocate, leaving the site's future open (Department of Defence 2026). Decades of military use have changed its ground, yet it still holds life: when I brought the site into the tool, it recorded 1,646 trees. Hobbs et al. (2006) call places like this novel ecosystems: shaped by people, but still ecological, and still owed care. This is where Design Companion is put to work. Leeuwin is also Whadjuk Noongar Country. The tool does not speak for its custodians, and it does not replace their knowledge of this place (Tuck and Yang 2012).

Client, programme and brief

Design Companion is conceived as a design-support tool for professionals working in architectural, urban and landscape projects. Its purpose is to help designers and other stakeholders understand the competing needs, relationships and potential consequences of design decisions. However, unlike conventional design tools, Design Companion recognises the environment and its living systems as fundamental stakeholders and protagonists of design.

The stakeholders of Design Companion extend beyond its direct human users. Designers, architects, planners and communities are direct users who interact with the tool, evaluate proposals and understand their potential impacts. The tool also represents non-human stakeholders: flora, fauna, trees, roots, rhizomes, soil, water systems, habitats and the ecological networks that connect them. These are not merely environmental elements that a project must accommodate; they are living systems with their own needs, relationships and conditions for survival. Their presence and continuity must actively inform and influence design decisions.

Humanity itself is also a fundamental stakeholder, including present and future generations who depend on the health and continuity of these ecological systems. This perspective challenges the conventional anthropocentric understanding of architecture, proposing a more inclusive approach in which human and non-human life

are interconnected and mutually dependent. Roudavski (2020) argues that non-humans can be recognised as clients and users of design.

Design Companion therefore aims to make these often-overlooked stakeholders visible throughout the design process. Rather than identifying environmental consequences after construction, the tool enables designers to anticipate potential impacts, understand ecological relationships and communicate possible transformations before they occur, the way a render shows a client how a building will look before anything is built.

Its brief is to make ecological information accessible, represent human and non-human needs, identify potential impacts, communicate design consequences and support informed decisions. Ultimately, Design Companion seeks to transform who and what is considered important in the design process, positioning ecological systems and humanity as interconnected protagonists in shaping the built environment.

The Whadjuk Noongar people, the Traditional Custodians of both Warwick and Leeuwin, are not clients of this project. They are rights-holders, with knowledge of and responsibility for Country that no dataset can hold. Design Companion does not represent them or speak for them, and turning their knowledge into one more layer of data would repeat the move that Tuck and Yang (2012) warn against. In a real project at Leeuwin, their voice would need to come first, through direct engagement, before the tool is used and alongside it.

In practice, the application opens on a map of the world. The designer finds their site and draws its boundary, and the tool loads what is already there, including the trees, the plant communities, the animals that live among them, and the dependencies that connect them. The first wall or roof a designer places lands among them, and what it displaces is shown at once, together with the alternatives that remain. The same project can be opened in the standalone application without a Rhino licence, so that a community meeting or a council officer can see the same consequences the designer sees.

Once the building is finished, its record would stay with it. This returns to the Death Manual, the first stage of this project, which designed a building in reverse, starting with its end, then its life, and only then its beginning. A QR code on a building designed with Design Companion would let anyone walking past read what was on the site before, what the design affected and what it gave back, how long its parts are expected to last, and how it can be taken apart at the end of its life. It would also show the building's ecological debt being repaid, with the date by which it will have given back what it took, and whether that date is being met, pushed back or brought forward. Open to everyone and kept up to date, the record would stay with the building for as long as it stands.

Design development and testing

FROM A VERDICT TO VISIBLE HARM

The earliest versions judged a design. In Semester 1 the web prototype returned one of three verdicts, GO, FLAG or REFUSE. In June the tool moved into Rhino. Revit is great

for documentation, but restrictive for free design, and Rhino is the other way around, so Design Companion set out to bridge that gap, keeping the freedom and flexibility of Rhino while giving every wall and assembly the data and documentation of BIM. It was a problem I had myself as a designer. Inside Rhino, the verdict was rebuilt on eleven ecological parameters averaged into one score.

At the mid-semester review, the Leeuwin community vision plan scored –4.36 on a scale from –5 to +5, and was refused. The verdict was clear, but it was a dead end. It told the designer that something was wrong without saying what, or what could be done about it. A single number hid which relationship had broken and for which species, and a strong score in one parameter could quietly cancel the loss of a habitat in another. It also arrived at the end, once the design was already made, and a tool that only says no is a tool designers learn to switch off. Above all, it contradicted the idea of earning, because earning is a process and a verdict is a single moment. The verdict was replaced, gradually, by what the designer can see. Animals trapped by a design are held in floating bubbles that ask for a solution, marks show where an animal strikes a building, assemblies are highlighted with alternatives, and the root systems of planted communities and the links between animals, assemblies and plants are drawn on the model. The score did not disappear; it became visible.

MOVEMENT, SCENARIOS AND LETTING THEM GO

Rhino is a static environment, but ecology moves. In August I built a separate window, the Living Field, where animals roamed their home ranges with flight paths and walking patterns set for each species, and where a fire could run across the site. From it grew a deck of twenty scenarios, ordered the way the Death Manual is ordered, from the end, to the life, to the beginning, among them a heatwave, an extreme high tide, a drought, a value gap and a dieback front. The intention was that running a scenario would reveal a flaw in a building that the designer could then fix. At the mid-semester review the tutors asked whether this was more an animation than a simulation, and they were right, because the fire was scripted, not computed. The Living Field was abandoned in late September, and in October the twenty scenarios were reduced to the three that have data behind them. These are dieback, a soil-borne disease that kills Banksia and jarrah; drought, which Perth's drying climate is making more frequent; and varroa, a parasitic mite that kills honey bee colonies, and with them some of the pollination that plants rely on. The movement stayed, now inside the Studio, the tool's main 3D view. What was left behind was the drama that the data could not support.

FROM HARM TO FIXES

When animals began to strike buildings in the model, crashing into walls, glass and other assemblies, each one was trapped in a red bubble to show that the building had harmed it. At first, each trapped animal could be released with a button. It was satisfying, and it was false, because nothing about the building had changed in order to release it. In October the release button was removed. A trapped animal can now only be released by a design move, a change of material, form or position, or by the designer accepting the loss and recording why. Bird strike on glass is the clearest case. Collisions with buildings kill an estimated 365 to 988 million birds a year in the United States alone (Loss et al. 2014, 8). In Design Companion, a glazed facade that birds strike is highlighted, patterned bird-safe glass is offered, and once it is chosen it is drawn on

the building itself. This is where the veto became a negotiation. The tool shows what a decision costs and which other ways remain open; the designer decides, and the decision stays on the record.

BEING HONEST ABOUT THE DATA

As the plugin grew, it came to hold and index thousands of values for hundreds of species, and I was asked how much of that data could be trusted. An audit of the species data in September found 241 species whose values had been assumed from a default rather than taken from a source for that species, and 23 species wrongly labelled as Western Australian natives. They were corrected, but the audit changed the tool more than the data. Every value in Design Companion now carries one of four labels that say how it is known, whether measured on the site, published for that species, modelled from a rule, or illustrative. A value is only called published when its source describes that species; root traits come from AusTraits (Falster et al. 2021) and mycorrhizal partnerships from FungalRoot (Soudzilovskaia et al. 2020). All the data is cross-referenced, and its links update every time the plugin runs. The count is sobering. Of about 19,800 values, one is measured on site, 3,216 are published and 16,488 are modelled, and 130 still have no data. Design Companion is diagrammatic and will never be exact. Its purpose is to give the designer a felt sense of consequence, an experience of designing with accountability, and to be open about where that sense comes from (Gaver 2012).

MAKING THE ECOLOGICAL CHOICE THE EASY ONE

If the ecological option takes hours longer to model and research, it loses. Garrard et al. (2018) observe that biodiversity-sensitive design practices exist but have been slow to be taken up. Much of the tool's growth answered this. New assemblies were developed and integrated into the tool, growing from 15 in June to 137 by October, each carrying its data, among them 73 green wall systems, stratigraphic and rammed-earth walls, planters, and plant groups that place real species together in minutes. In October the tool also gained a standalone application, so that the same Studio now works with or without Rhino.

ONE BRIEF, THREE WAYS OF WORKING

The final test applies the tool to one brief at Leeuwin Barracks, designed three times. Version A follows the vision plan with little care, clearing the lot and filling the site with a basement car park. Version B is current good practice, with the same basement, planter balconies and native landscaping. Version C is designed with Design Companion, with no basement, and the building lifted on pads around the root zones and stepping down towards the river. The dwellings and the facade stay the same in all three, so the differences come from the process and not from the programme. The comparison is visual. It does not prove that the tool produces better buildings. It shows what each way of working is able to see, and what it leaves out.

Critical reflection

Design Companion has limits, and these limits are part of the project rather than something to hide. The tool does not claim to reproduce an ecosystem with complete accuracy or to predict exactly what will happen when a building is placed on a site. Ecology is too complex, variable and ever-changing for that. The project is a diagrammatic representation of relationships and possible consequences in order to make them visible during design. Its purpose is not to achieve perfection, but to create a different reaction in the designer; an experience of designing with accountability.

This became particularly clear during the development of the Living Field and the scenario system. At the mid-semester review, the question was raised of whether it was more an animation than a simulation, and that criticism was correct. It showed me the difference between communicating a relationship and predicting one. What remained was movement as a way of communicating ecological relationships, while the drama that the data could not support was removed.

The second important limitation concerns the data itself. The audit in September showed that some values had been assumed rather than sourced, and correcting them led to a more important change, with every value in Design Companion now labelled according to how it is known. This does not make the tool completely accurate, but it makes its uncertainty visible.

Making this uncertainty visible is important because the suggestions made by Design Companion are not neutral. The tool is built through choices about what relationships to represent, what to measure and what counts as a risk. In that sense, the tool also carries my own values. Following Gaver (2012), the knowledge produced through making is provisional. The project should therefore be understood as an exploration and a proposition rather than a final ecological authority.

The largest limitation is that the tool has so far been tested mainly by the person who made it. It began as a problem of my own, as a designer with no way of seeing what my moves did to a site while I was still making them, and building Design Companion was a way of bridging that gap for myself first. It has since been tried informally by architecture students and practising architects, but never in a structured test. The next step would be exactly that, a design competition in which participants answer the same brief twice, once with Design Companion and once with Rhino, Revit or a tool of their choice, so that the outcomes can be compared and the tool judged by the work of others rather than my own.

Conclusion

This thesis asked how a building can begin to earn its ecological footprint from the first design move.

The answer it offers is that earning begins when the life of a site is present in the design from the start, and when each move shows what it costs while the design can still change. Design Companion is a response to this question by making ecological information part of a dynamic design process. The tool does not wait until a building is finished to evaluate its consequences. Instead, as the designer moves, changes and

develops the project, the living systems of the site respond. Each design move can reveal relationships, potential damage and alternative ways of proceeding while the design is still changing.

The project therefore shifts ecological responsibility from a final assessment to a continuous negotiation. The designer is not given a single correct answer but is asked to repeatedly consider what each decision affects and what alternatives remain possible. In this sense, a building begins to earn its footprint in the design tool, through decisions made visible as they happen, and keeps earning it, through its record, for as long as it stands.

Design Companion does not claim to produce perfect ecological outcomes. Its contribution is to make the ecological consequences of design dynamic, visible and open to negotiation. This perspective may help bridge the gap between the ecological responsibility architecture seeks to achieve in principle and how each design decision can be actively negotiated with the living systems already present on a site as the design continues to change. In this way, designing becomes an ongoing process of accountability, where a building does not simply occupy a site, but continuously negotiates its place within the life already there.

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