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Design Technologies in Landscape Architecture

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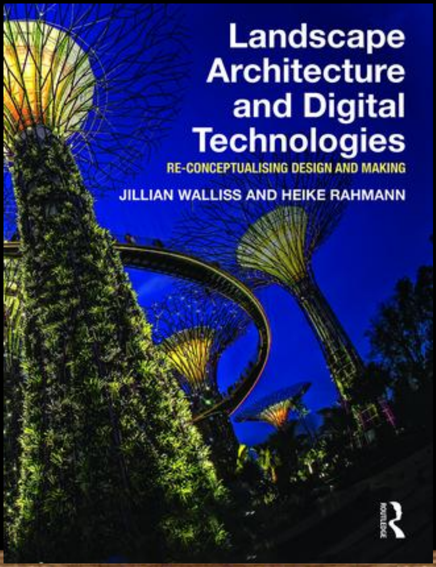
Landscape Architecture and Digital Technologies
RE-CONCEPTUALISING DESIGN AND MAKING
JILLIAN WALLISS AND HEIKE RAHMANN
ROUTLEDGE


BIM
for Landscape
Landscape Institute
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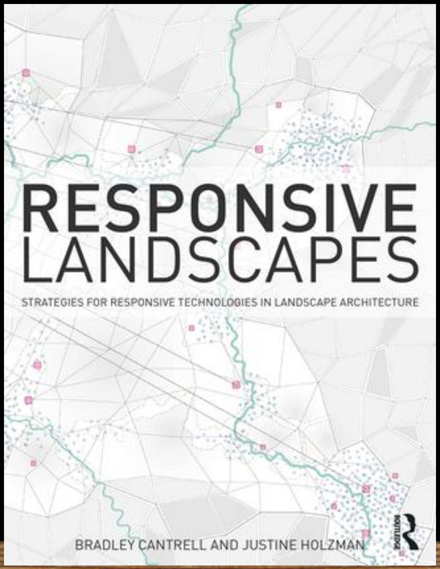
RESPONSIVE LANDSCAPES
STRATEGIES FOR RESPONSIVE TECHNOLOGIES IN LANDSCAPE ARCHITECTURE
BRADLEY CANTRELL AND JUSTINE HOLZMAN
ROUTLEDGE


REPRESENTING LANDSCAPES: DIGITAL
EDITED BY NADIA AMOROSO
FOREWORD BY JAMES CORNER

Introduction

For any questions, please contact:

Grace Harrison, Editor

Umar Masood, Marketing Manager

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New methods of designing, modelling, building and interacting have increased through the advancement of digital technologies across the built environment. With the implementation of Level 2 BIM (Building Information Modelling) earlier this year for all public-sector works in the UK, and to celebrate the release of our collaborative book *BIM for Landscape* with the Landscape Institute, this FreeBook brings together a collection of chapters on using digital tools in landscape architecture. Written by leading experts, the chapters showcase key topics such as fabrication, 3D modelling, responsive technologies and digital tools for BIM. For details of all of the books featured here, and for other related titles, visit our full list of recently published titles at www.routledge.com/landscape.

If you would like to discuss a project you may want to publish, please contact our editor, Grace Harrison.

Chapter 1 – Materiality and Fabrication, taken from 'Landscape Architecture and Digital Technologies'

In this chapter, Jillian Walliss and Heike Rahmann explore the increase, development and challenges of digital fabrication techniques as part of the design and construction processes. Shown through a range of project examples, from large-scale infrastructural projects to a detailed focus on components and systems, this chapter highlights how the use of these technologies within landscape architecture has resulted in greater emphasis being placed on material-led creative and evolved designs.

Jillian Walliss is Senior Lecturer in Landscape Architecture at the University of Melbourne, Australia.

Heike Rahmann is a landscape architect and Lecturer at RMIT University, Australia.

Chapter 2 – Digital Tools, taken from 'BIM for Landscape'

This chapter explains the software and tools which can be used on a BIM project, offering criteria for selecting software, questions to ask and potential issues to consider. It clarifies that, whilst BIM is not software itself, specific software functionality is essential in order to meet the Level 2 BIM standards. Combining these requirements with a practice's strategic objectives, this chapter helps you to identify the right tools you need to begin the BIM transition.

The Landscape Institute is the professional body for landscape architects in the UK.

Chapter 3 – Responsive Technologies, taken from 'Responsive Landscapes'

Authors Bradley Cantrell and Justine Holzman investigate the idea of 'responsive' landscapes in this chapter, which have been traditionally approached from a Human Computer Interface (HCI) perspective, and how they can be used to re-purpose and expand design practices. The chapter follows the evolving methodologies of sensing, processing, visualization and actuation and how these are transforming our perception of different environments.

Bradley Cantrell is an Associate Professor and landscape architect at Harvard Graduate School of Design, USA.

Justine Holzman is a landscape researcher and Adjunct Professor at the University of Tennessee, Knoxville, USA.

Chapter 4 – Sensing Landscapes through Perspectives, taken from 'Representing Landscapes: Digital'

In this chapter, Maria Debije Counts showcases examples of digital student perspective drawings from Pennsylvania State University that highlight how illustrations can be used to inform and develop sensory-based landscape design investigations. Advanced 3D digital modelling tools have enabled the testing of landscape compositions earlier on in the design process, resulting in the ability to quickly shape and edit different perspectives and respond to questions raised. This chapter includes a range of 3D landscape perspective drawings generated using tools such as AutoCAD, Rhinoceros and Photoshop.

Maria Debije Counts is a visiting instructor at Pennsylvania State University, USA.

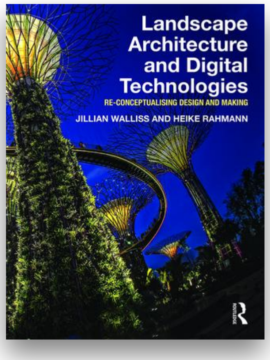
Please note that many references and footnotes have been removed. You can purchase a fully referenced version of each title through our website. Additionally, please be aware that all references to other chapters found within the text relate to the original book the excerpt was sourced from rather than this FreeBook.

CHAPTER

1

Materiality and Fabrication

Chapter 1. Materiality and Fabrication



The following is excerpted from *Landscape Architecture and Digital Technologies: Re-conceptualising design and making* by Jillian Walliss, Heike Rahmann. © 2016 Taylor & Francis Group. All rights reserved.

Learn more: i

Economies of scale and limited budgets often limit the opportunities for bespoke design in landscape architecture. Furniture, engineering infrastructure, paving and lighting are frequently specified from design catalogues, rather than specifically designed and constructed for a project. Advancements in digital fabrication and construction processes however provide new opportunities for exploring materiality and construction techniques, thereby broadening the scope of landscape design practice to feature a stronger commitment to 'making'.

Digital fabrication describes the use of computer-controlled machines as tools to make parts or components during the construction process. Considered a 'sub-category' of Computer-Aided Design (CAD) and Computer-Aided Manufacturing (CAM), digital fabrication has been applied for over 50 years in engineering and industrial design in the manufacturing of products ranging from airplanes and cars to consumer goods.[1]

Within architecture, digital modelling techniques – such as Computer Numerical Control (CNC) milling – have been experimented with since the early 1970s. However, a more committed investment in new fabrication techniques became necessary as the design of complex forms and surfaces began to challenge conventional construction techniques. Gehry Partners and Gehry Technologies have contributed significantly to the advancement of digital fabrication. The design and construction of the Walt Disney Concert Hall in 1989, conceived as the 'first comprehensive use of CAD/CAM'[2] in architecture, signalled an important step in the evolution of architectural manufacturing and construction. As Branko Kolarevic explains as constructability becomes a direct function of computability, the question is no longer whether a particular form is buildable, but what new instruments of practice are needed to take advantage of the opportunities opened up by the digital modes of production.[3]

With its intriguing complex curve structure, the Concert Hall project tested the limits of materiality and constructability by working between digital and physical models developed with CAD/CAM fabrication methods at various stages in the process. Originally conceived as a stone building, these explorations included generating full-scale physical prototypes of the exterior stone walls from digital templates and the milling of the stone surface to test the curvilinear shapes and material breaking points. When it was later decided to construct the building using metal, CAD/CAM processes were employed to solve the sheet components. And in a further ground-breaking development, contractors worked 'out of the same computer model without shop drawings, fabricating their components directly from the computer model'.[4]

Architects now regularly explore a range of fabrication techniques as part of their design and construction processes, with CNC cutting (2D fabrication) one of the most commonly applied. Other techniques include subtraction fabrication where a volume of material is removed from a solid using multi-axis milling, additive fabrication where a material is developed through an incremental layering of material, and formative fabrication where material is reshaped using mechanical forces such as heat and steam. These new techniques are accompanied by a renewed interest in materiality, uncovering new composite materials and working with familiar materials such as concrete and wood in innovative ways, and exploring the mutability of materials where properties change according to conditions. This extends into an investigation of 'biomimicry technology' where designers look to biological precedents for inspiration.[5]

This focus on materiality, fabrication and manufacturing processes has led to what Kolarevic describes as a new emphasis on material-first design processes, re-establishing architecture as a fundamentally material practice.[6] This technology-inspired direction states Kolarevic produces new architectural forms that are '*affecting* in novel ways our perceptions of surface, form, and space through carefully crafted *effects*'.[7]

Fabrication techniques therefore offer landscape architecture far more than an efficient construction process, fundamentally shifting concepts of design generation. Nick Dunn observes that 'this process has facilitated a greater fluidity between design generation, development, and fabrication, than traditional approaches which necessitated a more cumulative, staged process'.[8] Within a digital fabrication process, material testing and prototyping assume an important part of the design process. Further, the ability to make components or objects directly from digital design information, states Dunn, is a major transformative moment for design disciplines,[9] and is captured in the commonly used term 'From File to Fabrication'.

This process is demonstrated in the manufacturing of the steel work for the Supertrees featured in the *Gardens by the Bay* discussed in Chapter 3. The Supertrees were fabricated by Singapore company TTJ Design and Engineering, who applied Tekla BIM software in the development of the general drawings and the connections. The canopy presented a particularly complex geometry (Figure 4.2a), requiring the detailing of interlocking branches as a delicate network of steel tubes, enclosed by a stainless steel cable for structural support. Working with the designers and BIM software (which provided immediate updating of any changes), each tree took just 6 weeks to model, with the engineers claiming that standard CAD modelling would have taken three times longer.[10] Once the general drawings were agreed upon, the software was used to develop shop drawing, which indicated joint design and the position of steel bolts. The fabrication factory worked to these shop drawings, along with 3D models that helped the fabricators to visualise the structure. These structures were preassembled in the factory to check and paint, before being sent to the site for their final assembly, as shown in Figure 4.2b.

Characteristics of landscape architecture such as scale and unpredictable site conditions can make it more challenging to engage with fabrication. For example the flowing surfaces of LAAC's *Landhausplatz* introduced in Chapter 1 were fabricated in situ. The final geometry of the scheme could not be established until the removal of all the existing paving from the site, which occurred late in the documentation process.[11] Consequently the use of precast concrete would have extended the construction schedule. Instead the smooth topographic surface was constructed from concrete panels fabricated on site using a B7 concrete mix. A timber template set out with surveyor precision, shown in Figure 4.3a and 4.3b, was used to define the precise geometries. The surface was constructed over a layer of foam glass gravel which was covered in a 15 – 20 cm of quick-setting concrete which was then grooved and polished.[12] A mix of black, yellow and white granite chips was mixed into the concrete to develop a more dynamic finish to the surface, as shown in Figure 4.3c.

Despite these challenges, there are many aspects of digital fabrication that are of significant value to landscape architecture. This chapter explores this potential, beginning with the construction of the large-scale infrastructural projects, such as the *Victorian Desalination Plant* and *Max Lab IV* projects, introduced in Chapter 1. Both schemes were conceived and designed using parametric models. As we will explain in more detail, the construction phase can be considered a 'paperless process' with the digital models offering the data necessary to directly inform the construction machinery.

Towards a paperless construction process

Undoubtedly one of the greatest advantages of working with digital terrain models in landscape architecture reveals itself in the delivery of projects that involve a significant proportion of earthworks. Economic and environmental considerations increasingly require the balancing of cut-and-fill volumes while simultaneously demanding high-quality design outcomes. Precision, productivity and effective site management and coordination prove to be vital in delivering complex topographic landform within increasingly tighter time-frames. This heightens the need for landscape architects to operate in 3D terrain models informed, as Peter Petschek suggests by 'new developments in surveying and visualization' that 'affect how we receive data and visualize terrain in Landscape Architecture'.[13]

ASPECT Studios' design for the *Victorian Desalination Plant*, as well as Snøhetta's proposal for *Max Lab IV* would not have been achievable through conventional design and construction processes, instead relying on precise digital terrain models as well as new construction technologies. Developments in the construction industry have focused on introducing more time – and subsequently– cost-efficient technology which has its origins in the large earth moving practices associated with the mining industry. Whereas conventional earthwork construction relied on time-consuming processes that involved staking out the terrain on site to mark reference heights for the proposed landforms, bulldozers are now able to directly embed 3D design models into the machine's system, reducing the need for paper-based documentation. Peter Petschek suggests that these stakeless grading processes could achieve cost savings of up to 15–20 per cent.[14]

For example, the overall scope and complexity of the Desalination project provided enormous challenges for all stakeholders involved in the project's design and construction. In addition, the project was extremely fast paced, a factor of financial constraints and the project's political significance. The expanded role for the landscape architects was also achieved with financial efficiency gained by working with the digital model. First, the major topographic forms emerge from the need to maintain the huge amount of fill generated from the excavation on site. Second, the iterative design generation process facilitated by 3D modelling was time efficient with far more exploration and iterations than in other more orthodox design processes. According to ASPECT Studios, these iterations were produced in less than 20 per cent of the time required using more conventional representation techniques. Third, this speed in working with landform translated right through to the construction process. The landscape digital model was fed into the consolidated engineering model, which was then send to surveyors in Brisbane to convert the files into formats, readable by the bulldozers.

Stakeless grading

Effectively, the incorporation of satellite positioning and 3D digital models into earthwork construction processes recasts the entire design and construction procedure into a monumental example of 'file to fabrication'. Simple machine- controlled systems provide small monitors to visually reference and navigate between existing and proposed terrain, more advanced systems control the positioning of the blade via GPS and robotic total stations located on-site. Increasingly important in large-scale infrastructural and landscape projects with significant earthworks are GPS-directed machines, which enable the machine operator to reference their location on the site plan in real time while simultaneously controlling cut-and-fill volumes to the highest level of accuracy.

Bulldozers used in the Desalination project were fully automated without the assistance of grade foremen, meaning that no manual input was required to control the blade's position and machine location on-site. Simultaneously, the dozers recorded the new profile, subsequently allowing the surveyor to check the proposed landform against the existing profile without referring to 2D plans. Although 2D drawings were initially produced by the engineers to check the design, the new technologies provided a far more reliable control systems. Melvyn Leong from the engineering firm Thiess in charge of constructing the Desalination project notes 'nobody looks at drawings anymore'.[15]

The *Max Lab IV* project was constructed using similar technologies. Working with PEAB, one of the leading construction and engineering companies in Scandinavia, enabled Snøhetta to utilise the latest technology and to program their terrain data directly into the bulldozers. The real-time GPS positioning also allowed the adoption of a more effective in-situ construction process instead of temporarily storing excavated soil for later application. Thus, cut-and-fill procedures occurred in one-move operations meaning the waved landscape could be constructed simultaneously to the excavation of the building foundation.

Due to this process, almost 60 per cent of landscape was completed only 4 months after commencing the construction, allowing the design and construction team to achieve the design within the tight time-frame. More importantly, this digital design and construction practice proved to be the biggest cost-saver on the project, effectively allowing the landscape architects to 'buy' acknowledgement from clients, who before the project did not pay much attention to landscape values.

Strong competition and demands for ever increasing productivity drives further developments in construction technology. In 2015, Japan's largest manufacturer of heavy construction equipment, Komatsu, announced its newest investment in technology that will mark the next step towards fully automated construction processes.[16] Driven by Japan's declining population, leading to labour and skill shortage in the surveying and construction industries, Komatsu has started to reposition its business focus from heavy to soft machinery, investing in new drone technology. The drones will focus on site surveying using sensors and cameras to produce high-precision 3D point cloud data, thereby shortening the surveying process from multiple days to a few hours. This data can be overlayed with proposed terrain models directly into the dozer's computer. Ultimately, the drones should be able to control the entire grading process including navigating blade position, profile checks and machine movement, giving rise to unmanned construction machines. Komatsu predicts that the first drones and fully automated dozers will be in use on construction sites for the 2020 Olympic Games in Tokyo.

Similar to the influence of fabrication technologies on the architectural profession, these advancements in earthwork construction should expand both the client and the landscape architect's ambitions for the design potential of landform. While these construction techniques are presently associated with large-scale infrastructural projects, their future application will extend into smaller site works as technology continues to become more affordable and accessible.

In the following discussion we move from large-scale landform to a more detailed focus on the materiality and fabrication of landscape components and systems.

View Figure 4.4a and 4.4b; The Victorian Desalination Plant posed challenges to coordinate the complex site and the construction process.

View Grading process and earth work construction for the MaxLab IV project;

Figure 4.5a - GPS controlled bulldozer

Figure 4.5b - Real-time control of profile levels

Figure 4.5c - During construction August 2011

Figure 4.5d - Completed landforms February 2012

Material behaviour

Landscape architects are increasingly interested in a 'material-first' design practice where the consideration of material behaviour and fabrication techniques are given more prominence at the beginning of design processes.[17] Of particular interest is the design of infrastructural components such as geo-textiles and geo-cells that control runoff, sedimentation and erosion processes and have conventionally been associated with engineering.

A focus on performance combined with parametric modelling and fabrication technologies expands the scope of landscape architecture design to encompass the materiality of surface, the fabrication of systems and the innovative uses of stone, concrete and timber. As the following three examples will demonstrate, these design processes emphasise the testing of material behaviour and performance through a mix of physical and digital prototyping. They also highlight how fabrication technologies alter the relationships between the designer and contractor and offer more efficient manufacturing techniques that encourage customised approaches to design detailing.

Fabricating surface

In his 2013 seminar subject Surface FX, Brian Osborn interrogated the potential of CAD/CAM techniques in the design and fabrication of landscape surfaces. The seminar, which formed part of the Landscape Architecture program at the University of Virginia, focused on 'the dynamic boundary between the ground and human inhabitation' as expressed in erosion control systems, drainage structures, paving and retaining walls. These surfaces state Osborn 'have the unique capacity to simultaneously influence biologic process and sensory experience (effect + affect)'.[18]

Importantly, the seminar emphasises material behaviour rather than material properties (with the later placing emphasis on questions of durability and strength). Instead a focus on behaviour encourages the exploration of the 'tendencies of material' in relationship to dynamic environmental conditions and processes including the consideration of 'emergent happenings' such as transmission, erosion and failure.[19] Chris Woods's project *LAG* demonstrates how an exploration of material behaviour considered against temperature fluctuation can inspire novel form making. Working with concrete, Woods examined how the thermal mass of concrete responded to temperature change, with these principles applied in the design and fabrication of a concrete seat.

The design intent was not to produce a homogeneous condition but to instead manipulate the thermal mass to create varied conditions through temperature. Beginning with a solid form, Wood subtracted material to create 'a gradient of voided space'.[20] A one-third-scaled prototype was constructed using high performance ductal concrete and CNC fabrication, as shown in Figure 4.6a. Testing in different conditions recorded through thermal imaging highlighted temperature variance of up to 10 degrees.[21] The final form was fabricated and features a 'slow' and 'fast' end. The fast end responds quickly to changes in temperature, for instance warming quickly on a cool morning, while the more substantial massing of the slow end maintains temperatures for longer. In a further detail, the thermal coefficient of the thin concrete edge was increased through the addition of metal aggregates.

View Figure 4.7a-b. The final form of the concrete seat incorporated knowledge gained from testing the material behaviour of concrete and features a 'slow' and 'fast' end.

Osborn's ongoing research project *Tech Mat* (Temporary Erosion Control Mat) builds on the agendas of Surface FX to explore the potential of paper in controlling erosion on sloping sites.[22] Beginning with convex and concave shapes, Osborn explored how these geometries influence processes of erosion and deposition over sloping sites. A complex pattern comprising concave and convex forms proved valuable in producing a series of small terraces that balanced and stabilised soil and water movement (Figure 4.8). These explorations provided the principles for a more refined form, which evolved into a folded surface that could be flat-packed for ease of transportation and site installation. Material testing of paper explored its ability to absorb water and to support plant material while slowly degrading. *Tech Mat* prototypes were constructed and tested on an 80 per cent slope with the results incorporated into a larger-scale version, which further evolved through detailed consideration of suitable planting materials (Figure 4.8d).

A final prototype emerged as 'a single, highly articulated surface, capable of modulating a range of environmental effects over time'.[23] The structural form of the paper-based geo-textile interacts with the dynamic processes of erosion and deposition to produce terrace structures, while the degradable qualities of the paper encourages the embedded mineral additives and plant seeds to drop into the trapped soil. Over time the plants will replace the eroding structural strength of the paper to stabilise the slopes and slow water runoff, contributing, what Osborn hopes are 'aesthetically satisfying forms and memorable places for human habitation'.[24]

This 'material first' design process produces an innovative response to erosion control which is conventionally solved with minimal consideration of aesthetics, materiality or ecology. Osborn's focus on the materiality and performance of landscape surfaces is equally shared by the design practice of PEG office of landscape + architecture who we first introduced in Chapter 2. As we discussed previously, PEG are interested in the manner in which pattern through geometric repetition or temporal re-occurrence can register, guide and convey site processes.

PEG argue that the capacity of geometry to articulate site functions such as water flow or plant growth make pattern a valuable strategy for extending engineering solutions beyond conventional approaches.[25]

PEG has been exploring the potential of these concepts in the development of new approaches for maintaining the extensive number of vacant sites (over 60,000) found across Philadelphia. So far, a Neighbourhood Transformation initiative, which began in 2002 has cleaned over 3000 vacant lots. Adopting a 'greening' strategy', this program removes rubbish, regrades the sites, establishes lawn and trees and reinstates a picket fence around the vacant site's perimeter. PEG is interested in developing an alternative approach which 'achieves the same aesthetics of care but provides more expressive diversity with lower maintenance'.[26]

Similar to Osborn, PEG explores the potential of customising geo-textiles for constructing new strategies of surface control. In a distinguishing feature, PEG's design response registers the relationship between organic and inorganic material on the ground surface through the application of pattern which they argue is particularly useful in working with the phenomena of vacancy.[27]

This philosophy informs their design concept for the *Not Garden* (and in a further iteration *Not Again*) which offers a contemporary interpretation of the geometric patterns of the historic knot garden. Working with parametric software and laser-cut fabrication, a series of repetitive patterns shown in Figure 4.9a were cut from geo-textile material. This material was then laid onto the regraded surface of the vacant site. Over time, plants grow around the patterns, which as illustrated in Figure 4.9(d), remain legible. PEG has explored this approach with a variety of intricate patterns and planting material ranging from turf to flowering drought tolerant ground cover. As an alternative weed control measure, achieved with minimal maintenance, the registering of the pattern on the lot's surface contributes to an 'aesthetic of care'.[28]

These concepts are further employed in the project *Edaphic Effects* that focuses on issues of water infiltration and the design potential of customised geo-cells. During rain events over 16 billion gallons of raw sewerage currently flows into Philadelphia's rivers and streams. Encouraging on-site water infiltration and retention on the extensive vacant sites forms an important strategy for addressing the issue. PEG's *Incremental Infrastructure* project, funded by a 2011 Boston Society of Architects research grant uses 'customized substrates' and new configurations for geo-cells to propose innovative responses to on-site storm water collection.[29]

Conventionally, geo-cells are geometrically uniform 3D structures filled with plants, soils or gravel that are laid within surfaces to encourage water infiltration. PEG maintained the infiltration characteristics of the cell, while developing alternative shapes that accommodate a greater variety of pattern. These new patterns emerged through parametric modelling shown in Figure 4.10(b), which allowed the designers to explore existing and new water flows. Prototypes were then developed, using petroleum-based plastics (commonly applied in the manufacturing of geo-cells) and compostable corn-based plastics, which are currently limited to use in the packaging industry.[30] These customised geo-cells were then installed on-site to test their effectiveness for drainage, as well as design effect.

The design and fabrication processes shared by Osborn and PEG reveal the expanded scope for design and making in landscape architecture as it begins to explore the potential of digital technologies and fabrication, while simultaneously interrogating material behaviour, biologic process and sensory experience. In the following example we introduce the design practice of Marco Poletto and Claudia Pasquero who are directors of ecoLogicStudio. Their research-driven practice explores the relationship between computational design and an urbanism inclusive of ecological systems, by incorporating ecological processes into fabrication techniques and prototyping.

Fabricating systems

Aiming to 'embed technology into material organizations that become part of everyday ecological practices',[31] ecoLogicStudio seek to intensify and cultivate biodiversity. Drawing similarities with the research-driven design practice of landscape architect and philosopher Gilles Clément, they state:

> The formalization of the garden becomes for Clément a process of formalised transmission of biological messages or, in our terms, of algorithmic coding; algorithms are for the gardener machines for breeding biodiversity.[32]

Prototyping and fabrication are central to their practice. These models says Poletto are not representational but instead operate as 'machines that compute occupations and patterns within a non-homogeneous surface'.[33] They help to 'solve spatial problems in relationship to urban or environmental forces', with feedback loops 'offering mechanism of self-regulation' allowing an understanding of how systems evolve and change.[34] This design philosophy is evident in ecoLogicStudio's explorations of algae.

Their interest in algae was triggered in 2006 by an encounter with a local botanist in London's Victoria Park where algae was slowly colonising the park's ponds.[35] This formed a catalyst for *ecoMachines*, a prototype that interrogated the highly efficient machine-like qualities of algae. Initial experiments modified architectural components in order to host algae colonies. This 'choreo- graphing of biological systems' within the prototypes highlighted new 'potentials for evolution and interaction, both within the environment and with an excited public'.[36] EcoLogicStudio has subsequently explored hybridities of form and algae systems across a range of scales.

The *Simrishamn Regional Algae farm* (2011), commissioned by the local municipality near the Swedish Baltic Sea, proposed a new economic–urban system for an ageing population.[37] The potential of algae as a source of renewable energy was used to draw local farmers, residents and fisherman into a collaborative plan of action. This master plan was conceived as a participatory interface, mixing top-down investment strategies with bottom-up community involvement.[38] Strategies outlined in Figure 4.11a include filtering gardens, an underwater museum, high-tech algae farming infrastructure, greenhouses and migrotowers. Architectural prototypes were conceived for different sites. The *Hanging Algae Garden* offered an 'interactive public space of cultivation' positioned between the Simrishamn Marine Centre, the Tourist Office and the port. Comprising the seven most common algae species within the region, the public contributed to the garden's cultivation by blowing carbon dioxide into the photo-bioreactor bags. Hand-held magnifying glasses allowed the visitor to observe the micro and macro algae. The *Hanging Algae Garden* was presented as part of an exhibition, featuring a floor map and tourist map documenting the regionally distinctive algae, prototype speculations and an algae-based gourmet lunch finale.

EcoLogicStudio's installation *Hortis Paris* (2013) exhibited at the EDF foundation, Paris as part of the Alive Exhibition, featured a full-scale working model shown in Figure 4.12 of a 'man-made eco-system'. Working with flows of energy (light radiation) and matter (biomass and carbon dioxide), the prototype showcased processes of self-organisation and self-regulation. Visitors participated in the farming processes, and were invited to influence the system's growth through an air pump system within the photo bioreactors which modified nutrient content (Figure 4.13). Embedded sensing technologies provided data to a virtual interface accessible by smart phones, encouraging participants across the globe to send tweets to 'nurture the virtual plots'. EcoLogicStudio describe this interaction as 'a computer generated sedimentation process', with the visitors both physical and virtual conceived as cyber gardeners.[39]

Their most recent project *Urban Algae Canopy* shifts their algae explorations from exhibition to urban structure. The canopy forms part of the *Future Food District Project* curated by Carlo Ratti for the Expo Milano 2015.[40] The development of the structure shown in Figure 4.14 continues the themes of technology, biological systems and interaction evident in earlier projects to present a 'bio-digital canopy integrating micro-algal cultures and real-time digital cultivation protocols on a unique architectural system'.[41]

Increased solar access influences algae growth, thereby altering the transparency of the canopy. Similarly to the *Hortis Paris* installation, the visitor interacts with carbon dioxide levels, further manipulating the shading and transparency of the canopy. Pasquero comments: 'In this prototype the boundaries between the material, spatial and technological dimensions have been carefully articulated to achieve efficiency, resilience and beauty.'[42] CNC welding technology creates flexibility within the morphology of the canopy, allowing control over water behaviour and thereby creating a further responsive relationship between water and algae. The canopy is envisaged to produce up to 150kg of biomass daily (60 per cent of which are natural vegetal proteins) while releasing oxygen equivalent to that produced by 4 hectares of forest.[43]

Poletto observes that many design projects that claim to be performative are actually produced in a linear and predictable manner. Often, a computational approach leads to an early separation of design from the forces and systems of the external world. In contrast, their design processes rely on physical and digital prototypes, positioning design within 'interrogative open models' that facilitate 'way of thinking about behaviours'.[44] The prototypes operate as material and system explorations that are not necessarily scalable, instead requiring multiple processes to construct new hierarchies and configurations reflective of different scales of interventions.

EcoLogicStudio highlight the contribution of the Valldaura Self-Sufficient Lab (developed by the Institute for Advanced Architecture of Catalonia) in advancing the application of technology guided by ecological principles. The research centre applies knowledge gained from ecological processes and resource management to explore self-sustainable design options that address the challenges of the twenty- first-century city. A 'green fab lab' works with natural resources including minerals, earth and wood in a combination of high technology and ancestral processes, a 'food lab' interrogates food production processes encompassing growth, human consumption and waste management including technologies for large-scale and small-scale production, while the entire Valldaura development operates as a 'energy lab' ensuring efficient management of power and water.[45]

We conclude our discussion of fabrication with a detailed exploration of the innovative design and construction processes necessary in the realisation of the *Diana, Princess of Wales Memorial*. Most landscape architects are familiar with the evocative clay model that formed the starting point for Gustafson Porter's winning scheme. Few are aware of the innovative design and fabrication processes that allowed the hard granite 'necklace' to be manufactured in just 26 weeks.

The making of the *Diane, Princess of Wales Memorial*

At the time of winning the design competition in the summer of 2002, Gustafson Porter knew the major challenge was to identify how to construct the stone memorial, the major component of the design. With 9 months allocated to design, and a year for construction, Gustafson Porter initially employed designers experienced in Rhino. They soon realised this 3D modelling package would not provide the complex information needed for manufacture, so they turned to the automotive car industry, the Ford motor company, for help. This decision was the beginning of a ground-breaking design and fabrication process, which to date has received minimal attention in landscape architecture. What follows is a detailed description of this process, which should be read in conjunction with the diagram shown in Figure 4.15, which visually documents the innovative construction process and complex workflows.

The first stage of design development involved taking a rubber mould of the clay model (prepared for the competition), which was then used to produce a cast that could be digitally scanned. A highly accurate GOM scanner, commonly used in the automotive and aerospace industry, produced a detailed 3D point cloud of the cast. GOM (Gesellschaft für Optische Messtechnik), established in 1990 specialises in optical measuring products and processes such as 3D digitising, 3D coordinate measurements, deformation measurements and quality control.[46] This was the first time this software had been used for architectural purposes.[47]

SurfDev (Surface Development and Engineering), a design and 3D scanning bureau with expertise in developing accurate freeform shapes for manufacture were then commissioned to further develop the 3D model. The scan was trans- formed into a surface mesh CAD model (using the Uniserf program) that became known as the jelly mould (a term used in the automotive industry for the basic form of a car prior to detail design). In a parallel process, Gustafson Porter developed sections at 1:100 exploring the human height and scale of the memorial. SurfDev and Neil Porter met weekly, working between the sections and the digital model, with the final digital model emerging after 9 weeks.[48]

The basic profile of the memorial was envisaged as two edges, containing a middle section of textured blocks. Adopting this form, the smooth jelly mould was broken into a 3D puzzle of 549 separate blocks (with a 5mm gap), detailing the shape and location of each stone. The model produced the shape of the stones as they intersected with the ground plane, providing the Arup engineers with enough information to produce an underside stepped foundation and devise the water drainage.

Envisaging the stone textures was a more challenging process, requiring the expertise of Texxus Ltd. Founded in 2002 by industrial designer John Gould, Texxus specialises in the production of textured surfaces. In 1999 Gould noticed that designers had no means of generating the texture they wanted for a product on a screen.[49] Working with software sources from the car industry, John devised techniques for simulating a 3D surface pattern onto a 3D form. Fortunately, Neil Porter had worked with John during his architecture degree. In a chance encounter, Neil Porter's appearance on TV reconnected him with his former employer, and the dilemma of how to texture the stone was solved.

Working with the representation of Princess Diana's life through the metaphor of water, Gould and Porter developed textures of water conditions moving from mountain brook through rapids into gentler waters. Textures, abstracted from photo- graphs, were explored within Photoshop, followed by 3ds Max, where forms were repeated and extruded into depths of up to 50mm.

The individual block configurations developed from the jelly mould formed the base for Texxus to accurately place and align the digital textures. Two types of prototypes were developed concurrently. The first involved working with the Vero Software company, a leader in developing and distributing CAD/CAM software for design and manufacturing processes for stone and wood working, metal fabrication, tooling and production engineering. Using software developed only 6 months prior, Vero digitally prototyped the texturing of the stone. This tool path analysis (applied to granite for the first time), allowed for the visualising of the finished block, and importantly, provided an indication of machining time, thereby informing decisions on efficiency and how much detail to include in the textures. For example close inspection of the textured stones reveals small ridges, which aided in faster stone cutting (as distinct from a smooth finish), and also resulted in a less slippery surface.

The second prototype tested the effects of adding water into the memorial. Most of the water is fed in at the highest part of the memorial and flows down through the different textures. However, at certain moments water is added into the system, to produce very particular effects such as the section known as 'the champagne bubbles'. Working with Professor Peter Davis at Imperial College, a hydraulic engineer, Gustafson Porter and SurfDev produced a half-scale 3D CAD model (produced in hard foam) to test the relationship between location of water nozzles, water pressure, textures and effects. This testing occurred at laboratories at Imperial Collage, London and Davis's Somerset workshops.

Finding suitable stone and stonemasons presented a further challenge, with the expectation that British stone and British technology should be used to construct a memorial to a British princess. After much research to find a light- coloured stone that would sit happily in its historic landscape context, the extremely hard silver-grey De Lank granite from Cornwall was selected, along with Northern Island stonemasons McConnell and Sons.

McConnell and Sons had previous experience working with scanned regular shapes from physical models to produce matching pieces of stones.[50] However, this construction process would require their machinery to read detailed textures from a digital file.

Their OMAG S.rL. CNC production centre was reprogrammed to handle digital files. Two types of digital files were sent to the stonemasons: 549 separate files describing the shape of the blocks (the file size was small enough to be emailed), and the more complex texture files which were sent on disc. The extremely hard granite required heavy-duty equipment and tooling, with the first piece of granite wearing out the first tool after cutting just one section of stone.[51] It became clear that the OMAG could not produce the work alone, with the quarry purchasing two Terzago Macchine S.r.L saws. Vero International Software developed CNC software, hooking the circular saws up to Vero Software for the first time.[52] The saws were used to remove the bulk of the stone. To save time and energy, only half of the stone was sawn, with a sledgehammer then used to break the stone apart, ready for the finer tooling. Manufacturing started at the end of June 2003, with the quarry in full production by the end of August. Three machines operated at a minimum of 100 hours a week, with manpower of 21 hours a day.[53]

Three shapes of finer-cutting tools were used: the saw, the bull tool and the flat-bottom tool. The hard granite continued to prove challenging, quickly wearing down diamond studded foster bronze tools. The texturing and the cutting of the stone worked in parallel with the finalisation of the digital texture files. Construction of the memorial began before the completion of the stone fabrication. Working with an accuracy of +/− 0.5mm, the completed stone blocks could be laid in sections, confident that the precision of the manufacturing process would create a final seamless finish.

The stone was 100 per cent machined, with a dolly-punch finish to the kerb, the only part of the process completed by hand-held pneumatic tools. In just 26 weeks, 520 tons of De Lank granite were cut into 549 stones.

Significantly, the manufacturing route dramatically revised the workflow of design and construction, allowing the designers (Gould, Gustafson Porter, SurfDev) to work directly with the quarry. Conventionally, a project contractor and a stone contractor would have been positioned between the designers and the quarry. For example the stone contractor would go to the quarry and purchase the stone and issue it back to the stonemasons. A more direct process not only aided accuracy, but also allowed for a far more efficient design development and construction process.

The designers and contractors all benefited from the technical knowledge gained from working on the project. While McConnell and Sons had to invest extensively in new equipment and software to complete the job, the experience developed their future capability to work on the most sophisticated stone work.[54] John Gould went on to develop other architectural stone projects such as the V&A courtyard. For Gustafson Porter, the experience confirmed the importance of landscape architects working with 3D digital models, encouraging them to employ recent graduates with digital expertise.[55] The firm became more confident in manipulating space and form on larger scales, as demonstrated in later work on phase two of *Gardens by the Bay*, Singapore.

Designed for a 200-year lifespan, the *Diana, Princess of Wales Memorial* is one of the most visited free tourist attractions in London. For landscape architecture it represents a critical precedent featuring an innovative fabrication process and manufacturing route. As John Gould concludes 'History was made when the entire structure was machined using three and five axis disc saws and milling machines directly from 3D CAD files.'56 The extraordinary stone finishes achieved in the completed memorial fountain shown in Figure 4.16, provide clear evidence that the fabrication process did not diminish the poetics of the design. Instead the digitally driven process was essential to realising the design ambition expressed in Gustafson Porter's original competition entry.

Conclusion

Digital technologies encourage seamless and sophisticated workflow processes, bridging the gap between design and making in unprecedented ways. This presents multiple opportunities to expand the creative potential of landscape architectural practice, encouraging more comprehensive form and material explorations beyond predictable or of-the-shelf solutions.

The ability to translate designs directly from 3D digital systems into physical installation without depending on 2D abstraction, so called 'file to fabrication', opens new avenues for more efficient, automated production processes. Advancements in the engineering industries together with the development of a new generation of high-tech construction machineries, support the design and construction of complex earthworks in an extremely time and cost-efficient manner with increasing precision. These developments also facilitate a stronger appreciation of the value of landscape architecture as established in relationship to Snøhetta's *MaxLab IV* project.

Driven by a material-first design approach, digital fabrication also signals a shift in the way landscape architecture design is conceived, emphasising digital and physical prototyping to test material performance (effects and affects) and constructability. This process encourages the exploration of components as well as ecological and material systems to develop customised design solutions, where the form is no longer compromised by limited consideration of materiality or traditional construction operations. The exciting potential of a material-first approach is clearly reflected in the design qualities achieved in the *Diana, Princess of Wales Memorial* which could simply not be achieved without CAD/CAM processes.

These new workflow models are built on changing roles and responsibilities of designers and contractors, drawing on highly specialised knowledge and skills of manufacturers – often not even associated with the landscape profession – early in the design exploration and considerations of constructability. This rapidly shifting design and construction practice is evidence of an expanded collaborative environment driven by the potential of digital technologies which we explore further in our final chapter which introduces Building Information Modelling.

CHAPTER

2

Digital Tools

Chapter 2. Digital Tools

The following is excerpted from *BIM for Landscape* by Landscape Institute.

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Introduction

This chapter starts by looking at the distinguishing features of software suitable for use on a BIM project. BIM is not software, and there is no out-of-the box, one- size-fits all BIM software solution; however, some specific software functionality is required to meet BIM Level 2 standards. After looking at the technological requirements, some criteria for selecting software are discussed. Questions to ask and issues to consider are suggested, both within a practice and in discussions with software providers and resellers, aiming to help IT managers and decision-makers identify packages that meet their strategic and business needs, from BIM authoring and design to cost management. This decision-making process starts with a look at a practice's strategic objectives, the requirements of BIM, and the common ground between them.

What software is suitable for use in a BIM project?

Two fundamental principles determine whether software is suitable for use in a BIM project: object-based design and information exchange. BIM processes are based on these key software functionalities. Object-based design connects information describing an object with the geometry by which it is visually and spatially defined. Information exchange, or interoperability, is the capacity to work with and share information with other software packages, without any loss or change to the information.

Parametric functionality is also key to BIM processes, in which a change made to one aspect of an object is cascaded to every view of that object, allowing greater control over the form of objects and their associated information. There are many parametric software solutions, and many drafting packages allow the use of parameters. The questions to ask are 'Will changes automatically apply to every instance or type of object?' and 'If an object is changed, will the specification also be updated?' In other words, to what extent does the software link the representation of objects with the information that describes them?

Software used as part of a BIM process has some other specific characteristics. First, it is intelligent, in the sense of an interaction between an object and the data defining it – for instance, allowing the modelling of a tree's growth over time and its interdependence with other trees. Intelligent software can also set rules to be applied automatically on the implementation of a design, giving the designer a warning if constraints are broken during the design process.

A second key software characteristic is enabling simulation and the creation of 3D models; furthermore, the designer is able to work with objects with their own attributes to create virtual models. This combination of graphics and information is vital to producing a virtual asset that can be used throughout the project's life cycle. Simulation allows the modelling of some critical features, such as climate, heat and movement. It can enable rapid calculations and better-informed decision-making. Software used in BIM is moving towards virtual design that accurately represents a physical site, and 3D models are often envisaged as the ultimate BIM tool. Modelling objects with their own attributes means that when one type of object is changed, every instance of that object will also be changed accordingly. The quantity of data that can accompany objects means that the range of design and analysis functions available is constantly expanding, serving to deliver the principles and aspirations of BIM still further.

The underlying technology within software tools determines their effectiveness in a collaborative project environment. Database functionality requires that objects are classified in a database, which should be arranged semantically to allow queries to be run. Uniclass 2015 is the classification system required for BIM Level 2, but there are a number of other classification systems in use across the construction industry. Information management functionality should allow the syntactic and semantic association of objects and the interoperability in information exchanges between other packages and users, as well as internally.

'Uses of BIM' software capabilities

The 'uses of BIM' concept (Kreider and Messner, 2013) offers a helpful perspective on how software may be used in BIM projects, categorising operations by function under the headings of gather, generate, analyse, communicate and realise. This classification of aspects of a BIM-enabled workflow highlights the role of technology within the design of built environment projects; a package that creates a 3D model from a point cloud survey can be part of a BIM process as much as a digital tool for creating planting schemes, or performing cost calculations.

Gather

Gathering is the capture of information about a facility or landscape, which allows the measurement and identification of objects and enables the management of the BIM process. Software processes that can collate and interpret surveying data are one example of the gathering functionality. For example, a project team that has gathered information about a proposed development can do an early quantity take-off, enabling cost management processes to begin sooner.

Generate

Generating refers to placing specific elements into a design, from plotting general features such as topography to individual objects such as street furniture and planting (Figure 16.1). This process includes defining objects and their position, as well as specific details such as performance requirements. Objects are generated at a specific Level of Detail and for a specific phase of the project; for example, the placement of planting or hard works within the landscape.

Analyse

An exciting aspect of BIM analysis is the ability to predict an asset's performance in use, before construction actually begins. This can show how a design will be used or how it will work within its environment in many ways; for example, water flow as run-off and within piped runs, slope analysis, aspect analysis, hill shade analysis, Zones of Visual Influence, sun and shade analysis, rainwater collection volumes, parking capacity, crowd simulation or vehicle simulation. Understanding climatic factors and usage of the site in the design stages helps ensure that designs are fit for purpose, although it is important to remember that analysis offers likely scenarios not certainties. These types of analysis can help the employer's team and future users of the site to understand an asset's design better, and facilitates more useful feedback throughout the development process. Analysis can also show whether a design is proceeding correctly, and identify clashes within designs.

Communicate

The communication functionality of software in BIM projects means that every stakeholder in a project who needs information can access it. Information exchange is fundamental to BIM and facilitates many of its other functions. For instance, generating visualisations, whether static, animated or interactive, provides a realistic representation of the asset and enables the employer to assess or demonstrate its intended use (Figure 16.2). Software can also generate images to display data visually.

Realise

Realisation refers to the physical creation of an asset and the various elements that make up the whole. Software can provide the necessary information in the right format to the correct standard to enable off-site fabrication or the on-site assembly of design components or systems, for instance, as well as clash detection. It also allows construction tasks to be streamlined, such as scheduling contractors' work on site for the smoothest operation.

Software tools for landscape

These categories of BIM capability are applied in this section to software that is commonly used in landscape practice, along with some BIM-specific tools, identifying functionalities required for landscape BIM projects.

Landscape architecture software

Landscape-specific software provides the landscape practitioner with the tools to design planting schemes and hard works, including the specification of materials and positioning of objects. The ability to apply simulations can demonstrate how plants and trees develop over time, for example, and 3D representations can demonstrate the design intent. The requirement to produce traditional 2D project documents within BIM Level 2 projects is met by these packages. Landscape tools also need to meet supply chain information requirements, including the capability to use manufacturers' or suppliers' information, as well as providing relevant information in a usable format for contractors and landscape managers (Figure 16.3).

Geographic Information Systems (GIS)

GIS is primarily an analysis tool, providing the facility to apply customised algorithms to multiple spatial datasets, which can be used for site context analysis, and as part of wider masterplanning and regional development strategies. It can be used at regional level to monitor the impact of development, or bring together a number of developments within an asset portfolio. At site scale GIS can monitor how the site is used and responds to its environment over time. This can provide insights into site performance and enable the identification of changes or enhancements to allow for different conditions on site, such as management of areas prone to flooding, for instance. Although traditionally a 2D package, GIS is increasingly able to incorporate 3D model information and combine geographic datasets with BIM information and imagery to enable visualisation.

Geodesign tools

Geodesign tools can generate masterplans at site and super-site scale to develop options and analyse them against a site's context. The ability to prescribe the size, materiality and location of proposed development types within a landscape context gives geodesign tools an extra dimension to GIS. For example, placing 3D realistic wind turbines in the landscape for the purposes of a Zone of Theoretical Visibility enables a more realistic representation of the visual impact of such a development. This capability is augmented by the ability to generate road, water and flora 3D objects from 2D mapping data and overlay these on 3D topography (Figure 16.4).

Specification software

Specification software works with authoring tools to provide information about the installation and management of objects. As various materials and techniques are proposed by designers and contractors, the specification can be used to check whether these materials meet requirements. The provision of relevant information in digital form to project managers and contractors for planning and managing workloads improves oversight of a project, and ensures that the latest standards are implemented. Specific software should be able to exchange information with other tools used in the BIM workflow , with the capability to input design information and apply classification to objects as required. It should also be able to communicate this classification information to facilitate cost and therefore the classification of specifications required. This information should then be communicable to other software packages such as asset and facilities management packages, databases and spreadsheets.

Cost management software

Various cost assessment tools can be used within the workflow to determine construction and maintenance costs, based on materials and site information. A system must be able to gather quantified information in automated form about the materials and objects on site, and classify them by space, zone and region according to the site designations specified within the project COBie. (COBie is the exchange mechanism that enables information to be delivered across the life cycle of the asset, explained in more detail in Chapter 18.) This can be used to assess the initial site development costs, and then handed over to the management team as part of the Asset Information Model (AIM) for ongoing site costs monitoring. The analysis capabilities within the cost assessment and simulation process can forecast site costs from an early stage. Cost management can be coordinated with the project management tools to provide cost prediction milestones to inform the employer's decision points and to monitor progress.

3D BIM authoring software

BIM authoring software should be able to gather and incorporate existing site information, including geometry, project-relevant material and asset information. Applying properties to BIM objects within the tools allows elements of the objects to be specified; for example, price information or embedded carbon. Classifying spaces by assigning them to named zones or regions in a design can allow quantity and cost to be allocated by sub-space, enabling improved cost and project management. The software should be able to produce the appropriate level of graphical and information detail for each specific stage of the project. It should be possible to position design objects in 3D or based on rules with respect to one another, with site elements prescribed, arranged and sized so as to meet the performance requirements.

Analysis should be possible within the software, or it should offer the option to share information with other packages to allow analysis for additional technical services provided by the project team. It should be able to determine whether a design meets requirements through assessment against performance criteria; for example, checking whether a footpath meets the correct slope requirements. Where relationships between objects are defined during design these too can be tested for compliance.

Making information available to other software packages is a key activity of a BIM authoring tool. It must be able to export and import geometry and information relating to the objects being designed, enabling the design team to work collaboratively with the rest of the project team. It should provide a realistic representation of the site to allow project stakeholders to engage with the design, with a clear indication of materials and the spaces created, as well as diagrammatic representations of objects within traditional design views such as sections, elevations and orthographic views. BIM Level 2 requires 2D outputs from files, so the software needs to be able to produce the drawn information. In terms of realisation, BIM-authored information should be usable as part of the Project Information Model (PIM) and Asset Information Model (AIM) to enable the construction of the asset components and their management, respectively.

BIM viewing and review software

BIM review and viewing software brings together models in a federated form to coordinate information and resolve spatial clashes. The ability to coordinate files from different professionals is key to its success as an analysis tool, validating designs in relation to one another within the same 3D environment and identifying issues for resolution.

COBie software

COBie provides for the maintenance requirements for specific objects, with the hosting software highlighting the appropriate management of scheduled tasks. It also provides a useful source of information on as-built assets so that managers can replace items correctly and easily when needed. By providing a standardised format for information, the COBie can enable the visualisation of analytics based on the whole site's performance. It can be used to control and regulate the construction process as it serves as the central repository for information on all planned works for maintainable assets.

COBie can be managed in different software packages; a spreadsheet is appropriate for COBie in table form, whereas a database should be used for XML. COBie can be exported from within BIM authoring tools or by altering other files to match the COBie structure. Assigned by space, zone and region, objects should be classified in terms of both their location and their association with a component, system or assembly, so they can be filtered and analysed within these terms.

The Common Data Environment (CDE)

All consultants should be working from the latest versions of files, so a common platform for version control should be established that meets the project's agreed standards. All project information is available on the CDE, a highly transparent project management tool where all activity on files is recorded, providing auditability and robust version control.

Clash detection

Also known as clash avoidance, this is the process of examining different project teams' models and identifying any overlaps or interfaces that require changes. When the virtual model is correct, the likelihood of discovering that designs need amendment or of costly mistakes being made in construction is greatly reduced – one of the major benefits of BIM.

A user can perform intra-software clash detection, importing another consult- ant's model into the same package with which it was created, and clash-detecting within that software. Extra-software clash detection can be used when working between different packages, using specific clash detection software. Manual clash detection is essentially the norm, however. While software can semi-automate the process, clashes still require identification and interpretation by an experienced professional inspecting the interfaces of their work with that of other consultants. Clash detection activities should be planned as part of the process of establishing the requirements of a BIM project at every stage.

Digital Plan of Works

BIM Level 2 requires the ability to manage information deliverables and their content, as well as responsibility for completing or feeding into them. The BIM Toolkit allows tasks to be allocated on a stage by stage basis according to the RIBA Plan of Works. Tasks may be assigned to one consultant within this process using any classification system for the numbering of tasks and Uniclass 2015 to choose the objects to be created. It also includes a Level of Detail option for every element that defaults to the LoD appropriate for the stage in which the task is assigned (Level of Detail is explained in full in Chapter 19). The Toolkit is intended to serve as a reference point for the tasks assigned rather than a project management tool, although it does include a number of features that enable the project team to make notes and comment on tasks and deliverables.

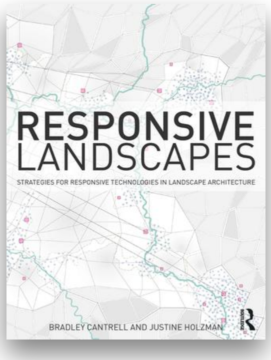
Reference

Kreider, R.G. and Messner, J.I. (2013) *The uses of BIM: Classifying and selecting BIM uses.* University Park, PA: Pennsylvania State University.

CHAPTER 3

Responsive Technologies

Chapter 3. Responsive Technologies



The following is excerpted from *Responsive Landscapes: Strategies for Responsive Technologies in Landscape Architecture* by Bradley Cantrell, Justine Holzman.

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The term "responsive" denotes that an object engages in a process of feedback, a conversation between two actors. In architecture and design this has typically been approached from a Human Computer

Interface (HCI) perspective, centering on how human beings respond to or learn from this process. While the HCI perspective is important, it is only a single layer and the view must be expanded when considering the technologies needed to embed responsive systems in environmental or biological systems. This wider view may not even have human beings in it, instead it can be a set of considerations that focuses primarily on ecologies absent of direct human manipulation. Just as importantly, the implementation of these technologies inherently embraces re-purposing and extending by finding new uses for specific technologies or modes of making. Lucy Bullivant, author of *Responsive Environments*, speaks to this broadening:

> . . . the technologies involved, of sensing, computation and display, are in rapid flux, so anachronistic solutions need to be robust; breakdowns are an occupational and institutional hazard, and new schemes are not foolproof
>
> . . . designers are extending the versatility of equipment for crafted responsive environments to enable different sensing modalities. The difference is that they customize what exists in order to achieve the right results.[1]

This re-purposing points to new tools formed by hardware and soft- ware, generated from the needs of architects and landscape architects to expand their practice.

There are several potentials in landscape architecture supported by current technologies that address environmental and human forms of response. The ubiquity of computation in our daily lives expands the reach of digital technologies, fading them from objects to frameworks that alter our environment physically and perceptually. Methods of sensing and communication support early theories of ubiquity and it is important that a critical stance is developed between local interactions and territorial systems. Anne Galloway speaks to this condition in her article, "Intimations of Everyday Life":

> . . . ubiquitous computing seeks to embed computers into our everyday lives in such ways as to render them invisible and allow them to be taken for granted, while social and cultural theories of everyday life have always been interested in rendering the invisible visible and exposing the mundane.[2]

This invisibility stems from computing that is embedded not only physically but also perceptually. Proposing interaction beyond data will provide methods of engagement for connecting interaction to materials as well as influencing the materialization of systems, thus rendering invisible processes. This is a key component in HCI as it attempts to provide natural extensions of human activities, extending capabilities and responding in predictable and understandable ways. As ubiquitous computing is utilized to interact with ecological systems, there is a similar series of concerns. This begins with how sensing, processing, visualization, and actuation are choreographed.

Sensing as a larger concept refers to the input of data generated from recording or translating phenomena. While a sensing instrument may be universal, the implementation is unique to each site: different deployments will yield varying depictions or narratives. The implementation is a product of the instruments or organs that act as the inputs for information. It is the slight differences in the composition or tuning of these instruments that produces a specific dataset that can be accessed or imaged. This full array of sensing is important as it opens a being or device to a phenomenological connection with the environment. Sensing is often separated from processing and actuation as it produces a generalized dataset that can be discerned from other aspects and may be a product in itself. This sensed dataset is then accessible to be processed and visualized for a multitude of uses.

There is a vast difference between complex sensing networks and designers working with definable inputs—for example, a photocell connected to an Arduino microcontroller. Many of the experiments the design professions are seeing today involve this direct and localized form of sensing, a discrete connection between sensing mechanisms and the data they gather. This paradigm is changing drastically as huge sensing networks are compiling vast amounts of data across many different types of devices. Networks of this type are typically singular in nature and deployed for very specific tasks, such as the gathering of weather data, seismic data, or other forms of global or territorial data. In this manner the data is specific to the logistic or scientific endeavor at hand and is collected specifically for this purpose. As the cost of sensing hardware is getting cheaper these networks and the data they collect is growing exponentially and in many cases becoming less specific. This lack of specificity creates a data space that has become a virtual repository for streams of information, waiting to be accessed. The scale of these monitoring networks and databases constructs a space of "control, not freedom, . . . , and while we enjoy unprecedented access to information and personal communications devices, we are simultaneously smothered by the cloying ubiquity of networks that have no outside."[3] This internalization is a product of the sensing, but more importantly is the political, legal, and cultural paradigms in place that sequester information.

While sensing is gathering information, the ability to process this information emphasizes ways in which the information may be re- purposed, virtualized, or transformed. The processing of information is vital in the operation of responsive technologies as it takes the raw sensed data and builds relationships out of it. This may be as simple as remapping one stream of data values to create a relationship with another stream, or completely transforming the information. The augmentation of information to produce new relationships and realities through hacking is described by McKenzie Wark, author of *A Hacker Manifesto*:

> Abstraction may be discovered or produced, may be material or immaterial, but abstraction is what every hack produces and affirms. To abstract is to construct a plan upon which otherwise different and unrelated matters may be brought into many possible relations. To abstract is to express the virtuality of nature, to make known some instance of its possibilities, to actualize a relation out of infinite relationality, to manifest the manifold.[4]

Processing of information also works with a notion of temporality that builds a relationship between streams of biotic or abiotic information. This is most notable in HCI as the user is closely tuned to the behavior of the system due to an expectation of interactive performance. This ability to sync with physical events, or virtualized events, is often referred to as operating in real-time. The ability for a video game to display 50 frames per second of video or for a door to open when a motion sensor is tripped would be described as operating in real-time. Processing can also happen in a delayed state or information can be preprocessed, and then retrieved for use at arbitrary times. This temporal dimension is incredibly important in the construction of socio-cultural and biotic or abiotic relationships.

The ability to act upon sensed data through processing is related to methods of visualization. How do we see this information as static moments and sequences? How do we translate them into abstractions and complex relationships? Both the collection and the visualization of data are implicit in how we respond to it as it frames our under- standing of the information, curating our understanding and response. Because we intend to operate within complex ecological systems, visualization performs as a mediator to decipher a system. This requires multiple overlays that unpack not only the system but also the protocols that govern a system's operation.

> As we operate within the terms of this encompassing material and procedural environment governed by protocol, what we might term a protocology, there remains the issue of visualization. Identifying and understanding a landscape in protocological terms is necessary before that knowledge can be turned into an active design agenda.[5]

The forms of visualization can be multiple, but ideally it sets upon a method for active transformation coherently representing temporal and spatial relationships.

Acting upon the sequence of sensing and processing is guided by visualization and is made tangible through methods of actuation. Actuation is the transformation of sensed and processed data into a form of physical or virtual action. This speaks to a form of physicality in a process, an immediacy where the field in which sensing is taking place is being modified or acted upon. Usman Haque observed that "designers often use the word 'interactive' to describe systems that simply react to input," for example, describing a set of web pages connected by hyperlinks as "interactive multimedia."[6] Response or interaction denotes a full cycle where a phenomenon is sensed, the data is processed, and it is then actuated entering into a feedback loop where the product continues to be sensed, processed, and actuated again. This feedback loop is the basis for responsive technologies and is often built to be as reliable and consistent as possible. This reliability in the feedback loop creates systems that are predict- able members of a system of control. This type of interaction is limited. We might call it pushing, poking, signaling, transferring, or reacting. Gordon Pask called this "it-referenced" interaction, because the controlling system treats the other like an "it"—the system receiving the poke cannot prevent the poke in the first place.[7] This inability to provide resistance or counter the process can become problematic in responsive environments and is expanded upon in the discussion on expanding the feedback loop.

View *Figure 02.02 Prototyping components, Bradley Cantrell, 2015*.

TECHNOLOGIES

The action of sensing, processing, and actuation is the product of several technologies that create the ability to develop responsive feedback loops. The first stage, sensing, has a multitude of technologies that can be deployed to create methods to input information. Conceptually, sensing is a switch that detects its current position. While new technologies continually create nascent methods of sensing, often it is the clever re-purposing of existing systems that leads to new sensory modes. A quick overview of sensing technologies highlights sensors for acceleration, acoustics, flow, viscosity, density, motion, optical radiation, orientation, pressure, temperature, electromagnetics, and chemical proportions. It is important to note that, within these categories, the measurement may not be the phenomenon itself but instead an interpretation of the phenomenon to measure another property. There are overlaps in the sensing technologies that allow multiple phenomena to be sensed, depending on the method of deployment.

Actuation is enabled through technologies that alter the physical environment, manifesting itself through transformations. Technologies such as motors, servos, shape memory alloys, and many more provide ways for designers to transform the physical world. These technologies are used to render, regulate, control, and automate environments. Recently within landscape management practices, sensing technologies are used to monitor soil humidity. They are processed to actuate irrigation systems, creating efficient and timely applications of water. This feedback allows homeowners to have gardens, lawns, and landscapes that would otherwise be impossible in certain climates. Putting water consumption issues aside, this is a fundamental change in the way certain landscapes can live within non-native climates or highly disturbed environments. In a similar manner, this method of landscape intelligence is extrapolated through large-scale systems of irrigation that rely on the conveyance of water to grow homogenous crops—managed through autonomous systems this feedback loop is a simple relationship between a single biological need and a constructed prosthetic that supports this need.

View *Figure 02.03 Prototyping components, Bradley Cantrell, 2015*.

PROTOTYPING

In the past decade, the availability of technological tools, access to software development, and hardware prototyping marks one of the largest shifts to increase the ability for designers to prototype and experiment with responsive technologies. This can be seen in micro- controllers such as the Arduino or Raspberry Pi and the integrated development environments that accompany them. Not only are these development environments increasing in accessibility, they are also becoming directly integrated into common modeling and drafting tools with plugins such as Firefly for Grasshopper and Rhino.[8] This direct connection creates links between sensing and actuation with parametric modeling tools, going so far as to remove the necessity for coding and replacing it with a visual scripting paradigm. This collapse in the barrier to entry puts architects and landscape architects directly in control of the prototyping process where they can begin to develop proofs of concept. Beyond accessibility to tools is the proliferation of projects through open-source licensing, which allows each successive designer to build upon previous work. Deconstructing another designer's project to understand their code, hardware solutions, and overall methodology is invaluable and is an ever increasing source of common knowledge.

This ability to develop modes of interaction and deconstruct previous work creates an atmosphere where design through hacking and prototyping thrives.

> Hackers create the possibility of new things entering the world. Not always great things, or even good things, but new things. In art, in science, in philosophy and culture, in any production of knowledge where data can be gathered, where information can be extracted from it, and where in that information new

> possibilities for the world produced, there are hackers hacking the new out of the old. While we create these new worlds, we do not possess them.[9]

Conceptually this ethos is important and promises a robust methodology of testing and failure that is important to the progress of responsive technologies both in architecture and landscape architecture.

In this spirit, *Responsive Landscapes* presents case studies intended to be viewed as prototypes, tests, experiments, and "hacks." Experiments that lead us further into a deeper discourse on the relationship between sensing, processing, and actuation and how these developing methodologies are transforming our perception of the environment.

> The promise of our evolving supernatural facilities – thanks to a myriad imaginative prosthetic applications of digital technologies – demands that creative practitioners fully involve people in their development on both subjective and objective levels, enabling them to make their own connections between what are increasingly permeable cultural thresholds of perception and being. [10]

The case studies are at once about the technologies used to create them while also firmly framing our evolving view of a changing technological landscape—quickly emerging both inside and outside fields of environmental design. A space that begs to be richer, more diverse, and just through the design of not only culturally and socially significant landscapes but also through their relationships to the world as a whole.

VISUALIZATION, MAPPING, AND SIMULATION

In addition, the accessibility to technological tools creates a new lens that can be used to understand and interact with complex systems. Modeling software enables sophisticated simulation of site phenomena, providing tools for decision making within complex landscapes. The simulation of dynamic systems within the landscape enables designers to visualize and represent data with an increased knowledge of relationships. These models are effective as an interpretable representation because they establish a metric that translates numerical data from simulations into hybrid or coupled models. This metric becomes the underlying fabric of a representation that appeals to our ability to observe pattern and order in both short and long term cycles.

The development of these models creates custom connections between environmental phenomena and modeling or mapping methodologies. These connections are the key for developing common onto-cartographic methods, formats, and processes, which map the agency of things or, as Levi Bryant describes them, "machines." An onto-cartography defined by Levi Bryant is, "in one of its significations, a mapping of relations between these machines so as to discern their lines of force."[11] Machines within this context can be understood as physical materials within the landscape engaged in ecological systems, infrastructures, sensing or measurement devices, and as artificial intelligence, all acting and playing vital roles in shaping contemporary ecologies. Machines by definition are performative: they operate, act, and apply force, they have agency. The onto-cartography or map becomes the simulation and design tool for strategic intervention, an approach that recognizes the agency of technological machines and their connections to evolved biological, political, and economic machines. As ground-breaking as these methods are for the discipline, many of the models or simulations produced are a vast distillation of site systems, lacking the complexities existing within a site. There is a significant disparity between the accuracy of the simulation of particles in design software and many of the more sophisticated flow simulation tools. Operating at this low fidelity requires conscious methods of abstraction for highly complex systems.

When simulating the physical world, we rely on extracted data to develop a working model. The model is understood as a quasi- objective rendering of reality where the data itself is objective and curated for the purpose of creating a model and tools of measurement. These tools or measurement devices are designed with defined goals, associated not only with what it is measuring but also why it is measuring, and therefore creating a "synoptic" view of reality. This abstraction of reality requires a purposeful logic to assign material actors to quantities, values, forces, and locations, among other properties. The model or simulation produced from this logic is then tuned through observations of the physical world and used to manipulate, measure, and quantify selective aspects inevitably causing reality to become a product of the logic, a "selective reality."[12] The history of this condition is identified through the early forestry management practices and agriculture. To establish a metric in early forestry techniques through a "fiscal lens" concerned with overall production, the planting of trees were ordered within a Cartesian grid, simplifying methods for quantification and data extraction. This metric provided data associated with the economic viability of production, but subsequently ignored elements, such as biodiversity, contributing to the resilience of a forest ecosystem. The metric, ordered to easily observe stasis versus change, lead to an oversimplification of complex ecological processes by bracketing certain factors.

To navigate issues with the fidelity of the simulation and create a relational model of ecological dynamics, requires a hybridization of multiple models, pulling them together to function side by side as a composite simulation. There are currently working versions, of simulations bolstered by multiple models such as Google Earth, fluid dynamics models, and climate models. The virtualization of something like climate demands a considerable shift in the way that we are simulating material phenomena and building virtual worlds. A view of climate in the wake of climate change is much more totalizing, it encompasses not just hydrology, but hydrological systems, weather systems, and anthropogenic influences that act on climate. The way each element relates to one another represents the coup- ling of models that can be viewed as a combinatory projection, and weight the defining inputs to problem-solve through multiple lenses.

This form of simulation is projective, allowing for speculation and inquiry by opening up negotiation between accuracy, projected futures, and intention.

In many ways we are already implementing a slew of responsive systems through modes of production and automation for efficiency. “The architectural profession remains relatively steadfast in a distinction that divides designers from users, even though technology increasingly provides grounds for diminishing that distinction.” [13] This can be seen in several cases including climate control, agriculture, and logistics among many others. While the thermostat is an extremely simple device, it creates an important feedback loop that senses then processes through a simple “if: then” scenario, and then actuates. As an architectural mechanism, climate control creates an extremely important feedback loop to maintain an atmospheric equilibrium. Not only does this create space that is comfortable and climate that is convenient, but it also enables whole new modes of construction and program. This form of control opens the possibility for reliable cooling of food or the preservation of archival documents, cases that depend wholly on the feedback provided by sensors and the control of heating, cooling, and humidifying systems. This has evolved and current technologies are able to use predictive modeling to observe usage patterns and create efficient scenarios that attempt to not only optimize for efficiency but also for comfort.

Under a similar paradigm agriculture has evolved tremendously in the past century through automation, precision, and feedback. This evolution has occurred on multiple fronts through new technologies for harvesting and planting, more precise abilities for selective breeding and genetic manipulation, and political and economic efficiencies and exploitations. Responsive technologies are directly involved in each of these areas. Through precision agriculture, responsive technologies are deployed to more accurately plant crops, to take advantage of planting shifts from season to season or to optimize crop layout. Similarly, through the analysis of crop yields and terrain, hydrology, and soil characteristics, a phytogeomorphological approach can be developed to ascertain planting patterns.[14] These are physio-spatial manifestations of responsive technologies, but this can also occur through new synthetic forms of planting media, controlled monitoring, and sampling methods. As these methods continue to evolve they are slowly becoming more nuanced, from sampling per hectare to monitoring single plants. This evolution of precision changes the scale of interaction from the commercial agricultural scale of thousands of acres to the individual plant, making these technologies applicable in urban systems at smaller scales.

Logistics is also a case where responsive technologies are employed to efficiently operate a complex network of systems that adhere to simple, connected goals. On a larger scale than agriculture, logistics has fundamentally changed the way systems are controlled, tracked, and ultimately co-ordinated. This has altered our systems of retail and shipping, creating highly responsive networks that connect disparate elements. The largest retail companies such as Amazon and Walmart are essentially logistics mechanisms, creating extreme efficiencies in distribution. This has developed global scales of operation that are vastly larger than anything seen in human history.

Our environment is saturated with “smart” devices that we use every day. Many of these devices are embedded into our lives in such a manner that we hardly know they exist, functioning in the periphery and blending into the context of our environment.15 As designers of the built environment, our charge requires us to engage this layer of technology, which is increasingly affecting the environment.

NOTES

1. Lucy Bullivant, *Responsive Environments: Architecture, Art and Design*, 14 (see chap. 1, n. 20)

2. Anne Galloway, “Intimations of Everyday Life: Ubiquitous computing and the city,” *Cultural Studies* 18, no. 2/3 (March/May 2004): 384.

3. Alexander Galloway, *Protocol: How control exists after decentralization* (Cambridge, MA: MIT Press, 2004), 147.

4. Mckenzie Wark, “Abstraction/class,” in *The New Media Theory Reader*, Eds. Robert Hassan and Julian Thomas (New York: Open University Press, 2006), 213. Previously published as “Abstraction/clasee,” in *A Hacker Manifesto* (Cambridge, MA: Harvard University Press, 2004).

5. Burke, “Redefining Network Paradigms,” 71 (see chap. 1, n. 37).

6. Dubberly, Haque, and Pangaro, “ON MODELING: What is interaction?: are there different types?” 69–75 (see chap. 1, n. 16).

7. Ibid.

8. Rhinoceros 3d is a 3d modeling application, Grasshopper is a plugin for Rhinoceros that provides a visual programming interface, Firefly is a plugin for Grasshopper that provides direct connections to microcontrollers and external peripherals such as webcams or the Microsoft Kinect.

9. McKenzie Wark, "Abstraction/class," 212.

10. Lucy Bullivant, "Alice in Technoland," *Architectural Design* 77, no. 4 (2007): 13.

11. Levi R. Bryant, "*Onto-Cartography* Author Q&A," *Speculative Realism Series*, Ed. Graham Harman, 2014. http://euppublishing.com/userimages/ContentEditor/1396275575603/Onto-Cartography—Author Q&A.pdf.

12. James C. Scott, *Seeing Like a State: How Certain Schemes to Improve the Human Condition Have Failed* (New Haven, CT: Yale University Press, 1998).

13. Matthew Fuller and Usman Haque, "Urban Versioning System 1.0," in *Situated Technologies Pamphlets 2*, Eds. Omar Khan, Trebor Scholz, and Mark Shepard (New York: The Architectural League of New York, Spring 2008), 13.

14. John A. Howard and Colin W. Mitchell, *Phytogeomorphology* (New York: John Wiley & Sons Inc, 1985).

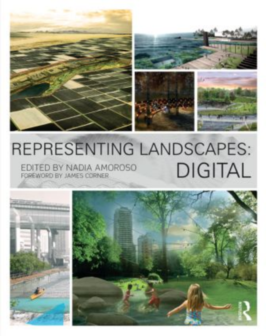
15. Malcolm McCullough, *Digital Ground: Architecture, Pervasive Computing, and Environmental Knowing* (Cambridge, MA: MIT Press, 2004).

CHAPTER

4

Sensing Landscapes through Perspectives

Chapter 4. Sensing Landscapes through Perspectives



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Maria Debije Counts

Landscapes are complex three-dimensional living mediums. Graphic representation of them involves a complex understanding of temporal, geometrical, and technical information. Landscape perspective drawings, in particular, can be used as an effective medium for design explorations as a means to expand sensory-based landscape design investigations: the negotiation between ourselves and the environment. This chapter is intended to show selected examples of digital student perspective drawings of the Pennsylvania State University that test the experiential qualities within the context of student studio design projects at various stages of conceptual development. While qualities of the selected drawings may share similarities in content, stage within the design process, and/or style, it is my hope that the distinctiveness between these similarities and differences relative to how each student is testing *sensibility* through perspective drawing approaches is most evident.

Recent advances in 3D digital modeling have made testing the spatial compositions of landscapes a task that students can utilize at an early stage of the design process to reveal the perceptible geometries and 3D qualities of a site with relatively basic modeling techniques. Such digital 3D representation may have an impact on the direction of the design, depending on how the design was generated. 3D digital landscape models provide a platform from which the scale, spatial "rooms" or "occupiable" areas, and views into and out of spaces, can be understood. No matter what the scale or stage in the design process such a model is incorporated, all of the above have an effect on the experience of any given site. As illustrated in the digital 3D model views (Figure 14.1), a digital landscape model has been generated from contours and plans in AutoCAD. This provides not only accurate dimensions in 3D of the proposed site and its spatial arrangements of forms and features with surfacing, but also creates digital "occupiable" spaces that begin to suggest the overall circulation of how one might move through it and what it might look like compositionally. In this example, landforms, paths, buildings and canopy trees are constructed as measured abstract forms and then intentionally rendered with a limited color palette to allow the student to focus on the spaces that the elements within the designed landscape will create in terms of "rooms" or spatial sequencing.

Using this approach, the student is then able to use the digital model to generate multiple perspective views from the same model at different viewpoints. Because of the relative ease and speed at which a variety of views can be shot, saved and edited to show only desired layers of information, the student quickly grasps the overall configeration of the site itself and is able to test this composition through views and later use them as a basis for design revision. How does something look from that angle? Will the site be visually engaging? What sorts of spaces will the formal geometries of spaces create? Will there be spaces of enclosure or openness? Th are the sorts of questions that are generated from this form of perspective rendering through visually articulating the 3D qualities of a landscape.

Testing temporal conditions of a place affects the landscape and the experience of a landscape. "Digital lighting studies" in perspective drawings can aid in the visualization of how a space changes over the course of time. In Figures 14.2 and 14.3, two students explore this notion of time through an amplified landform study over the course of one day. Two-hour digital rendering sketches reveal dramatic shifts in sunlight and shadows on the site. This process reveals how the orientation of the sun affects the visual experience of landscapes. Renderings have been generated from 3D models and lighting and shadowing techniques were applied within the digital model and edited in Photoshop. Natural elements such as sky backgrounds, planted form, and digitally sketched textures have been incorporated to suggest what time of day the perspective is of, while more advanced lighting techniques are generated in the digital model and later enhanced in Photoshop. Artificial lighting is explored for those areas as needed within the design in need of illumination. As a result of these two studies, the canopy strategy in both designs was improved in some areas to provide more shade and open views. In addition, these perspectives triggered a series of enquiries which led to design improvements. Examples of these questions were: "to what extent will lighting be controlled on the site?"; "will dappled lighting play a role in the overall site design?"; "to what extent will the path and other formal geometries be choreographed around light?"; and "how will the site be experienced at different times of day?".

Materiality in landscapes is essential to the internalization of environments. Bridging the gap between conceptual ideas about materials and how those ideas manifest into real textures and things of substances can be an extremely productive exercise through perspective-collaging. Figures 14.4, 14.5 & 14.6 use texture and materiality along with various atmospheric techniques to convey seasonal changes and environmental conditions, such as portraying the "quality" of the landscape during wet weather conditions.

Programmatic ideas are tested in Figures 14.4 and 14.5 through a patch-collage technique. By creating the basic structure of the picture in these two illustrations, these students quickly alter the quality and overall design idea of the spaces by collaging materials to specific designed geometries that were originally built in a 3D digital model. This process involves a series of rendered perspective views from a digital model and a library of digital material clippings from which the students then quickly have collaged and stitched together into the perspective views, to showcase new ideas. Th base drawing provides the structure and overall view of the space, while the technique of using Photoshop to add materials is quick and flexible. As a result, interesting juxtapositions of materials and forms meet each other, some of which will remain, while others will be replaced by another texture based on best judgments, learned through completing this exercise study. These materials and geometries suggest particular programmatic ranges of the site that are extremely useful to see at this stage of the conceptual design process. In this case, it was important in testing how the site is proposed and likely to be used and how the elements of the designed spaces will actually function as a place. In addition to testing program through materiality, these students also tested programmatic range throughout the year by rendering the drawings in winter. Figures 14.7 and 14.8 depict elegant ways to showcase winter scenes with snow-covered hills, usable winter landscape spaces and activities for people to experience the site even in the cold. Th planting palette is also challenged. Th additions of dogwoods in the foreground (Figure 14.8) frame the scene and add dimension and character to the overall picture.

Both these two studies as well as Figure 14.10 are examples that showcase further development of materiality and expanded programmatic range. For example, the textures and materials reveal the juxtaposition of architectural features such as the bridge and the landscape coming together to form spaces. Textures are applied to the surfaces of the model itself and, at this phase of the design, test not only what material is going where, but how it will be affectecd by other factors such as light, season and use. These two 8–10-hour drawings depict more highly rendered effects and as a result, are more photo-realistic and more accurate depictions of what happens when form, materiality and light come together than the previous figures discussed above. “Pulling out” landscape elements of the picture frame creates an “extended view” of the space and brings to the viewer’s attention the “designed elements” within the landscape (Figure 14.9).

Whether it is testing the formal geometry of site, temporality, materials, or elements such as water or the planting choices, 3D digital perspectives provide the platform for representing landscapes; complex 3D living media, as a means to impact our perceptions and sense of spaces. Approaches to revealing sensual qualities of existing and proposed sites alike can vary from simple abstract drawings (Figure 14.1) through complex night scenes (Figure 14.11). When used as a design tool, experiential perspectives of conceptual unbuilt projects, such as those included in this chapter of student work, demonstrate different approaches and outcomes that can aid in the development of the design process. As a collection of images, they illustrate a richness of dynamic inquiry and reveal something different about the perceptive qualities of landscapes.