ECOLOGICAL DUALISMS UNDONE:

EXPLORING THE ROLES OF IDEOLOGIES, ZERO WASTE, AND QUALITATIVE LIFE-CYCLE ANALYSIS IN PUNTA CANA'S BUILDING MATERIAL CULTURE

A thesis presented to the faculty of the Graduate School of Cornell University
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A B S T R A C T

Materials, as the physical human-environment interface, are key challenges and requirements for sustainable design. This study investigates the epistemology of building materials to understand the considerations and consequences of material selection, both in abstract and within the specific context of Punta Cana. By employing reflective research methods to interpret six environmental building philosophies, this study reveals the building community's need to resolve inflexible dualisms regarding technology, globalization, and cultural meaning to overcome professional divisions that hinder interventions toward sustainability. The results call for common goals, such as zero waste, to explore a wider range of suitable building solutions and provide unified sustainable design criteria. Finally, a qualitative life-cycle analysis suggests that bamboo, a building material commonly disregarded by dualistic mindsets, may convey more environmental, economic, and social benefits in Punta Cana than concrete, the prevailing Dominican structural building material. The conclusions of this study call for increased criticism and ethics throughout the design process to avoid misleading assumptions, represent implicated stakeholders, and promote context-based building solutions.

Keywords: sustainable materials, environmental philosophy, zero waste, vernacular, bamboo, Dominican Republic

BIOGRAPHICAL SKETCH

Jessica Anne Ekblaw is an aspiring interior designer and green building professional. She was raised in upstate New York and graduated from Vestal Senior High School in 2006. Her concern for the environmental impacts of buildings grew during her undergraduate attendance at Cornell University, and this interest inspired her to become a LEED Accredited Professional in 2009. In 2010, she received a Bachelor of Science with Distinction from the Design and Environmental Analysis program with a concentration in interior design. Upon graduation, Jessica enrolled in the newly created Sustainable Design Studies graduate program at Cornell University and worked to enrich learning experiences as a teaching assistant for design lectures and studios. By bringing concepts from her graduate minor, Science and Technology Studies, into the design field, she has begun to explore the design process, particularly how designers perceive their material options, and hopes to reveal how assumptions can be questioned to explore sustainable possibilities.

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LIST OF ABBREVIATIONS

AIA	American Institute of Architects
BEAM	Building Environmental Assessment Method
BREEAM	Building Research Establishment Environmental Assessment Method
CASBEE	Comprehensive Assessment System for Built Environment Efficiency
CEB	Compressed earth blocks
CFC	Chlorofluorocarbon
CSR	Corporate social responsibility
EPA	(United States) Environmental Protection Agency
EPS	Expanded polystyrene
FSC	Forest Stewardship Council
HCFC	Hydrochlorofluorocarbon
LBC	Living Building Challenge
LCA	Life-cycle analysis
LEED	Leadership in Energy and Environmental Design
MBDC	McDonough Braungart Design Chemistry
NASA	National Aeronautics and Space Administration
NCARB	National Council of Architectural Registrations Boards
PCEF	PUNTACANA Ecological Foundation
PISÉ	Pneumatically Impacted Stabilized Earth
PVC	Polyvinyl chloride
TQM	Total quality management
UN	United Nations
UNCED	United Nations Conference on Environment and Development
UNEP	United Nations Environment Program
WCED	World Commission on Environment and Development
USGBC	United States Green Building Council
WTO	World Tourism Organization

INTRODUCTION

The following exploration challenges prevailing dualistic mindsets that shape material and environmental epistemology. The use of dualisms in a complex and dynamic world is problematic because assumptions can preclude consideration of functional, sustainable materials and promote uncritical use of predominant, and often unsustainable, methods. By analyzing the conceptual bases for material use in new construction, this study overcomes the limitations of the many studies that focus on technical solutions alone, which neglect the need for philosophical and lifestyle changes when problems have social, rather than technical, roots.[1] *By revealing and resolving the underlying values and conditions that fuel divergent thinking regarding technology, sourcing, and cultural aesthetics, designers and the general public in Punta Cana and beyond can embrace a wider range of material possibilities, reduce waste, and foster sustainable development for the specific needs of stakeholders and unique locations.*

Overview and Significance

The building industry currently pursues many objectives, including aesthetics, functionality, safety, and environmental sustainability. Often, these goals conflict within given solutions, and designers debate the favorability of general approaches and specific strategies according to their priorities. As the building profession becomes immersed in the Digital Age, the ranges of knowledge and possible solutions expand, but further clarity is not always achieved. In fact, the onset of change tends to increase the divergence of viewpoints, separating reactionaries from revolutionaries. These oppositions become greatly apparent in the frequent debates regarding sustainable building practices and studies of their underlying building philosophies. First, green builders often favor either highly technological, scientific, and performance-based building solutions or local, traditional, and low-impact building solutions. Similarly, environmental builders debate the costs and benefits of globalization, as opposed to locally sourced building strategies. Finally, designers differ in their embrace of vernacular and high style aesthetics. With seemingly opposite viewpoints, arguments regarding proper means and measurements for sustainability divide the profession and hinder significant changes toward its common environmental, social, and economic goals.

Materials, as the physical interface of user interaction with buildings, play a key role to define the intent, meaning, and impacts of built environments. As a subset of their general environmental building philosophies, professional groups form opinions about materials based on individual and collective values and experiences. Builders that favor tradition may perceive material science, global trade, and International Style as oppositional and threatening to vernacular that utilizes local labor, materials, techniques, customs, symbols, and site details. Alternatively, many postmodern designers welcome the high level of control associated with innovative and/or imported materials and may believe all historic methods lack the "advanced" performance they value. These personal and professional assumptions, as well as other barriers, often prevent serious consideration of the full range of possible material solutions. By habitually excluding possibilities, designers may inadvertently ignore solutions better suited to fulfill the specific needs of human and nonhuman inhabitants.

The public often perceives technological, globalization, and aesthetic debates as First World concerns, but the architectural "best practices" identified in these deliberations can also greatly influence outcomes in developing countries. For communities seeking First World standards of living and comfort, such as Punta Cana, Dominican Republic, it is important to find a middle ground between industrial techniques and traditional practices to develop locally sustainable material usage. Punta Cana, in particular, faces a specialized set of challenges as it is situated at the intersection of First World tourism and Third World development. To promote sustainability in Punta Cana, development must support not only environmental health but also economic and sociocultural stability in communities. Universal building and developmental solutions are not necessarily attainable or desirable; strategies often do not translate effectively across environmental, social, and economic divides. All actions must be suitably tailored to their given contexts in order to perform according to green designers' intentions. Therefore, caution and study is necessary to avoid unintended consequences associated with exchanges between the Dominican Republic and industrialized nations, such as the United States.

Need for Research

This study is prompted by the need to examine the impacts of materials used in design and construction. Careful consideration of material use must not only properly guide future development but also spur immediate action to combat the lasting impacts of throwaway culture. While campaigns increase awareness of consumer recycling programs to decrease personal refuse, buildings remain the largest contributing sector to the waste stream. Building construction and demolition comprise 40% of the solid waste generated in the United States,[2] which totals 250 million tons each year.[3] Accumulated wastes pose high risks and costs to society and the environment, including the opportunity cost of land use, the lost value of discarded resources, and water and soil contamination. Action should be taken to return materials to natural cycles, closing the loop between material use, disposal, and reuse. As Maf Smith, John Whitelegg, and Nick Williams argue, “The built environment must be seen not only as the major source of environmental problems but also as the locus of the solution to these problems.”[4]

In addition to restricted land use and ecological health, detriments to indoor environmental quality caused by hazardous material consumption and waste can directly threaten occupant health. On average, humans spend 90% of their time inside buildings; the quality of interior spaces is therefore critical to human comfort and safety.[5] Harms related to chemical sensitivities, such as Sick Building Syndrome, entail economic and health losses. As employee salaries and benefits are the largest investments for business owners, commercial designers recognize opportunities to raise productivity, decrease sick days, and lower medical costs by selecting low-emitting materials.[6] The ability of materials to support user and environmental wellbeing reveals that architectural goals need not conflict; environmentally friendly materials should be explored and manipulated to meet aesthetic and functional requirements as well.

Lastly, designers currently lack an ethics of the built environment to guide their design decisions toward sustainability. Present building ethics are largely restricted to the moral codes of professional organizations, which are intended to regulate business practices, and general environmental ethics. These efforts fail to cover the specificity and extent of design issues worthy of specialized study and debate; the building industry requires a recognized set of ethics to address matters of design itself, including environmental, social, and economic obligations. Current emphases on numerical performance data, regulatory compliance, and client demands can overshadow these vital qualitative considerations, particularly without organized ethical discussion. Once established, an ethics of the built environment could help designers avoid uncritical assumptions and realize the extent of their responsibilities as professionals capable of producing lasting change.[7]

Purpose and Scope of Research

The purpose of this research is to raise conceptual questions about design practices that have physical consequences for individual, community, and global welfare, which include both human and nonhuman entities. More philosophical texts are being published than ever before, but humans are less aware of the philosophical importance of their simplest actions. Philosophy of technology is gaining credibility as an academic field because technology is an expression of a way of thinking; it is a cultural artifact, shaped by dualisms of theory and practice, humans and technology, science and technology, and artifice and nature.[8] By questioning conventional ways of thinking about the built environment, this thesis intends to challenge designers to think critically and holistically about their material selections, applying philosophy to actions. With renewed awareness and questioning, designers may overcome former perceived tradeoffs between building objectives, realizing new synergies between aesthetics, functionality, safety, and environmental sustainability.

The scope of this thesis includes the theoretical and applied grounds of architectural material culture and ideologies. Theoretically, several environmental ideologies predominate throughout Western culture to shape material culture. These ideas, when applied to a specific time and place, connect abstract concepts to their concrete consequences. By selecting present-day Punta Cana as a case study, I have defined three themes that play a role in material selection for new building construction in the Dominican Republic and many other communities globally. Analyses of the three themes— technology, globalization, and cultural meaning— will explore human-environment and interpersonal relationships. These analyses will illuminate problematic assumptions that must be challenged to promote sustainable material use. A literature review will explore broader considerations of material history, environmental philosophy, and regional characteristics, whereas research chapters will be more firmly restricted to material culture as it is mediated through the themes of technology, globalization, and cultural meaning in Punta Cana and in Western culture.

Questions for Exploration

- What are the grounds, stakes, and alternatives to dualistic thinking regarding technology, globalization, and style, both in abstract and in the context of Punta Cana?
- How should current designers conceive of the buildings and materials they construct? How should terms, such as *natural*, *technology*, *local*, *modern*, and *hybrid*, be used within the building industry, and what are the implications of their use?
- How can humans overcome barriers that prevent exploration of a wider range of sustainable building solutions?
- How can communities with different means, values, and goals interface symbiotically to yield short-term and long-term benefits?
- What merits does a goal of zero waste offer to guide non-dualistic sustainable mindsets and actions?
- What are the benefits, costs, and barriers of using rapidly renewable and biodegradable materials in specific contexts?
- How do bamboo and concrete compare environmentally, socially, and economically for application in Punta Cana?

Methodology

To explore the three identified dualisms impacting material culture in Punta Cana (technology, globalization, and cultural meaning), this thesis will use the green building and ethical logics presented in Simon Guy and Graham Farmer's "Reinterpreting Sustainable Architecture: The Place of Technology" as a framework.[9] Each dualism and logic entails histories, concepts, and rationales that are imperative to understand and tackle the ideological challenges preventing sustainable material utilization. Reflexive strategies will explore epistemology in both abstract and concrete examples. Subsequently, analyses of the environmental, social, and economic impacts of bamboo and concrete will demonstrate the implications of non-dualistic consideration of crop-based materials within Punta Cana. Qualitative methods will recognize a wider array of factors necessary for material selection beyond quantitative data.

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B A C K G R O U N D

Introduction

The purpose of the literature review is to provide background information about material culture and environmental philosophy in Western culture and Punta Cana, introduce prior research to date, and provide direction for subsequent research. As this thesis presents both research and design inquiries, this review of literature will span a range of topics relevant to sustainable design and development. To support the research inquiry of dualistic thinking within material culture, I will provide and respond to existing theoretical grounds. To establish a foundation for the design inquiry of material applications in Punta Cana, I will describe case-specific, programmatic details and recognize regional precedents.

First, the literature review will explore past and current human conceptions of nature and human-environment relations. The “Human vs. Nature” dualism will provide a conceptual basis for later dualisms within the research inquiry. Similarly, the subsequent chapter detailing environmental ideologies and movements will reveal the outcomes of humans’ translations of their environmental values into theories and actions. The scope of ideologies and movements discussed will center around material use and technology to relate closely to the “Results” chapters. Next, a brief history of material use and development will explore the impacts of material changes over time and a proper path for future use and development. The final literature review chapter will provide details for the design inquiry. By analyzing the development, vernacular, site, and region of Punta Cana, designers will better understand the physical requirements, goals, and impacts of their designs and select suitable materials for their applications.

As an introduction to the researched topics, the literature review will raise issues that extend outside a narrowly defined scope of material culture and ideology and will not be fully analyzed in my thesis. For example, a discussion of the history and culture of Hispaniola supplements an understanding of local values and customs critical to material selection and context-specific design. In addition, comprehension of intangible material traits, such as technological mediation, implementation, and social acceptance, is equally important to successful material usage as the physical properties of materials themselves. Likewise, the goals, developments, and effects of ecotourism reveal the intentions of material applications and their relationships to wider communities. As a result, the literature review will cover a wider scope than the research chapters to provide a proper foundation for more focused study.

Environmental Philosophy, Philosophy of Technology, and the Human vs. Nature Dualism

Environmental issues, such as resource use and waste, are complex and often generate dissent. Even when stakeholders agreeably define the challenges they face, groups often disagree on proper methods for short-term and long-term remedies. Conflicting views regarding the use of technology, the merits of globalization, and the significance of cultural meaning in building construction and operation present persistent divides that prevent action. Despite society's common views of these debates as solely First-World, modern issues, these disputes have historical roots, extending beyond the origins of each novel invention. To fully understand the tensions regarding technology, international contact, and aesthetics, one must explore the underlying ideas that fuel differing perceptions these immaterial factors of materials. Specifically, fundamental conceptions of nature shape the desired relationship between humans, buildings, and the environment, as well as technology, the mediating means (Figure 1). Humans' vision of nature has its own contextual history worthy of consideration.

Environmental and technological philosophies, or ways of considering the nature of the environment, technology, and humans' place within them, have changed significantly over time. The values that shape human relationships with nature can be dominionistic, humanistic, naturalistic, negativistic, aesthetic, moralistic, scientific, symbolic, and/or utilitarian, and it is the balance of these ideologies that shifts with contextual factors.[1] As environmental philosophy contemplates the status of nature and philosophy of technology considers the effects of human interventions, the study of these fields in tandem offers fruitful insights into the ethics and outcomes of human-environment relationships. These ideologies have tangible impacts by shaping actions, and the choice to preserve, conserve, exploit, or neglect the environment has consequences for human knowledge and survival. In particular, environmental and technological philosophies dictate the use of natural resources, shaping the development of material culture. However, the material effects of ideologies do not foster a comprehensive understanding of the reasoning for the vast alterations in human relationships to nature. In order to chart changes in environmental and technological philosophies, it is important to observe transformations in culture and the needs of society due to the codependent relationship of beliefs, actions, and conditions.[2]

Within the contemporary, Western context, goals toward industrial "progress" and environmental protection often conflict, causing humans to perceive dualisms without middle ground. However, by challenging assumptions regarding nature, decision makers may realize that the barriers to environmental symbiosis may be more psychological than physical. Consequently, the divide between local, traditional, low-impact solutions and high-tech, modern, performance-based solutions is likely founded on the perceived separation of humans and nature. Despite a common goal of ecological and human health, ideologies foster opposite, dualistic approaches, idealizing either minimum intervention or maximum control in nature. The alignment of views of nature that have diverged over time is key to collaborative work toward this shared goal. To uncover a proper path, this chapter will explore the origins of the divide between humans and nature, changes in ecological building philosophies over time, the development of technological philosophies, and ideological impacts on the use of technology and materials. By analyzing historical views of nature and technology and their relations to architecture, Western society can realize the need to change its fundamental values and perceptions of the environment to attain socially, economically, and ecologically sound solutions (Figure 2).

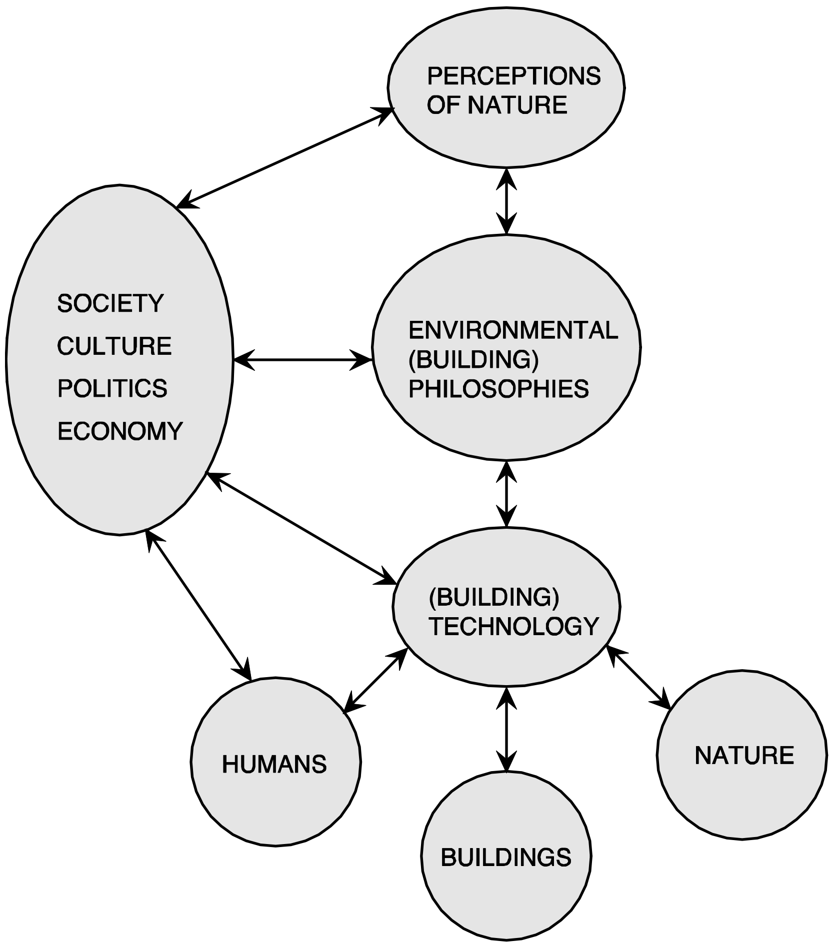

Figure 1:
Human-environment ideological flowchart

Values and beliefs, ideologies, actions, actors, and contextual factors interact in continuous, dynamic, co-producing, and mutually reinforcing relationships. To understand the relationship between humans, nature, and technology, it is important to consider the roles of all listed entities, as no parts can exist in isolation.

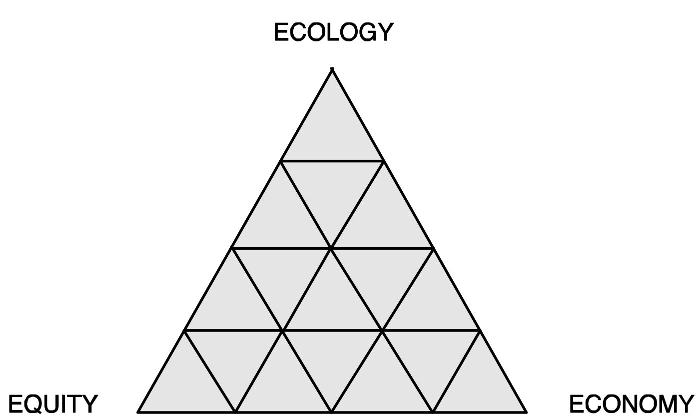

Figure 2:[3]
Sustainability pyramid

All human interventions, including technology, are combinations of ecological, socially equitable, and economic factors, or the triple bottom line. The edges and points of the triangle disregard at least one of the critical factors for wellbeing; sustainable strategies fall near the center of the triangle as holistic approaches.

Early conceptions of nature

The ways humans understand nature directly impact their values, their desired relationship to the environment, and the actions undertaken to achieve their goals. Although ideas and impressions change according to their dynamic contexts, most strongly held beliefs undergo a slow transformation over time. The continuity of views justifies the value of historical study to discover the roots of current ideologies.

Many environmental scholars identify the biblical book of Genesis as an early, yet enduring, work that influences modern philosophies that guide human life in the environment. By providing abundant resources and designating humans as supreme rulers over other species, the Judeo-Christian tradition justifies human use of natural entities solely for human purposes. In addition, the book of Genesis establishes dualistic ways of thinking by contrasting light and dark, heaven and Earth, and man and woman.[4] While the simplified reality presented by oppositional concepts was likely helpful to communicate biblical teachings to the uneducated masses, dualistic thinking has persisted in contemporary culture. A lack of consideration for hybrids and coexisting entities has consequences; if humans perceive the need to subdue and conquer nature, their views preclude the possibility of social and ecological harmony. In addition, humans may consider themselves separate from nature, ignoring the necessity of environmental health for their own continued existence.

While the Bible is often cited as the beginning of human ecological views, other earlier or contemporary sources communicate complementary ideas. Aristotle states that the materials nature yields are simply means to the end of form, and objects rely on human agency alone to bring them into being.[5] However, although ancients perceived nature to lack the agency to transform its elements with meaning, nature was not without power to shape human actions. Pliny the Younger notes the need to design architecture according to the characteristics of the natural site and landscape. Pliny's objectives included anthropocentric goals of comfort and aesthetics; many ancient building methods were low-impact by contemporary standards, but they were not fueled by ecological concern. Builders were required to consider sun angles, views, weather, climate, and topography to produce quality living environments due to a lack of means to control nature.[6] In alignment with the notions of his time, Pliny likely felt no inherent obligation to protect nature and used its capital to his enjoyment and advantage. Similarly, Vitruvius echoes anthropocentric reasoning to consider the natural environment. He claims assessments of topography, climate, air, and water are important to maintain occupant health and sought healthy lands to fulfill human wants and needs alone, rather than comprehensive ecological interests.[7]

Natural factors influenced not only form, methods, and site selection but also material application. Historically, natives used local materials, such as reeds and clay in Mesopotamia, because alternatives were unavailable to the masses.[8] Ancient Western cultures were ecological by necessity, but the continued use of local materials also became a source of national pride and regional identity. For example, Alexander the Great refused to import materials from overseas; Alexander likely saw the value of cultural development to foster empire building.[9] Despite the environmental health supported by early, low-impact practices, nature lacked inherent value to humans; it was considered an important means but not an end in itself.[10] Without values of ecological responsibility communicated between generations, populations are liable to degradation when technological innovations eliminate the need for environmental responsiveness.

These early conceptions of nature are primarily framed under the environmental philosophy of anthropocentrism. According to anthropocentrism, environmental considerations extend only to human concerns.[11] Nonhuman entities lack inherent value and only are worthy of protection if humans place value upon them.[12] Despite a sole focus on human interests, anthropocentrism does not condemn nature to degradation; as humans rely on the health of ecosystems for their own survival, humans may act as protective stewards of the environment. However, without understanding of ecological maintenance or altruism for the global community, anthropocentrism can lead individuals and nations to become shortsighted and seek unsustainable, personal gain. Additional ethics and knowledge is critical to avoid selfish acts that can accompany perceptions of human superiority.

Despite the problematic environmental assumptions of human superiority within biblical texts, religious beliefs later became key sources to attribute inherent value to natural entities and advocate for responsible resource use. While the book of Genesis recognizes nature as God's creation or work, Hildegard of Bingen recognizes God within all things during the Middle Ages.[13] As nature became God, rather than an isolated work, humans came to glorify and revere nature as sacred perfection. Similarly, Saint Augustine acknowledges God's presence in nature, but he also differentiates between levels of sacredness, maintaining human superiority above other life and sentient beings.[14] In this way, past and present ideas blended to combine new veneration of nature with historic perceptions of human dominance. This hierarchy served to guide human relationships with the environment, privileging anthropocentric goals but also considering the value of nature. With respect, society aimed to avoid wasteful, destructive behavior. The new appraisal of inherent value within nonhuman entities indicates a shift toward an ecocentric perspective, in which nonhuman entities are worthy of moral consideration regardless of human utility.[15]

The preferences of Renaissance architect, Leon Battista Alberti, for modest architecture reflects these new beliefs, balancing human and natural values. Alberti introduces a novel approach to integrate intellectual and ethical arguments into architecture, in contrast to the formal and technical instructions that dominated before. Unlike past scholars who idealized ornate and immense designs, Alberti argues vanity is a vice that disrespects the ideal of nature. Maximizing resource use and using nature as a model for building practice communicate nature's preciousness and wisdom. In addition, Alberti believes humans should respect nature not only for its sacredness but also for its immense power.[16] Centuries later, Laugier reiterates nature's indifference to humans, who must protect themselves, and that simplicity of form and materials is sufficient to protect humans from the elements. By honoring the primitive hut as a fundamental model of minimalism, Laugier, like Alberti, attacks new developments that seek vanity, rather than utility.[17]

Laugier's and Alberti's translations of respect for nature into simplicity of form clearly illustrate the process in which values inform building ideologies. Humans did not consider nature fragile and in need of protection, as many environmentalists claim today. Instead, nature was a model to imitate; its endurance and power were inspirational to humans seeking to maintain superlative sacredness to other beings. To mimic nature's simplicity and refinement, architecture should seek purity in its forms and processes as well. Laugier's and Alberti's beliefs reflect the cumulative knowledge of centuries; religion, comfort, necessity, and ethics all inform their assertions. Despite hopes to model buildings after nature to acknowledge possible symbioses, these fundamental beliefs and emerging ideologies would inform further dualistic thinking in which technological transformations opposed nature's purity and simplicity. The building philosophies of future scholars, built upon the ideas of all who came before, would dictate the role of technology within the relationship between humans and nature.

Nature-based environmental philosophies

Many early environmental philosophies addressed building with respect to nature, based on both past beliefs and new developments. With the emergence of industrialization, social change became apparent fuel for ideological and methodological arguments, spurring strong reactions to events and trends. These intense beliefs yielded more defined mandates for architectural practice and ecological living.

Jean-Jacques Rousseau's views of nature shifted perceptions of sacredness and power into values of blissful enjoyment. Rather than seeking to worship isolated nature or imitate its lessons, Rousseau recognizes nature as a sanctuary and escape with restorative benefits.[18] By considering nature as pure and leisure, Rousseau contributes to the inverse relationship between humans and nature, in which humans spoil nature's value through manipulation, extraction, and work.[19] Rousseau's romantic perspective presents problematic assertions. Why restrict knowledge of nature's valuable entities and processes to observation alone? Can humans not use nature while respecting other beings? If use of nature is inherently harmful, how can humans support themselves to survive? This final question presents the key challenge to Rousseau's directive; he does not provide a path for humans to live in nature. If human manipulation is assumed unnatural and destructive to nature, and "natural" nature is the ideal, then humans foster self-eliminating goals. William Cronon, in his essay "The

Trouble with Wilderness," recognizes humans as natural beings who cannot live without an environment. Consequently, scholars must provide ethics to guide proper action, rather than simply prohibitive measures.[20] Rousseau's context of Romanticism weakened his concerns for the landscapes of human life, but later scholars would bring greater focus to humans' living environments.

John Ruskin, as an art critic and social thinker encountering industrialization, began to shift thinking away from wilderness ideals to provide guidance for the built environment. While many philosophies regarding form and nature's importance emerged before, the Industrial Revolution spurred strong viewpoints to direct the specific use of technology and materiality. Ruskin and Robert Blatchford call for the preservation of nature to protect its value, declaring buildings' role in overconsumption and industry's role in creating crowded, filthy cities. Consequently, Ruskin and Blatchford link technology to pollution; any item requiring mass production and dispersal necessitates cities that produce unfavorable living conditions.[21] Under capitalism, both workers and nature are "others" to exploit.[22] Rather than seeking continual growth and development with new inventions and structures, materials and architecture should create a sense of place and pride within its people. Top-down knowledge and imported materials and techniques inspire changes based on scientific discoveries, eroding tradition. Therefore, to Ruskin, indigenous, decentralized techniques and historic preservation, reflecting accumulated wisdom, are best for the environment, its citizens, and the identity of unified communities.[23]

In agreement with skepticism of continual change and fear of scarcity, John Stuart Mill advocates a self-sufficient, stationary state, in which industrial and population growth cease. Mill counters prevailing notions that material growth is necessary to avoid stagnation;

the stationary state allows unlimited increases in social benefits, morals, and knowledge and levels the social inequalities and crowding associated with capitalist production. Mill's ideas can also apply to buildings. According to the stationary state, communities should value preservation over expansion by opposing new construction and provide exposure to natural areas, which are essential for human wellbeing.[24] John Muir also opposes unconstrained technological growth. He claims humans should conform to the rest of nature, rather than unceasingly attempting to surpass natural constraints. Muir, in contrast to Mill's goals of social equality and equity, seeks equality for all species, breaking the historic hierarchy of human superiority. Accordingly, technological expansion, which consumes excess resources and isolates humans from their proper role in nature, should desist.[25] Despite differing values and aims, Mill and Muir support similar methods to reach the equilibrium they desire.

Although the intentions of Mill's and Muir's philosophies are honorable, they are based on dualistic thinking that opposes all technology and glorifies the absence of physical expansion under all conditions. Calls to return to nature adopt a robust, anti-technological stance, denying the possibility for human health, natural benefits, and industrial production to coexist. These assertions assume that no human intervention benefits the environment. In other words, all nature is ideal, and any unnatural, namely human, manipulation is inevitably less desirable. Humans are deemed inferior and dangerous beings, separate from the purity of nature. Consequently, ideas that restrict human actions in fear of destruction prevent human attempts to work symbiotically with nature, as natural beings themselves. Industrial reformers and similar-minded Luddites disregard the need for these parties to interact for humans to survive. In order to allow beneficial human actions and avoid selfish, damaging exploits, one must change these underlying beliefs. By understanding humans' connection to and reliance on nature, citizens may be able to overcome their dominative history and instincts to treat nature with respect and proper care. Nature must be seen as an ally and tool to assist human happiness and safety, rather than an isolated entity to protect or conquer.[26]

Industrial-based environmental and technological philosophies

Despite the strong reactions of environmentalists against industrialization, most citizens did not support abstinence from technological development. Henry David Thoreau claims most men were attracted to society over nature, perceiving a sharp divide between the two.[27] However, many scholars did not embrace technology without regarding its consequences, contrary to the fears of the industrial reformers. By seeking a balance between technological shifts and human and ecological health, modern environmental philosophies began to overcome dualisms that prevented a more symbiotic relationship between humans and their environment.

Heidegger and Marcuse were notably sympathetic to a changing conception of technology. Heidegger was one of the first scholars to analyze technology as a philosophical subject beyond its instrumental value.[28] While Heidegger insists technology cannot be defined, his working definition of technology extends beyond the layman's association with gadgets. Rather, technology "enable[s] man to transform knowledge into means for meeting a particular end";[29] it is "a way of thinking and style of practice." To these scholars, technology is neither static nor inflexible; it is as capable of modification as any idea. In Marcuse's critique of technology, he advocates the introduction of humanistic criteria into technological reform.[30] With liberation, Marcuse believes "certain lost qualities of artisan work may well reappear on the new technological base," bringing humans closer to the natural materials they meld.[31] Manufacturers can negatively use technology as a tool to manipulate society, but by liberating the senses with human labor, technology can be a tool for discernment. While Marcuse critiques modern society, his "first theory of emancipation" communicates a middle ground in which technology opens humans to further understanding of nature and themselves.[32] Heidegger also relates the ability of buildings, as forms of technology, to bring humans into a closer relationship with nature. Building is essential to dwelling, and dwelling allows humans to fully experience, support, and interact with the fourfold, or the earth, sky, divinities, and mortals. In this way, Heidegger believes buildings are means of *techne*, a Greek term signifying the "letting appear" of essential form and meaning, and a *poiesis*, a way of bringing forth and revealing the truth. Technology can help humans interpret nature, and by gaining a deeper understanding, they will be better able to interact sensitively in their environment.[33]

Later in the 20th century, other environmental historians would echo beliefs in nature as a medium for human knowledge and labor. Rather than isolating nature in attempts to preserve pristine wilderness, William Cronon recognizes the value of humans' daily interactions with their environments. The assumed prestige of purity, an illusion in itself, should be questioned.[34] Backyards can be equally valuable to protected areas; each is ideal for different purposes. Richard White recognizes this divide when he recognizes two problematic stances environmentalists often take toward work. Analysts tend to consider work as inherently destructive to nature or work as a means of knowing nature. By exploring the latter without romanticizing traditional, manual labor, work can help humans learn how to live more symbiotically within their environments, protecting nature instead of threatening it.[35]

Aldo Leopold advocates this closer relationship with nature but also voices skepticism that benefits will arise without changes in human values. Knowledge of proper action is important to respect and protect nature, but without changes in underlying beliefs and values, humans are still liable to selfish tendencies. To regulate human interaction with nature, Leopold proposes a land ethic lacking from past moral codes. The land ethic does not prevent resource use, but it affirms the right of all living things to exist, regardless of their value to humans. This biocentric worldview shifts humans' role from conquerors to members of nature; humans not only *could* interact in harmony with nature but also *should* respect natural beings as a part of ethical citizenship.[36] The land ethic extends to all human actions, including technology. To foster an ethical and informed human-environment relationships, Leopold acknowledges the benefits of continuing technological use under new criteria for gentler use. New criteria can shape building methods and materials that preserve resources for other humans and species, but techniques alone are not a panacea. Architects must adopt a broader worldview to realize the possible extents of their actions and correspondingly proceed more carefully and gradually. Humans can learn from the enduring wisdom of nature, seeking to mimic its gradual changes to avoid tragic consequences. With a biocentric worldview, humans can realize their roles as parts of nature.[37]

Heidegger reinforces Leopold's cautions against uncritical applications of technology. Heidegger urges humans to be aware of the limits of technology because the problems it resolves may produce alternative complications or destruction. Neither nature nor artifice are static, or even distinct, entities; all are interconnected and dynamic. Technology can be beneficial to human relationships with nature when used mindfully, but society's blind embrace of technology in pursuit of modernity can transform it from a means to an end in itself.[38] Heidegger explains, "Efficiency… is fine insofar as we do not think that efficiency for its own sake is the only end for man."[39] Heidegger's beliefs are later echoed in the Brundtland report, which acknowledges that technology is not intrinsically benign and calls for understanding of natural systems and caution when applying technology, as unsustainability is caused by carelessness.[40] Technology is humans' means of interacting with the environment; it is critical for survival, but to fully benefit human and nonhuman life, it must be balanced with other values, including ecology, social equity, localness, and a shared meaningful existence.[41]

Nonetheless, not all scholars embrace Heidegger's urges for technological conservatism. The Marquis de Condorcet imagines technology as a viable means to utopianism. As an advanced, efficient tool set, technology could increase secularization, education, and equality; without want, humanity could enjoy life in peace.[42] Fuller also advocates a less constrained pursuit of technology despite concerns similar to those of environmentalists. Their differing approaches lie in diverging underlying values; Fuller views human ingenuity as the key to survival, whereas Leopold and Heidegger consider technology simply a means for knowing nature, the ultimate source of prosperity. Material wealth is limited by nature's given resources and solar income, but humans' intellectual wealth is unlimited and cannot decrease. In response to limited natural resources, Fuller claims humans must apply their accumulated knowledge in unique ways to increase survival potential, allowing increased populations to subsist with less resources and combining parts to produce goals unattainable in isolation.[43]

However, as Fuller sharply focuses on social survival, he risks neglect of prior economic ideals and ecological concerns in support of anthropocentric gains. For example, Fuller argues technology should be implemented from problems' outsets regardless of monetary cost. In terms of "true wealth," solutions cost nothing but time, which will be refunded by machines' efficiencies. To Fuller, true wealth is the capacity to cope, regenerate healthily, and live more freely. Although human health is ultimately tied to ecological health, hastiness to implement technology to conserve social time may conflict with environmental stability. Fuller encourages social cooperation and individual enterprise to maximize real wealth without caution, based on the assumption that human ingenuity is always beneficial.[44] When technology is the source of future survival, increasing manipulation of the world is both necessary and desirable. However, goals of human knowledge and "progress" alone can hinder the ecological and economic tenets of sustainability, necessitating more integrated considerations of values and stakeholders.

The various approaches presented here indicate the possibility and reality of both dualistic and non-dualistic thinking regarding human technology and nonhuman nature. The Marquis de Condorcet and Fuller represent the eco-technic proponents, imagining the ultimate benefits of technology with less concerns for costs. Alternatively, William Morris, Ruskin, and other Romantics embody eco-centric principles, proclaiming the lost value surrendered to technological means.[45] Finally, Heidegger and Marcuse represent a mediated view of technology by denying fixed values or assumptions and examining both the merits and dangers of various technological uses. Alex Hall conceptualizes these stances as utopian, anti-utopian, and dystopian, respectively. While the dystopian perspective maintains a sense of pessimism, it allows a precautionary approach that is also receptive to new technological possibilities.[46] Society should not abandon the benefits and knowledge of technology but be open to other ways of thinking, including instinct and attentiveness to nature.[47]

Impacts of ideologies

All conceptual ideas have implications for the physical world in which humans live. At times, scholars propose ideologies to actively promote paths for future action, but the relative strength of fundamental values and unconscious patterns of thinking within individuals can more strongly impact societal actions than publicized strategies. Technology, as both conceptual idea and physical artifact, is an important entity to promote ecological, economic, and equitable decisions. However, technology is a means to achieve other valued ends; the basic values that shape actions do not lie within technology itself, but in the desired goals technology seeks to accomplish. Therefore, it is critical to analyze the beliefs and ideologies that guide technological philosophies, rather than tackling the problem of technology as an isolated cause.

According to this view, Engels suggests a different way of looking at relationships between humans and nature. Beyond assemblages of distinct forms, dialectics asserts that humans and nature are not static, isolated entities; they are interrelated, hybrid, coevolving forces. Dialectics, as a new way of studying nature, can translate into a new way of organizing society and its actions, favoring relationships over entities. For example, ecologically, a building's relationship with its site, in terms of exploitation, decomposition, support of processes, and exchange, is more important than what the building itself is, in terms of form, materials, aesthetics, and internal function. Each physical component and its composition have implications for the dynamics within and beyond the building site, but it is processes, rather than the physical entities, that hold great importance. When one cannot study the details in isolation, as formerly held in metaphysics, one realizes a more complex relationship with nature beyond the dualisms and generalizations encouraged by metaphysics. The varied technological strategies of Heidegger, Leopold, and Fuller later echo Engels' dialectics with the common theme of interconnectedness, which dictates a broader way of thinking.[48]

While Engels targets new cognitive processes to support cohesive, global welfare, Hardin emphasizes the need to shift societal values to guide sustainable action. In his renowned article, "The Tragedy of the Commons," Hardin recognizes the limits of technology, claiming some problems, such as population and its consequences, have no technical solution. He defines a technical solution as "one that requires a change only in the techniques of the natural sciences, demanding little or nothing in the way of change in human values or the ideas of morality." Therefore, society requires a fundamental change in values to tackle current environmental crises; debates of technological strategies are simply guises that mask essential differences in beliefs.[49] The discovery of these values dictates the responses to many value- and goal-oriented questions. One can address, what ends do technology, the means of human action, serve? Who deserves ethical consideration in decision making? Anthropocentric, biocentric, or materialistic drivers yield vastly different responses. These basic goals and beliefs affect the selection of efficient and effective methods, as well as for whom the strategies should be efficient or effective, and the balance of economic, social, and ecological factors in solutions.

Schumacher voices complementary ideas supporting value-based solutions. To Schumacher, technology has the potential to benefit all societies, but the underlying principles regulating its use can dictate very different outcomes for lifestyle. In other words, material entities are neither moral nor amoral in themselves; it is the use and meaning people ascribe to objects that shapes their associations. Schumacher claims the Western world, problematically, has lost sight of technology as a means to human contentment and security; instead, technology serves production and consumption as ends. Technology could be used beneficially, but misguided goals evoke its vices. Emphases on efficiency, materialism, and maximization preclude adequate respect and concern for individuals, society, and the environment.[50] In contrast, Schumacher cites other examples, such as in Buddhist traditions, in which technology is used as a symbiotic tool for human and natural interests, not an efficient, conquering machine. Their work is more beneficial for both human and nonhuman stakeholders because their goals for work are more intangible, reflecting self-improvement over materialistic production. To live sustainably, societies must realize their true goal of aiding welfare, rather than fueling consumption.[51]

In order to preserve the benefits of human labor, Schumacher suggests dividing technologies into two groups: those that enhance human skills and those that displace human labor through automation. He reasons that technology that replaces human labor with machinery is dangerous due to the perceived separation of humans from nature, the denial of self-improvement through work, and machinery's ability to exploit and decimate nature at an increasing rate before full consequences are realized. In contrast, technologies that enhance human skills are beneficial to learn about nature and contribute to the community.[52] By recognizing the differences between technologies, rather than considering all interventions as a homogeneous group, Schumacher encourages critical judgment of technological use with a more inclusive framework of considerations. This framework must originate with a shift in values, which in turn will shift ideologies and actions.

Consequently, technology is not value-neutral as society commonly believes. Marcuse asserts that scientific and technological developments are driven by specific groups' motivations, which are masked by the factual appearance of science. Technology materializes these underlying values, which have physical consequences for ecological health. Therefore, society must question technology to avoid being controlled by the hegemonic values that technology represents. For example, if technology is a means to fulfill the ends of human health and happiness, why must humans unceasingly seek progress? Without a clear goal, what does *progress* mean? Incessant development reveals that technology often arises not as solutions to defined problems, but as ends in itself, affirming Schumacher's concerns. Technology presents business opportunities, revealing Western society's dominant values of economic growth and monetary gain above wellbeing. At its worst, technology devises new complications that it can solve, creating perceived needs, or wants and desires. According to technological determinism, technological fetishism decreases human control, ascribing technology its own autonomy. In addition, technology can overlook possibilities that other strategies, such as art, can reveal. This wider outlook can encourage practitioners to judge the use of technology at each instance to determine appropriateness for specific political, economic, social, cultural circumstances, creating more appropriate solutions for the dynamic, diverse environments they encounter.[53]

Another critical consideration to guide the use of technology is pacification. As a property and goal of technology, pacification subdues both nature and humans as it resolves struggles. Pacification requires diligent care because it is necessary for survival but is undesirable in excess.[54] As Hardin recognizes the need for mutual coercion, which limits certain antisocial liberties to increase overall freedom,[55] pacification also combines repressive and liberating elements. At an optimal level, pacification represses nature to a level that allows humans to survive with adequate nutrition and shelter from the elements and predation. In absence of pacification, humans would suffer the repression of a constant struggle to survive in chaos. Alternatively, excess pacification removes humans from labor and the environment to seek unlimited wants without satisfaction. Therefore, technology should seek to fulfill needs without creating unsustainable wants. Rather than seeking a materialistic end, technology should be designed to pacify the struggle for existence. Superfluous contentment is repressive because complacency prevents one from imagining and seeking beneficial change. Consequently, humans should redefine their needs and values to promote a standard of living of moderate pacification, attainable and sustainable for all humans.[56]

Nonetheless, the dynamic and subjective qualities of humans and nature pose difficulties to obtain these proper balances. To Gregory Bateson, uncertainty regarding organisms', including humans', roles in their environments is a fundamental problem; without consensus regarding the most basic aspects of existence, humans are prone to divergent opinions on all successive levels of issues. Due to their implications for knowledge acquisition and actions, ways of thinking are worthy of contemplation and resolution. Bateson identifies two environmental viewpoints: the creatura, in which all sources of difference are inherent to entities, and the pleroma, in which humans attribute all differences they perceive. Each view yields different opinions on basic tenets. Analysts of the creatura perceive humans to be a part of nature, whereas followers of the pleroma consider humans as external interpreters. Likewise, the creatura investigates broader solutions at a systems level, in contrast to the pleroma's identification of problems within individuals.[57]

Views that capture the complexity of the environment seem favorable to explore full circuits of internal and external actors. Past ideologies that identify the organism or family as the unit of survival can cause self-interest and doom for species or ecosystems. Instead, the unit of survival should be Bateson's "flexible organism-in-its-environment" to consider the vital roles of the organism and its ecosystem in a mutual, dynamic support system.[58] This ecocentric philosophy encourages humans to design technology to enhance environmental flexibility, rather than to increase personal gain. To better conceptualize the "flexible organism-in-its-environment," Lovelock proposes the notion of Gaia, the Earth as a superorganism composed of all entities. Like Bateson, Lovelock recognizes the different actions resulting from holistic and reductionist views. He claims conventional science is too reductionist for environmental health, dividing the environment into isolated spheres of influence and study. Instead, humans must convey the complexity of problems because no issue or entity can be isolated from its contextual factors. In other words, the world, in totality, is more than the sum of its parts and must be considered as a synergetic system.[59]

Other philosophers, such as Lewis Mumford, also promote balance and wholeness in environmental ideologies. Mumford, as a leading proponent of ecological thinking in the 20th century, urges scientists, designers, and the public to look for interrelationships to yield unrealized synergies.[60] These synergies include interactions of humans with their environments; the recognition of human dependency on the Earth supports a nondualistic framework in which humans, as a part of nature, engage in mutually sustaining relationships with nonhuman partners.[61] Identification of humans as natural blurs the boundary between the human-made and the natural. If humans are a part of nature, what is the meaning of *human-made*? In place of formerly oppositional definitions, the human-made becomes a subset of the natural. According to Ken Yeang, these subcategorical distinctions can be useful in some analyses if terms that formerly fostered assumptions and exclusion shift to convey further understanding of worldly organization and interactions.[62]

Nonetheless, not all scholars recognized the interconnectedness proclaimed by environmental holists. When commenting on an exhibition of design work in the 1970s, Ada Louise Huxtable proclaimed, "This spectacularly beautiful work, elegant, formal, and totally detached from the world around it, represents a kind of counterrevolution in today's educational thought and practice." Not only does Huxtable promote the belief that humans can isolate themselves from nature through their architecture, but Huxtable also glorifies this separation as desirable. Huxtable claims that modern buildings can and should provide the comfort and control that humans seek but neglects the unintended consequences of seeking, in vain, to remove humans from nature.[63]

Society must recognize science's limits of isolated variables, time lags, and need for genius. In the past, observation was sufficient to allow people and animals to make informed decisions without understanding mechanisms, but at that time, localized actions entailed lower risks to global survival.[64] Modern technological innovation entails high risks due to widened spatial scales and shortened time frames, including high energy demands, rapid resource consumption, pollution to land, air, and water, and the manufacture of chemicals with unknown effects. With the magnitude of these risks, do building systems threaten the lives they intend to support? Readers of Heidegger often interpret that the growth of modern technology must halt to avoid exhausting the environment, opting for Schumacher's category of less resource intensive technology. However, architecture *intends* to manipulate resources in order to provide a level of shelter and safety that the natural environment lacks. New buildings are technology and entail intentional human change, and it is illogical to condemn technologies that achieve desired ends simply due to "unnaturalness."[65] Decision making based on assumptions of "naturalness" or automation is insufficient; designers must judge each technological innovation based on the merits and consequences of its outcomes.

Despite inabilities to generalize technology and architecture, many architects maintain strong support, opposition, or mixed beliefs toward technology and change in general. Mixed views often entail enthusiasm for new methods but uncertainty of limits. Doubt of use combined with a faith in technology itself indicates not a doubt in innovations but rather a doubt that humans will use technology responsibly. Consequently, humans require environmental ethics to guide human interventions in the environment; the power of technology should not be wielded arbitrarily.[66] Scientific "fact" is not immune to error. Confidence in science can create a false sense of security, undertaking immense risks without adequate concern. High stakes, irreversibility, and human limits illuminate the necessity to proceed with caution and consider contexts carefully in all circumstances.

While inclusive thinking is key to sustainable action, difficulties in its application prevent widespread use. Humans lack the necessary knowledge to consider all factors and have limited time to determine proper environmental actions.[67] Nonetheless, acknowledging the need for contextual consideration is a critical first step. As Hardin relates, "we can never do nothing"; the status quo is a form of action and must be compared to any suggested alternative.[68] Humans need not impose only ideal solutions; rather, they should be receptive to more attainable, incremental improvements. Approaching problems with an inclusive and open mindset, as beings inseparable from the Earthly environment, is likely to foster more ecological actions due to the values it instills. Humans are no longer seen as inherently harmful; all things are in a constant state of flux, in which humans are an integral part.

Conclusion

The underlying values, environmental philosophies, and impacts of these ideologies within Western culture provide insight into the divergent opinions regarding interventions within the natural environment. Views of technology, as a means of mediation between humans and their environment, are logically grounded in the ways humans conceptualize, value, and feel moral obligation toward nature. By understanding the origins of these disputes as deep environmental perceptions that have evolved over time, humans are better equipped to resolve their disagreements to tackle the challenges they face. As differing beliefs are a key source of the debates, an alignment of values is necessary to guide unified action. The replacement of dualisms with more flexible and contingent, yet unified, concepts would remove barriers that prevent appropriate actions and relationships.

Historical views of humans' divides and unities within nature have established the impossibility of extinguishing nature because nothing exists outside of nature. Although humans cannot kill nature if environmental changes are considered natural, a need for ethics arises to ensure alterations do not make nature inhospitable. Past concerns of "the end of nature" recognize undesirable impacts of intervention.[69] Do blander, greyer, less sublime, and more mediated landscapes signify desirable, modern success?[70] Many actions have elucidated changing human values toward nature: the establishment of national parks solidified an ethic of appreciation and preservation, whereas the Tennessee Valley Authority asserted domination over unpreserved nature.[71] What environmental values does the separation of urban housing and mechanized building systems from the nonhuman world convey?

Furthermore, is there a single interpretation of modern Western environmental sentiments that can be identified and shifted to a more sustainable path? Aiden Davison asserts, "To contest sustainability is to challenge the idea that there is a single ecological reality, a Nature, that stands outside of particular, embodied social encounters with the living earth; it is to affirm that there are a plurality of contested natures."[72] The multiplicity of nature, and of sustainability, have made these terms difficult to define historically; a malleable set of ethics, grounded in amenable values, is critical to steer future development yet change as actors discover new intricacies within their living worlds.

Past scholars provide promising material to form a proper set of values and mindsets to guide environmental, economic, and social survival. First, society must seek wellbeing as an end, rather than growth and materialism.[73] The pursuit of health, security, and pleasure should extend beyond humans to all beings, recognizing the interconnectedness of all life.[74] The concept of Gaia supports this necessary comprehensive view of the world as a dynamic, mutually dependent, living system.[75] With this view, humans will consider themselves a part of nature, releasing preconceptions of inherent human destructiveness. Change is necessary for life and cannot be stopped; therefore, humans should approach proposals for alterations with deep consideration but also open minds. Lastly, the need for assessments reveals the importance of context in decision making to maximize intended benefits and minimize unintended consequences. The achievement of a cohesive set of values would have extensive effects, as values guide ideas, ideas guide actions, and actions define humans' relationship to their environment.

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Sustainability Movements, Motives, and Metrics

The previous chapter, "Environmental Philosophy, Philosophy of Technology, and the Human vs. Nature Dualism," explored the relationship between perceptions of nature, the development of environmental philosophies, and corresponding actions undertaken through technology. The connection of ideas to actions highlights the relevance of understanding underlying notions when defining and enacting sustainable goals. Sustainability, as a movement that seeks to maintain equilibrium between and within humans and the environment, builds upon an understanding of nature, attained from a mix of direct experience and indirectly adopted ideas. Whereas the previous chapter studied professed, normative ideals, the following chapter will examine substantive developments regarding sustainability to reveal underlying ideological impetuses. An understanding of the definitions, values, measurements, and movements of sustainability will identify the strengths and weaknesses of current methods and the corresponding strengths and weaknesses in underlying ideologies.

Sustainability movements

The origins of environmentalism and sustainability inspire debates within scholarly and public forums. While some analysts claim the environmental movement is a product of the 1960s that has not faded, others claim its ideas have a longer lineage.[1] Environmentalism has undergone several stages of development, each with varied concerns and values, which complicate the establishment of sharply defined beginnings. The previous chapter links early perceptions of resource use and stewardship to biblical times and traces of ecocentrism to the Middle Ages. Historians may deem these natural considerations as ancient environmentalism, the original stage of development. Romantic writers and opponents of the Industrial Revolution may define a second stage in environmentalism, as a response to the introduction of unfamiliar, mechanical means. John Evelyn, William Morris, and John Ruskin embody the ideas of many reactionaries of the time, calling citizens to support "back-to-the-land" migration, scientific conservation, and wilderness ethics.[2]

Finally, Rachel Carson's *Silent Spring* is often cited as the founding work of modern environmentalism. Beyond former fears of spoiling the beauty of pristine nature through industrial production and pollution, Carson identified unrestrained chemical use as a danger to human and environmental health, spreading panic of the invisible and unknown. Subsequent works, such as Paul Ehrlich's *Population Bomb,* Garret Hardin's *The Tragedy of the Commons*, and Bill McKibben's *End of Nature*, fostered pessimism by rekindling concerns of carrying capacity and adding anxieties of climate change.[3] In addition, *Limits to Growth*, commissioned by the Club of Rome, describes the results of a simulation of future conditions with human actions as variables. *Limits to Growth* fueled apprehension of unseen consequences by stating that natural delays in ecological processes hide the true extent of damage and increase the likelihood of underestimating necessary control measures. The study provides scientific evidence that technology can delay and expand natural limits, but no technology is without costs and will continually encounter limits of scarcity and pollution. The Club of Rome raises a key technological debate: should society accept self-imposed restrictions with precautionary principles or continually push against limits? Technological optimists celebrate the resistance of limits, but technology does not resolve the problem of exponential growth within a finite system.[4] Ultimately, the presented evidence within *Limits to Growth* supports the former imposition of limits, as well as a combination of social and technical solutions.[5]

This modern stage of environmentalism, marked by dematerialization and detoxification, is widely acknowledged as a prevailing concern today; the general public and its representatives question the safety of their homes and workplaces, as well as the long-term sustainability of their interactions with the nonhuman-made environment.[6] However, the fluctuating popularity of ideas, such as Malthusianism, and the continuous efforts of groups, such as the Sierra Club, suggest that the idea of stages of environmentalism should not be taken too literally. Ages are not unified under solitary ideas, nor do societies entirely shift concerns at the introduction of new concepts. Therefore, the stages are simply punctuations in general development of environmentalism, varying in growth and concepts over time.

Historical discrepancies also likely arise from vague definitions of "environmentalism" and "sustainability." Environmentalism can be described as "advocacy of the preservation, restoration, or improvement of the natural environment."[7] Environmentalism tends to focus on the vitality of nonhuman environments and the activism undertaken to enact protections. Alternatively, sustainability takes a wider stance to ensure the livelihoods of both human and nonhuman entities. William McDonough defines sustainability as "meeting the needs of the present without compromising the ability of future generations to meet their own needs."[8] This study targets consumption as one of the primary concerns and barriers to sustainability. According to Worldwatch Institute's *Vital Signs 2003*, humans are exploiting resources 20% faster than their rate of renewability; depletion will impose limits on future generations to survive. In addition to the long-term dangers of consumption, short-term consequences, such as inequalities in availability, are also troubling. The stakes of devising sustainable strategies include not only future scarcity; history has proven that wars often arise due to limited resources. In both ancient and modern times, crop failure and water shortages have caused rioting, civil wars, and other social disputes.[9] Consequently, it is vital to protect economic and ecological health to prevent conflict from within.

These challenges persist and have even grown despite numerous conferences to tackle the reduction of harmful impacts of human consumption and pollution. The Brundtland Commission, formerly the World Commission on Environment and Development (WCED), was established in 1983 to address environmental deterioration effected by economic and social development. The Commission drafted the Brundtland Report, or *Our Common Future,* in 1987 to define sustainable development, its goals, and challenges. Similar calls for sustainable development and policies arose at Earth Summit, the United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro in 1992.[10] Agreements reached at Earth Summit led to the Kyoto Protocol, a treaty aimed to combat global warming through the reduction of greenhouse gas emissions, and Agenda 21, a blueprint for sustainable development on global, national, and local scales. The United Nations has continued to examine climate change in annual conferences in hopes of preventing future damages.

Reducing overconsumption and emissions impacts most aspects of human life in Western societies. Shelter and food are two immediate necessities to sustain life with significant environmental impacts. Developments of architecture and agriculture within the same Western context have inspired parallel movements over time. Both food and buildings originally utilized only local, unprocessed inputs and decomposed readily at the end of their short life cycles. Both fields generated few lasting environmental impacts for centuries.

However, over time, more industrial inputs transformed the nature of both architecture and agriculture. Buildings began to employ metals that disturbed natural ecosystems to extract and provide energy to process. Likewise, agriculture utilized fertilizers and pesticides, altering the chemical composition and health of ecosystems. International trade allowed the use of crops and materials in non-indigenous areas, displacing the native goods employed before their arrival. In addition, new innovations in both fields allowed vast changes in operating scales. Synthetic materials, formal innovations, and construction machinery allowed greater building spans and heights with ease. Monocultural schemes, genetically modified seed, and agricultural machinery accommodated greater outputs of crops and livestock. After millennia of traditional production methods, industrialization increased consumption, removal from natural cycles, and the speed of adaptation.

While industrial processes remain dominant in both architecture and agriculture, alternative methods and movements have grown with the realization of environmental degradation. For example, the organic food movement of the 1960s posed as oppositional to chemical usage in crop production; although organic methods had been used for centuries prior, it only became recognized as a movement once an alternative emerged.[11] Likewise, natural building techniques remerged as a movement with the "back-to-the-land" movements of the 1960s and 1970s.[12] In addition, later movements would include slow food and slow building, both responding to cultural resistance to the increased pace of industrial life, consumption, and decreases in quality.[13]

Several sustainable design movements persist today as an alternative to conventional building practices. The urban design field contributes New Urbanism, a movement that promotes pedestrian-oriented approaches to create walkable, affordable, safe, and neighborly communities, in contrast to automobile-oriented, sprawling suburbs.[14] However, many other sustainable movements provide general principles and values that apply to a wide range of design fields. In 1997, Janine Benyus introduced one such model, biomimicry, which claims nature provides models for product, food, and energy generation, manufacturing, and waste processing. As nonhuman nature has survived for millennia, humans should study nature's processes when seeking sustainable methods for themselves. Some methods employ nature's lessons with minimal manipulation, such as ethnobotany and polycultural farming. Others adapt observations to generate human-made interpretations, such as the imitation of spiders' silk to manufacture strong and lightweight fibers. Like the process of ecological succession, Benyus believes that by incorporating the lessons of nature, manufacturing and design industries can move from the linear life cycles, homogeneity, quantification, and oversimplicity of current modes, or the developing stage of succession, to the cyclical life cycles, diversity, qualitativeness, and complexity of a mature, stable stage of existence.[15]

Natural systems design tackles similar deficiencies in industrial processes. As a tenet of the British Arts and Crafts Movement in the mid-19th century, natural systems design rallied "against cheap goods designed for rapid obsolescence." The call to create unique, meaningful products based on social and economic conditions persisted through the works of the Bauhaus, Frank Lloyd Wright, and later Buckminster Fuller. Beyond values of quality, durability, and contextual suitability, natural systems design considers full product life cycles, safe biodegradation, and reuse of technical nutrients at the end of life. Sustainable architecture and agriculture are examples of systems optimized to their sites, function, social goals, production, costs, aesthetics, marketability, and waste reduction. Designers must act as activists to fulfill these objectives and empower users to make further changes as well.[16]

Today, sustainable buildings strive "to build with minimal impact on the natural environment, to integrate the built-environment and its systems with the ecological systems (ecosystems) of the locality and if possible, to positively contribute to the ecological and energy productivity of the location."[17] One growing sustainable building strategy is biophilic design, which echoes many concepts present in biomimetic theory and applies them directly to the built environment. *Biophilia*, a term coined by Edward O. Wilson, refers to the "idea that humans possess a biological inclination to affiliate with natural systems and processes instrumental in their health and productivity." According to Judith Heerwagen, biophilia likely evolved as a mechanism to protect people from hazards and help them access resources for food and shelter. However, biophilia remains important to building design because it has measurable benefits for performance, health, learning, and contentment. Various studies have found that contact with nature speeds healing and child development. In addition, natural light and ventilation increase productivity, lower stress, and boost motivation, which appeals to the economic interests of employers and the mental health of employees. Much current mechanical architecture denies the nature of humans as biological beings. Humans connect physiologically and psychologically to structures, and due to a neurological preference for nature, biophilic designs provide characteristics for wellbeing.[18]

While the enhanced connection with nature that biophilic design promotes aligns with biomimicry, it also suggests that humans are failing to properly imitate nature. Studies that prove benefits of natural lighting highlight the shortcomings of artificial lighting. A picture window separates occupants from nature; humans enjoy the sight of nature but lack an immersive, sensory relationship of place. Stephen Kellert claims this deep love of nature, biophilia, is "the missing link in sustainable design." Biophilic design outlines both environmental and cultural goals to help humans reconnect with a sense of place and defines six design element categories: environmental features, natural shapes and forms, natural patterns and processes, light and space, place-based relationships, and evolved human-nature relationships.[19] Biophilic design, as well as the other sustainability movements, will serve as an inspiration for change and provide direction toward more sustainable and healthy living.

Sustainability motives

Due to diverse and changing personal and cultural values, individuals' motivations and intentions for sustainability vary. However, assumptions can obscure the diversity and motives of environmentalists. Stereotypes often associate sustainability with affluence, denying environmental values in the Third World and poor First World regions.[20] Other stereotypes link the rise of the middle class to environmentalism; moderate wealth may allow citizens to consider the environment, a luxury unavailable to the poor, while the upper class selfishly exploits the environment. These assumptions, when generalized to an entire group, are flawed logic; not all environmentalists are wealthy, nor are all middle-class citizens environmentalists.[21] Changes in economy and society, such as the rise of the middle class and urbanization, are incomplete explanations to the expanded base of the environmental movement.[22] Factors of economic structure, cultural values, political institutions, media, science, organizations, and mobilization all contribute to new formations and action.[23]

Due to the unique combinations of these factors, environmental values and sustainable goals vary in different times and places. Ramachandra Guha notes that environmentalism in the Third World concentrates on social justice, whereas the First World is prone to favor environmental protections, such as species rights and landscape preservation. Each region's goals are products of their contextual characteristics. Citizens constantly confronted with human rights violations are likely to rectify short-term inequalities in social justice and insufficiencies of social support. Where the majority of humans' basic needs are met, societies are likely to seek more diverse, long-term visions of environmental health. The divergent visions of global goals can cause conflicts and consequences for international development and initiatives. In international contact, groups must be aware of the interests of others to develop symbiotic solutions.[24]

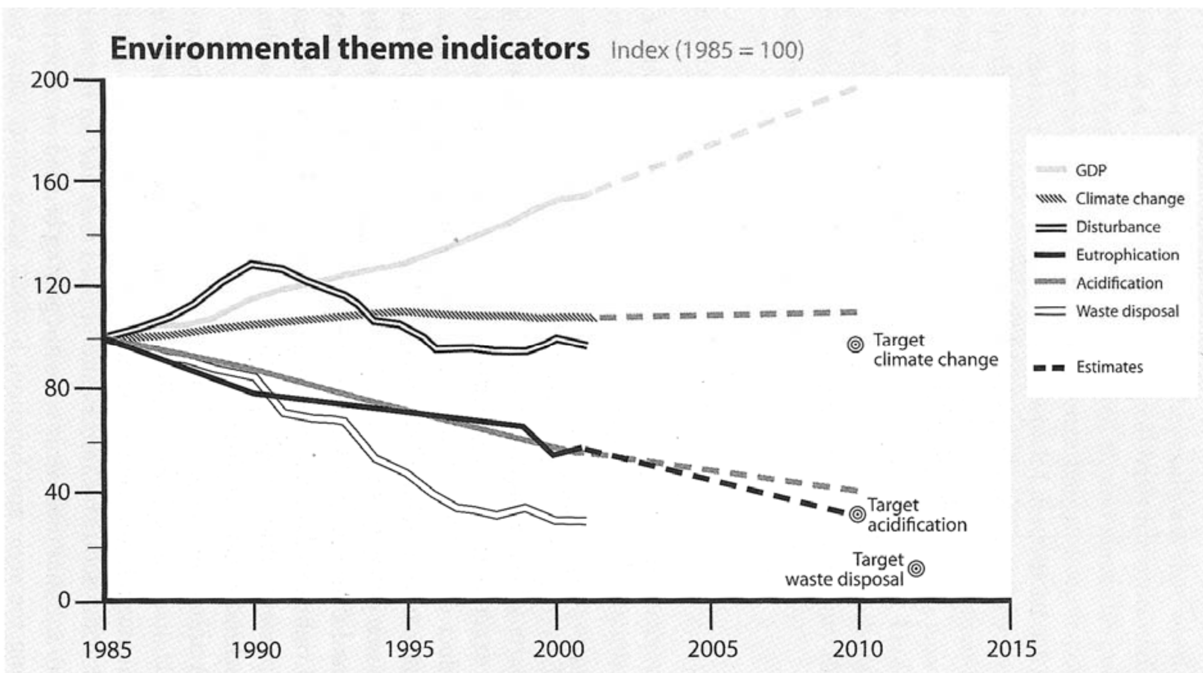

Figure 3: Environmental theme indicators, 1985[25]

Even when holding the location constant, changes within a given place cause environmental interests to change over time. Figure 3 charts and projects the perceived relative importance of environmental themes over time within Western culture. The data suggests greater emphasis on economic and climatic interests in future environmental goals with decreased interest in waste disposal.[26] However, future assessments are difficult to determine due to the confrontation of unexpected limits, discovery of new resources, and changes in cultural values. Nonetheless, it is important to monitor the significance of themes over time and prioritize goals to achieve desired ends in an appropriate timeframe and order.

However, the professed values discussed within political conferences may differ from industries' goals for sustainability. Adrian Parr recognizes that, when economic interests supersede ethics, industries may promote a shift from stewardship to disposable culture, despite the sustainable intentions of the general public. *Greenwashing*, or deceptively marketing products to portray ill-founded environmental benefits, presents viable opportunities to expand business revenues. The term *sustainability* is appropriately applied to action within many different areas of society, but when industry hijacks the term for greenwashed claims, the equality of environmental, social, and economic interests embedded within sustainability becomes lost. Sustainability culture must "subvert the commodification of the environment" to avoid further misguided consumption.[27]

In the field of green building, motives and methods can be mixed within individual works. Buckminster Fuller's geodesic domes represent scientific rationale, biomimetic geometries, and grassroots execution, attributes that often conflict in green architecture. The domes served as a "metaphor for the consciousness of the Earth," a positive yet vague message adopted and tailored by individual groups to fit their specific ideologies. As demonstrated by the US Pavilion at Expo '67, geodesic domes could present an image of the future with innovative form, immense scale yet conservative surface area, industrial materials, and advanced physics. Simultaneously, Fuller also provided how-to books to instruct laymen to construct their own domes from any available material, including cardboard and car tops. Rather than the immense and standardized image at Expo '67, domes for dwelling were intimate spaces, personalized to individual and local culture. Consequently, a single symbol could represent seemingly oppositional tactics to different observers depending on personal beliefs and application.[28]

Despite the cultural complexities embedded within architecture, architectural theorists have historically sought to categorize works according to their strategies to further understand architects' intentions. The categories of regionalism, technoism, and ecoism each address sustainable concerns with divergent methods. First, regionalism reacts against Modernism's uniformity, recognizing the need for variation to reflect climatic and social differences. Since regionalism, by definition, demands dissimilarities, it lacks defining characteristics as a movement and is only recognized for its responsiveness to local conditions. Regionalism is often noted in non-Western cultures with social and climatic challenges that demand local materials and low-tech operation, such as in Hassan Fathy's earthen houses in Egypt. Alternatively, technoism is easily identified by the prominent use of (often futuristic) technology to provide structure and manage the interior environment. Renzo Piano's and Richard Roger's Pompidou Center in Paris is an iconic example of this style, glorifying efficiency, lightness, capitalism, and scientific innovation. As a result, architectural theorists often consider technoism as oppositional to regionalism.[29]

Ecoism combines the techniques of regionalism and technoism by focusing on sustainability alone. Without dictating a preference for local strategies or technology, ecoism justifies both traditional and revolutionary approaches when proven most appropriate. One example is Renzo Piano's Jean-Marie Tjibaou Cultural Center, which combines local traditions and timber with Western technological design to create a responsive approach.[30] Ecoism presents a middle ground to the dualistic notions of regionalism and technoism by avoiding assumptions and adopting diverse strategies. These “isms” within architectural theory directly relate to wider environmental building philosophies, particularly the eco-centric and eco-technic perspectives that provide structure for this study.

Simon Guy and Graham Farmer detail six environmental logics, which include eco-technic, eco-centric, eco-aesthetic, eco-cultural, eco-medical, and eco-social. Conflicts arise between eco-technic followers, who believe technological interventions can solve all environmental problems without dramatic changes to modern lifestyles, and eco-centric advocates, who perceive human interventions as threatening to environmental health. Similarly, eco-aestheticists and eco-culturalists debate the importance of modern and historical identity within building forms, and eco-medicalists and eco-socialists contest issues of personal control and local participation in building construction and operation.[31] These viewpoints divide decision makers, presenting barriers for sustainable actions. Unified support is imperative to the advancement of sustainable building practices; therefore, a middle ground that respects the interests of various environmental philosophies is worthy of research to identify amenable strategies.

Some architects and designers have begun to question the assumptions and stereotypes that resist fruitful combinations of diverse technologies and methods. Ken Yeang seeks to break architectural and environmental stereotypes through his designs of green skyscrapers; Yeang openly “refute[s] the conventional wisdom that tall buildings are inherently destructive to the environment.”[32] Yeang is driven by the desires of contemporary cultures to maintain the familiarity and comforts of their innovations within an ethical framework. Aiden Davison communicates a similar openness to hybridities that are guided by the logical motives of human and ecological welfare. Davison states: “I neither reject our technological world as unauthentic nor embrace it as the only rational way to live. Rather, I consider that healing of our world's deformation requires that we resist the suppression of our practical moral reasoning by instrumentalist epistemology, recovering sight of ourselves as rational beings."[33] The attention that both analysts and actors within the building industry have given to sustainability motives, particularly in recent years, highlights the importance of studying the conceptual bases that guide actions with significant environmental and community consequences.

Sustainability metrics

Due to the different values and goals embedded within sustainability, many different systems exist to measure its status and achievements. Frameworks for ecological design are necessary to provide a set of organizing principles to identify harmful impacts, discover preferable alternatives, and ultimately guide design decisions.[34] Methods of measurement, and their embedded assumptions, often play a large role in selecting actions; like items absent from a checklist, excluded considerations are more likely to be neglected in solutions. Therefore, sustainability metrics should be inclusive and flexible to incorporate needs across times and places.

The "3 Es of Sustainability" is a common concept to define the scope of sustainable considerations. Figure 2 in the "Environmental Philosophy, Philosophy of Technology, and the Human vs. Nature Dualism" chapter illustrates the relationship between concerns for the environment, equity, and economy. When encountering unsustainable solutions, the benefits of these categories often conflict; social, environmental, or economic goals suffer.[35] Parr identifies a shortcoming of green design and environmentalism as only considering environmental goals, which leave social and economic values vulnerable to exploitation. Sustainable actions must protect each value equally to ensure the needs of all stakeholders are met.[36] Within the 3 Es, many organizations identify indicators to monitor the balance and achievement of sustainable goals. The United Nations' sustainability indicators include an array of measures, such as unemployment rate, relative gender wages, child nutrition, literacy rates, population growth, greenhouse gas emissions, air pollutant concentrations, key species rates, gross domestic product per capita, trade balance, and energy usage.[37]

The Ecological Footprint is a sustainability indicator that specifically measures resource management. By calculating the amount of land and water required to support current level of consumption and absorb current levels of waste, the Ecological Footprint can compare demands to the Earth's renewable supply to determine if current lifestyles are sustainable. Since the mid-1980s, human demands have exceeded the Earth's supply of resources. The average Western lifestyle uses nature's biological capacity faster than it can regenerate, indicating needs for change. However, because the Ecological Footprint focuses only on environmental concerns, it is best combined with other measures to ensure simultaneous social and ecological stability. The Human Development Index indicates socio-economic status; Figure 4 demonstrates the use of both measures to compare the relative sustainability of various nations and determine barriers to sustainable development.

The 3 Es and sustainable development metrics provide means to define sustainability and its extensive goals on a macroscopic level. These tools provide a framework to comprehend the mission of sustainability but lack explicit instructions for achievement. To supplement the general sustainability framework, other measures focus on specific industries or stages of development to provide more detailed mandates for change. For example, the

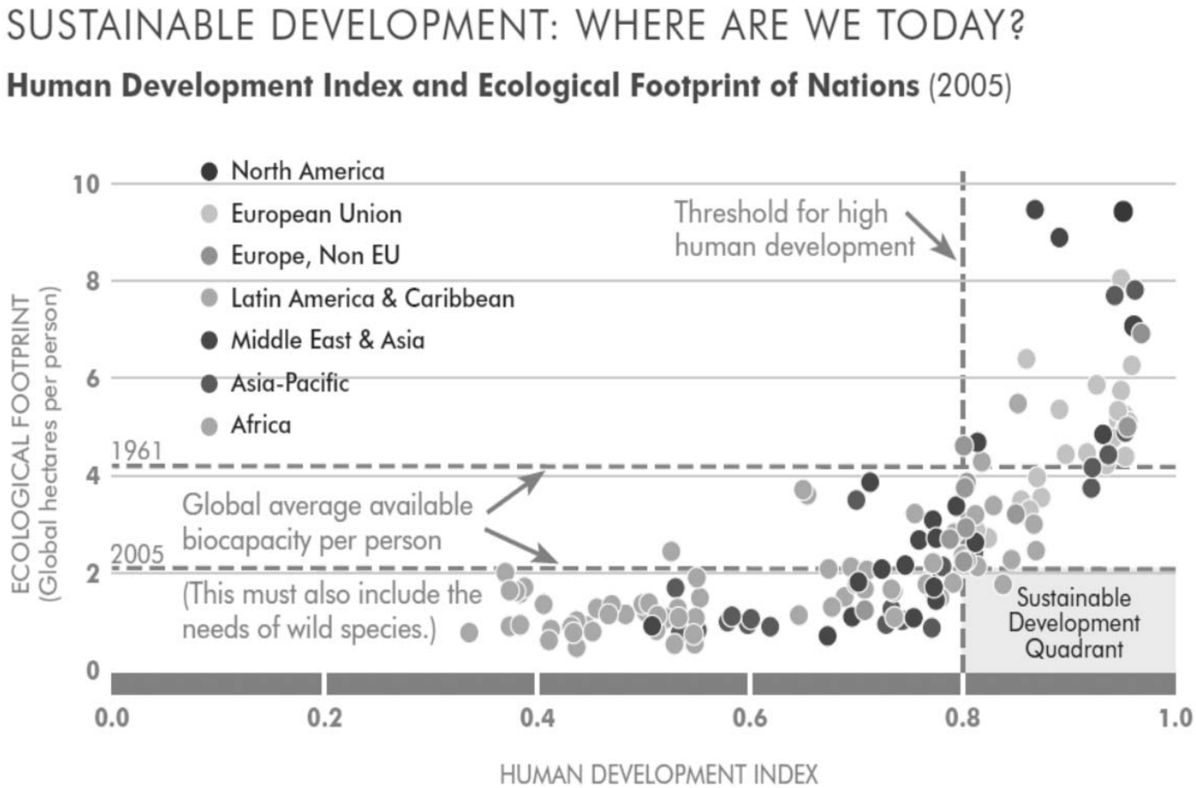

Figure 4:[38] The state of sustainable development in 2005 based on a combined measure of Ecological Footprint and Human Development Index[a]

green chemistry movement of the 1990s specifically guides the processing step of material production. Its set of twelve principles, which include the prevention of waste, use of only non-toxic chemicals, minimization of energy inputs, preference for renewable inputs, and preservation of function, provide a list of considerations for more sustainable processing methods.[39] The suggestions translate into actions that protect environmental, social, and economic interests.

Other metrics, such as zero waste, focus on material outputs and disposal. The zero waste movement reasons that the assurance that materials safely biodegrade at the end of life

[a] A data visualization graphic animates changes in sustainable development, as measured by Ecological Footprint and Human Development Index, at http://www.footprintnetwork.org/en/index.php/GFN/page/fighting_poverty_our_human_development_initiative/.

precludes the use of harmful chemicals in their production and high-energy processing that permits materials to last for generations. In addition, designing materials to be fully reused or recycled eliminates the need for further primary material extraction and eliminates the consequences of waste accumulation.[40] The concept of industrial metabolism encourages reuse not only within single companies but also across industries and processes, fostering collaboration and innovation.[41] Therefore, designers do not consider waste in isolation; as waste is a consequence of weaknesses in production and consumption, targeting waste reduction presents resolutions to challenges earlier in product life cycles in many fields. Consequently, zero waste serves as both a target and methodology for redesign and use.[42]

William McDonough and Michael Braungart's book, *Cradle to Cradle,* has played a key role in communicating the impacts of a zero waste mission on material life cycles. By identifying the "cradle to grave" manufacturing model as the cause of waste and pollution, the authors suggest the "cradle to cradle" model to eliminate the concept of waste and replenish, rather than deplete, resources.[43] These ideas arouse public attention and appeal by presenting options to maintain their modern standard of living with sustainable production. In contrast to the pessimistic pleas to reduce consumption to a minimum, these authors suggest current methods of production, not the concept of production itself, are harmful; an industrial revolution could utilize benign inputs and processes that eliminate the guilt of consumption. Paul Hawken also declares his belief that business can benefit the environment in his book, *Natural Capitalism.* His strategies, like McDonough's and Braungart's, include increasing productivity of resource use, shifting to biomimetic models, moving from products to services, and reinvesting in natural capital. Rather than stifling economic growth, as feared with many environmental interventions, this "new type of industrialism" could generate more employment and profits with less social and environmental consequences, fulfilling the integrated goals of sustainability.[44]

The zero waste movement's aspiration of capitalistic utopia causes skepticism within some scholars. Adrian Parr claims current levels of consumption are unsustainable for material production, even within closed-loop cycles. Natural resources have a limited regeneration period; consumption that exceeds the rate of production is unsustainable. Parr also questions the social effects of McDonough and Braungart's eco-effective industry. The cradle to cradle system, like the current capitalist system based on efficiency, does little to empower low-income populations, who account for 90% of global inhabitants. If the current infrastructure of mass production and distribution remains intact, new industrial practices will continue to allocate power to the elite minority. Therefore, Parr argues that with eco-effective principles, a corresponding shift in ethics is required not only to address the needs of individuals and communities but also to empower these groups to actively participate in the new industrial system.[45]

Designers often value specificity in sustainability metrics to provide clear direction for action. However, as shown by disputes arising from cradle to cradle design, professionals who voice support for specific strategies are often met with conflicting evidence. Due to the different values of groups and the impossibility of an ideal, universal solution, opposing information will inevitably arise and is likely to confuse professionals and consumers. Dr. Karl-Henrik Robert, a Swedish cancer scientist, recognizes the complications and uncertainty arising from scholarly, methodological debates. In 1989, Robert organized a group of experts to organize a framework based on universal agreement, The Natural Step. By looking for points of consensus and collaboration, Robert established four system conditions, or statements agreeable to all parties.[b] The broad imperatives apply to all human actions and, therefore, can be used to guide all forms of product and service provision. By avoiding support for any specific method, The Natural Step meets less contestation than more static and prescriptive frameworks. Indisputable, performance-based conditions allow users to focus on achieving ends, rather than strategic means, as goals and presents a more unified image of the sustainability movement.[46]

In contrast to The Natural Step, sustainability metrics designed for architectural construction, renovation, maintenance, and disposal tend to provide more quantitative checklist of strategies. Building rating systems include LEED in the United States and Canada, BREEAM in the United Kingdom, CASBEE in Japan, and GreenStar in Australia, among others. The dangers of sustainability indices include the tendency to follow checklists without concern for ethics, reliance on bureaucratic intervention for validation, and the uncritical defamation of industry. Green solutions that were once simple and effective become a hassle of forms, audits, and spreadsheets. The mindset of efficient resource use and operation creates paranoia, raises suspicion of industrial processes, and limits creativity and innovation.[47] In addition, the checklists tend to excel in quantifying environmental goals but often fail to acknowledge qualitative, social, and economic imperatives necessary for more comprehensive sustainable approaches.

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[b] System Condition 1: In the sustainable society, nature is not subject to systematically increasing concentrations of substances extracted from the Earth's crust.
System Condition 2: In the sustainable society, nature is not subject to systematically increasing concentrations of substances produced by society.
System Condition 3: In the sustainable society, nature is not subject to systematically increasing degradation by physical means.
System Condition 4: In the sustainable society, human needs are met worldwide.

Living Building Challenge (LBC), launched in the United States in 2006, seeks to overcome the disadvantages of conventional building frameworks that list best practices. Like The Natural Step, LBC presents general, performance-based standards that must be met in their entirety to achieve sustainable goals. In addition, LBC includes imperatives of "responsible industry," "appropriate sourcing," "democracy and social justice," and "inspiration and education" to include economic and social considerations in building design. LBC "defines priorities on both a technical level and as a set of core values, engaging the broader building industry in the deep conversations required to truly understand how to solve problems rather than shift them."[48] Approaches must be understood within their applied contexts to make suitable selections and integrate them into the landscape. The combination of values, study, application, and measurement techniques seems to foster a more intimate understanding of human-environment relationships, aligning building approaches with the landscapes they must work within.

Conclusion

This review of sustainability movements, motives, and metrics inspires several questions to be further investigated in this study. First, the succession of movements reveals changing environmental, social, and economic concerns, as well as the balance of each, over time. To adequately devise future sustainability goals, it will be imperative to be sensitive to these shifts, as hype can overshadow important considerations and upset their integrated equity. Technology will likely play a significant role in future values and the strategies deemed desirable for environmental interventions; this study will help outline the appropriateness of limits and when innovation is preferable. In addition, research should address the nature of the emergence of varied environmental values; how do unique personal experiences and shared cultural beliefs combine to establish ideological patterns, such as Graham's and Farmer's environmental logics? What factors are most influential in establishing environmental values, ethics, and subsequent actions?

At this point in sustainability's history, its definition and goals within the modern context are becoming better understood but remain at an early stage of development. This study will seek to add necessary depth to sustainability, introducing more complex concepts and psychology underlying human-environment relationships. A deeper understanding will likely illuminate proper paths to relate to nature, whether through imitation, manipulation, conservation, or preservation. Finally, the variety of metrics present in the marketplace indicate uncertainty regarding the measurement and communication of sustainable objectives and strategies. By examining the unities and divergences of sustainable development ideologies, this thesis may clarify a balance between the inflexible dictation of methods and the broad imperatives lacking instructional direction. Despite a significant history, the field of sustainable design requires further conceptual exploration to provide rationale for its critical decision making.

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Material History

Materials are the primary visual and tangible interaction points between human occupants and buildings.[1] Consequently, users' perceptions of materials largely define their concept of place, or *genius loci*, and the activities that shape their relationship to the environment.[2] The category and term *materials* is often studied in an anthropogenic and anthropocentric manner. Tom Forester in *The Materials Revolution* defines materials as "any physical stuff that is used by man to make things he needs."[3] According to this definition, a tree is not a material before humans have a specific intention for it; the tree must "become" purposeful wood for human use. All physical entities are defined as matter, but only those used by humans are called materials.[4] The architect, as the intermediary between ideas and materials, must consider the intents and effects of material use to align architectural actions with ethics and other societal values, such as aesthetics and affordability.[5]

Along with food and fuel, materials are a category of commodities, and as such, materials have much larger implications than consumption alone.[6] Materials link nations, economies, knowledge, people, and the environment within "the material cycle." Materials must be governed as a system to benefit both human and nonhuman stakeholders in short-term and long-term timeframes.[7] Current concerns regarding material unsustainability target the amount of goods societies consume, the production methods industries employ, and improper disposal at the end of materials' usable lives. In order to connect material usage to its corresponding environmental, social, and economic effects, one must study the history of material usage and development, including the roles of material science, waste, and crop-based materials in current material culture. The sequence of material innovations and the values embedded within them will suggest that a shift in consumer beliefs and behaviors must accompany technical measures to create a sustainable material system.

History of material usage and development[a]

120,000 B.C.	Organic materials of wood, reed, bamboo, wool, and skins erected by Neanderthal nomads
6,000 B.C.	Sun-dried mud brick created in Middle East, Egypt, and India
5,000 B.C.	Copper and bronze used for fixtures, finishes, structure, and tools
4,000 B.C.	Early stone building in Egypt
750 B.C.	Skilled thatch craft develops
400 B.C.	Burnt brick appears in Greece
200 B.C.	Glass blowing begins in Syria
0 A.D.	Stone popular in Rome
100 A.D.	Roman use of concrete for vaults and domes
1200 A.D.	Wood popular to build Roman towns
1400 A.D.	Iron production expands in wartime
1742 A.D.	Zinc extracted as a metal
1770 A.D.	Iron used for structural building elements
1800 A.D.	New concrete developments: Keene's cement, Portland cement, new formwork
1808 A.D.	Aluminum extracted as metal
1860 A.D.	"Age of Synthetics" begins with development of Bakelite
1950 A.D.	Use of plastic in furniture

Table 1: Timeline of material usage and development

[a] See Appendix A for a more detailed narrative of material developments and impacts.

Historical themes

The compilation of material developments reveals several historical themes. First, many considerations dictating material selection have remained constant over time. Functionality, cost, availability, aesthetics, and symbolic meaning have been primary concerns for millennia. William McDonough describes the housing of the Bedouin of the Jordan River valley to illustrate traditional material selection. Tents made from woven goat hair are functionally favorable because they provide shade and good air circulation in the hot climate, they are portable and easy to repair, and the fibers swell to become impenetrable in rainy weather. Goat hair is readily available, free, and culturally congruent to the Bedouin herding lifestyle.[8] However, the rise of synthetics, technological processing, and material science have introduced new material criteria globally, such as toxicity and recycling.[9] As manufactured chemicals, heat, and pressure are applied more frequently, commonly used materials become unsafe or unable to biodegrade and return to natural cycles. While some older materials, such as fired brick, also persist after their usable life, increased consumption due to shorter material life cycles and swelling populations highlight waste as a problem now more than in the past.

The passage of time also reveals decreasing material restrictions. Designers enjoy wider selection due to innovation and efficient transportation of materials; builders are no longer restricted to locally available resources. Additionally, rather than adapting formal designs to material capabilities, material scientists can create “designer materials” customized to unique applications.[10] However, increased freedoms entail responsibilities to avoid severe consequences for human and environmental health, including chemical imbalances, extensive energy use, and pollution. While newly available materials are desirable for the localized, short-term advantages they provide, green builders debate whether broader costs outweigh the benefits.

Another notable factor in material usage throughout history is technology. Many materials, such as glass, metals, and plastics, required refinement and increased production to reach the building level. Counter to popular belief, technology did not spring up suddenly at the dawn of the Industrial Revolution.[11] The development of bricks, from cob to the use of molds and later to the use of kilns, demonstrates ancient technologies that improved bricks' structural capabilities over centuries. While material discoveries, innovations, and the diffusion of ideas were slow and gradual in past, the time from conception to implementation is decreasing rapidly. Nonetheless, manufacturers and consumers should not fear a complete abandonment of traditional materials in favor of superalloys and composites. While Western societies are interested in "advanced" technology, consumer confidence must be built over time. Ideation, prototype testing, trial use, failure, revision, and legislation translate into a lengthy process before adoption; compared to materials for smaller-scale applications, building materials remain slow to change. Consequently, the building industry often adopts materials used by other industries once their performance has been proven. Landmark buildings are then critical to demonstrate and popularize a new construction material for widespread use. [12] Crystal Palace in London is often cited as an impetus for the increased use of steel, glass, and lightweight structural frames.[13]

Another general, although not absolute, evolutionary theme recognizes trends from heavy, load-bearing materials to light, tensile materials. James Strike raises several perceptual questions regarding the lightness of building skins. If stone structures gained prestige due to the innate appeal of impenetrability, does ultra light construction psychologically conflict with humans' needs for containment and shelter? If so, can better physical performance couple with a weakened sense of protection?[14] Do curtain walls, favored for daylighting and views, fulfill the social need for privacy? In the pursuit of sustainable materials, designers must consider these possible unintended social consequences.

Lastly, history shows that new material development impacts other materials. Most obviously, increased competition threatens existing products with replacement. Resources and markets are limited; therefore, opportunity costs are inevitable. However, changes in materials' symbolic content and meanings are less apparent effects of development. For example, the Greeks used either wood, terracotta, or stone to build their temples. The choice of material communicated different levels of permanence and prestige; wood was the least permanent and most economical, terracotta was the intermediate option, and stone was the most rare and prestigious.[15] Likewise, steel and glass applications antiquate brick and stone. The interconnections between different materials and their human consumers illustrate the influence of cultural perceptions in dictating material usage, which requires more attention. As the public perceives newly developed products as "modern," manufacturers must consider the consequences for the image and use of more traditional materials and environmental, social, and economic security.

The titles of the Stone, Bronze, and Iron Ages indicate the importance of materials as markers of historical eras. Materials, as the matter humans manipulate, provided tools for humans to become thinkers in ancient times and continue to influence perceptions and actions today.[16] With increasing control over contemporary material culture, or the Information Age, societies must consider their place in the environment to ethically use limited resources and explore more sustainable possibilities. What values do current Western material applications convey? The rapid spread of information will largely define material applications; the information that humans choose to explore and apply in their material explorations is as important to shaping future material use as the physical starting points of material development. As information is identified as the defining characteristic of the age, perhaps the definition of material is changing to include information itself.[17]

Reasons for a shift toward material science

The modern age of material development is largely defined by material science, or the "study of the properties of solid materials and how those properties are determined by the material's composition and structure, both material and microscopic." Material science is an interdisciplinary field with ties to physics, metallurgy, ceramics, and chemistry; the scope of material properties is too vast for a single expertise to tackle.[18] Not only do material scientists seek to understand the processes and characteristics governing existing materials, but they also apply their knowledge to alter current entities in a controlled setting to yield new possibilities. In this way, material science links basic sciences to practical application.[19] With the practical knowledge obtained from scientific studies, manufacturers create new materials for building construction, claiming specific attributes to appeal to designers.

James Strike recognizes that construction can lead design, or design can lead construction; materials can be a cause of intervention or be produced specifically to fulfill a particular design vision. Consequently, new materials and methods of construction change the practice and theory of architectural design.[20] According to Els Zijlstra, "Successful development of innovative materials is only possible when the properties of the material are improved by making it stronger and lighter, or improving its physical properties, or reducing the quantity required, or making it less expensive, more environmentally friendly or more durable."[21] Western consumers are attracted to claims of superior performance for a mix of environmental, social, and economic reasons, yet the effects of material science will reveal both support and hindrances to sustainability.

Many factors contributed to the rise of industrial and scientific materials in the United States in the 1860s. The United States had abundant resources, leadership in innovation, private corporate sponsors for material innovation, growing demands for infrastructure and consumer products, and legislative and fiscal support for development. In addition, war acted as a catalyst to research new chemicals and plastics, which were later applied to consumer products.[22] In an economy that increasingly emphasized commodification, the demand for new products and the perception of modern progress did not cease at the end of wartime.[23] History charts a steady increase in Western preferences for scientific rationale and technological development. In the early 20th century, the United States quickly transformed its agriculturally based economy to industrial production. This trend changed the types of materials consumed and their corresponding processing, technology, automation, and transportation with causes for concern.

While industrial materials have inevitably displaced or challenged older alternatives, several types of substitution exist beyond material-to-material substitution. Material science can substitute processing techniques to reduce energy consumption, capital, or human labor.[24] Experimentation can also change final products' properties, reduce the amount of material needed to manufacture final products (dematerialization), or reduce material toxicity (detoxification).[25] In these ways, material science seeks to increase efficiency to reduce environmental impacts. Despite beneficial intentions, efficient methods have inspired much debate within the green building community, which may identify efficiency as insufficient for sustainability. Nonetheless, efficiency has helped industrial materials grow due to increased profits, safety, and perceptions of eco-friendliness.

Modern architects also advocated for innovative aesthetics, construction methods, and materials. Otto Wagner and Frank Lloyd Wright both supported the use of new materials to develop unique architectural forms.[26] In addition to expanded creativities, industrial materials could also provide an opposite effect of standardization. Modernist architect Le Corbusier asserted, “Standardized materials should replace natural materials, which are infinitely variable.”[27] James Strike claims that Modernism primarily introduced new attitudes toward construction, rather than materials themselves. In other words, Modernists were more interested in the creation of form than materials. Standardized, industrial building materials, prefabrication, and mass production were favored simply because of their ability to produce the desired “kit of parts” for building.[28] The nonhuman environment does not produce standard organic parts; therefore, synthetics were more ideal for modern construction.

Some of today’s architects take an active role to promote material science. Herzog & de Meuron leads material investigations and uses materials as a lens for methodological debates regarding typology, process, and composition. Shigeru Ban also considers the exploration of sustainable materials as an architect’s responsibility to the world and developed his paper tubes as a personal endeavor.[29] In contrast, Peter Eisenman seeks immateriality and abstraction, rather than concrete materiality.[30] Dematerialization is a goal used to justify innovation; scientists can create less dense materials to reduce overall consumption and support environmental, social, and economic prosperity. However, dematerialization may assume all materials are relatively equal in impact; weight or volume reductions are futile if substitutes are more harmful.[31] Designers must not assume that using less of one material relative to another is desirable before assessing the impacts for each material usage.

The globalized network material science promotes can benefit understandings of health, environmental, efficiency, and cost considerations through increased interaction between disciplines. Experts must combine these insights to achieve sustainable material development. Whereas material science originated with solitary inventors, the field is now equipped with universities and corporate laboratories to accommodate the collaboration and research necessary for integrated designs.[32] Due to seemingly unlimited factors and options for material selection, businesses and the public can face confusion without effectively communicated material data.[33] Many organizations and online databases, such as Harvard University Graduate School of Design Material Library, Material Connexion, and Materia, must filter data into usable formats, controlling dissemination and concealment. Despite their limits, databases help to communicate a wide array of possibilities for unique material applications and encourage collective efforts between researchers and with entrepreneurs.[34]

In addition to the drivers for material science growth, traditional materials have faced many barriers that have decreased their use over time. Struggles to use crop-based materials include legal barriers of building regulation, technical barriers due to unproven performance, and commercial barriers of market entry, particularly in response to economic and political interests of competing material industries.[35] For example, straw bale construction is often not included in state building codes, but even when it is allowed, inflexible rules can prevent the use of new methodologies.[36] Consequently, a limited number of crops have been widely used as building materials, primarily straw, hemp, flax, wool, and reed. Also, there has been more enthusiasm for using crop by-products and waste materials than growing crops specifically for building purposes, excluding timber, likely due to lesser risks than specialized production. However, amongst the other hindrances, a psychological barrier to crop-based materials also exists in assumptions concerning performance and reliability.[37] Crop-based materials that have been used in construction, such as thatch and structural bamboo, remain at the periphery of Western building practice because of social stigmas and other assumptions. In accordance with the theme of this thesis, the problematic assumptions of material culture, I will primarily focus on the psychological barriers to crop-based materials in later chapters.

Critiques of material science and advocacy for alternatives

The expertise and benefits proclaimed by material science advocates do not excite all building professionals. Many sustainable designers fear the known and unknown consequences of the speed, content, and power of industrial material innovations. In the pre-modern past, innovations often developed over centuries; more drastic changes now can emerge within several years.[b] Forester cautions that, rather than tailoring human behaviors to natural limits, advanced technology empowers humans to manipulate their environment without full knowledge of the consequences. Unhindered by locally available stocks, materials can be imported or customized. Material expectations are rising as humans consume larger amounts and varieties of materials more quickly.[38] Satisfaction with new materials does not satiate material development; achievement fuels studies for even more new materials and consumption.[39]

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[b] See Appendix A for further detail.

Environmentalists also lament a shift to synthetics, in which plastics and composites are displacing metal, paper, leather, glass, wood, and natural fibers. The use of non-food crops in buildings has a long history; wood, wool, straw, and reeds, among other organic materials, have been applied for millennia.[c] At architecture's origins, all building materials were unprocessed by modern standards; early humans joined and stacked organic matter without working the material.[40] Nonetheless, the use of organic materials in architecture has declined sharply over the 20th century. In 1900, nearly half of materials consumed were from renewable resources. By 1995, only 8% of material sources were renewable. Concurrently, material consumption grew from 161 million metric tons to 2.8 billion metric tons during the 20th century.[41] These shifts cause great concerns of nonrenewable resource depletion and future generations' wellbeing.[42] Synthetics also tend to employ chemical additives, which are difficult to test and monitor. Without long-term trials recording both the duration and magnitude of exposure, scientists cannot be certain of a material's full impacts. As it is difficult to establish a non-harmful level of exposure, environmentalists argue that it is more efficient and effective to utilize materials without chemical additives or with long-term experience to protect human and environmental health.[43]

While all generations after the Industrial Revolution have noted the use of more industrial materials, counter movements have inspired renewed interest in crop-based materials as alternatives in the previous decades. The *Crops in Construction Handbook,* published by CIRIA in Great Britain, details the history, types, performance, and benefits of crop-based materials in support of their expanded use.[44] As a rule of thumb, recycled, minimally processed, and locally sourced materials tend to have less embodied energy than

[c] See Appendix A for further detail.

highly engineered, imported, or virgin resources.[45] With these criteria, crop-based materials can reduce waste through safe biodegradation, provide diverse markets for farmers, and reduce fossil fuel usage through shorter transportation distances and less intensive harvesting and processing than more industrial materials.[46] Not only can these materials mitigate carbon dioxide emissions in the early stages of their life cycle, but they also continue to sequester carbon after their harvest and store it throughout their lives.[47] Like scientific materials, crop-based materials can also tackle the challenges of dematerialization and detoxification. These benefits continue to spur interest in crop-based materials within the sustainability movement.

Like industrial materials, crop-based materials do not have identical properties as a category. Dan Imhoff's book, *Building with Vision: Optimizing and Finding Alternatives to Wood*, is a helpful resource to compare the life spans, resistance, climate, cost, flexibility, insulation, strength, permeability, and other qualities of crop-based materials, such as earth, straw bale, bamboo, paper, and fiberboard construction. *The Art of Natural Building: Design, Construction, Resources* by Joseph F. Kennedy, et. al., provides further detail into natural building materials and strategies to encourage their use within communities. Natural building, as a movement, values social and environmental sustainability, seeks healthy, beautiful, comfortable, and spiritual living environments, and uses easy-to-learn techniques and local, renewable resources. With a regional focus, natural buildings have no standard designs nor universal solutions. They draw on traditional building strategies and are designed to suit the local ecology, climate, and inhabitants of the new building area.[48]

In contrast to accusations of material science's limited scope, natural building strives to be extensive in its considerations. Natural builders closely study the needs of ecological sites and social communities, including toxicity, community impacts, physical site, longevity, microclimate, locality, privacy, and future development.[49] Rather than remain static and resilient, natural building is dynamic and responsive to ecological cycles. Western culture commonly encourages architects to isolate buildings from the natural world, but history and studies have shown that integration is important for both ecological and human health.[d]

However, it is these types of generalizations that contribute to problematic, dualistic thinking that creates opponents to material science as a whole, rather than judging each material as a unique entity. When associating Technology, a meta-category encompassing all technologies, with severe environmental and social disadvantages, societies resist technologies that could yield benefits without the stereotypical harms. Other tendencies can also overlook pertinent material criteria. Material selection resources, such as online material databases, *The Ecology of Building Materials* by Bjorn Berge, and *Crops in Construction Handbook* by CIRIA, often emphasize statistical performance data to compare material strengths and weaknesses. However, some environmental consequences would likely evade a quantitative life-cycle analysis of individual materials. This thesis will delve into the qualitative environmental, social, and economic impacts of materials with various origins and technological inputs to reveal the incongruities of individual traits with categorical assumptions.

Material ambiguity and middle ground

While the environmental criticisms of material science and benefits of renewable resources provide support for crop-based materials, it is too simple to believe all renewable

[d] See discussion of biophilia in “Sustainability Movements, Motives, and Metrics” within this thesis.

materials are environmentally and socially beneficial. Many types of renewable sources exist with different properties and effects, and designers must consider the scale, methods of production, transportation, disposal, and total resource usage, or materials' entire life cycle. Also, "technological materials" and "natural materials" are not as clearly and separately defined by composition or performance as designers may perceive. Many, or arguably all, material possibilities combine technological and natural inputs. Not all material technology conforms to stereotypical view of high technology as intelligent, phase-changing, mechanized, or responsive.[50] *If technology is defined as any human method undertaken to solve a problem, and materials are defined as matter humans use to meet their needs, all materials have a technological component. Likewise, if natural is defined as originating from the Earth, and all available inputs originate from the Earth, all materials also have a natural component.* This relationship will be explored further throughout this study.

The success of material databases, such as Material Connexion and Materia, demonstrate growing interest in green, innovative materials. Within the databases, which contain thousands of material entries, their "Naturals" categories list hundreds of crop-based materials that remain safely biodegradable after processing. Similarly, the *Transmaterial* series has begun to emphasize green materials, rather than innovation in general. The criteria for *Transmaterial* in 2006 were ultraperforming, multidimensional, repurposed, intelligent, recombinant, transformational, and interfacial without mention of environmental considerations.[51] Two years later, *Transmaterial 2* dedicated its introduction to discuss the merits of technology in material sustainability in light of "updated priorities," including rapidly renewable inputs, dematerialization, and increased performance to reduce energy use.[52] Green consumerism and environmental regulations have expanded the market for plant-based products.[53] It is important to support environmentally responsible production and mindsets to ensure continued demand and research in the future yet also remain critical of the broad categorizations they propose.

Conclusion

A brief study of material history and the categories of materials that have emerged over time reveals many key points for further consideration. A key focus of this thesis examines the perceived divide between scientific, technological, and industrial materials and natural, traditional materials. Trivedi argues that material scientists and designers should work to perfect materials and techniques, rather than create new ones.[54] This statement, as well as previous evidence, communicates material science's perceived isolation from natural-labeled materials, despite their shared Earthly origins. Rather than the antithesis to nature, humans and their technology must be revealed as natural with the possibility of symbiosis with nonhuman entities to guide sustainable human action.

The vast changes in material culture over time also explain the misalignment between evolving goals and conditions and more static policies. As policies dictate human action, regulations must properly guide material research toward sustainable development. For example, building codes demand certain technological and industrial materials due to the material culture when codes were written; standards must be reevaluated to reflect current values. Kennedy recognizes, "Though resource issues are often identified as being at the heart of sustainable patterns for building and development, they are totally absent from building codes." Rather than providing purely safety and performance criteria, codes could also address materials' origin, efficiency of use, plans for reuse, and other issues they currently ignore.[55] A shift from anthropocentric, short-term, and project-focused initiatives to a broader scope of longer term and ecological impacts could greatly raise green building standards and cause the public to assess their environmental philosophies and commitments.

Like the codes that guide their actions, most scientists, scholars, and designers seeking sustainability maintain a narrow focus on concrete issues to inform material selection. Studies evaluate material properties, provide recommendations based on statistical data, and call for policies to support their suggestions. Less research analyzes qualitative impacts of material usage, and very little exploration considers public resistance to material acceptance on psychological grounds. Consequently, this study focuses on the latter to explore the underlying assumptions that must be challenged to fully explore material possibilities before providing recommendations for current use and future development.

Kenneth Geiser also recognizes that scientific data and regulatory policies are not enough; the United States requires a change in consumer behavior to attain a sustainable material culture. Geiser states that a sustainable material culture optimizes material value, increases natural capital, minimizes risk transfer between generations, enhances the functioning of natural systems, and ensures no net loss of resources.[56] David Leatherbarrow in his essay, “Materials Matter,” writes that not only does the choice of materials matter but also the ways they are applied. Material orientation and proportions affect environmental and social quality, and designs should enable and sustain beneficial interactions. Materials also reflect societal views and are combined with culture over time, as Bruno Latour conveys in his nature-culture hybrid.[57] The case study of this thesis will reveal the unique, qualitative considerations of material implementation, rather than commending or condemning materials in isolation. This research’s case study highlights the need for more place-based research to illustrate the need for solutions to fit local ecologies, cultures, and economies for success and sustainability.

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The Dominican Republic

National and regional characteristics

The Dominican Republic presents a unique set of criteria to consider in design and development. No single country in Latin America is “typical”; therefore, no solitary conventional approach is appropriate for all regions of Latin America or even for a small, diverse area of the Dominican Republic. As social and environmental differences between regions are primary sources for disputes, external parties seeking to provide assistance or services to the Dominican Republic must carefully consider the disparities within and between nations to devise appropriate solutions. In their studies of foreign cultures, Howard Wiarda and Michael Kryzanek state, “The hardest task in describing a nation other than one's own is to define precisely its special character and culture without falling into the dangers of oversimplification and stereotyping.”[1] Within this study and further investigations, designers must be mindful of limitations and identify both patterns and unique local traits. The varied topography, climate, biodiversity, social organization, and political characteristics of the Dominican Republic present many challenges and opportunities to integrate modern and traditional influences in emerging architecture. A study of these conditions will reveal underlying values and goals that should be reflected and supported through design to achieve beneficial, sustainable development for all stakeholders.

Citizens of the Dominican Republic value the health of their diverse lands, which juxtapose fertile valleys, mountains, semiarid deserts, rich farmland, tropical rain forests, and beaches. Compared to the barren, impoverished land of their neighbor, Haiti, most Dominicans enjoy lush, rich vegetation and over 100 rivers that allow more possibilities for livelihood and material culture. Geographers identify the Dominican Republic as one of the most diverse countries in the world with over twenty distinct regions. The varied topography also yields climatic diversity; residents of the mountains enjoy clear and cool weather, whereas the plains and valleys produce humid and warm conditions. In general, the climate of the Dominican Republic is more temperate and pleasant than many other tropical regions.[2] However, the region is also prone to hurricanes, drought, floods, and earthquakes, which have resulted in complete destruction of areas in the past.[3] Extreme weather, as well as water and fuel shortages and improper land use, has fueled social and national conflict; specialized solutions could resolve issues in all three Es of sustainability by addressing the links between them.[4]

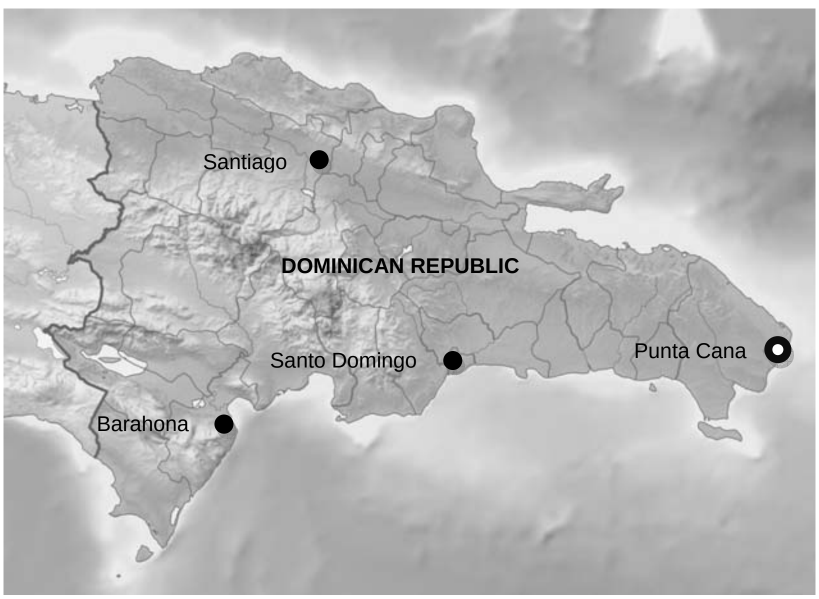

Figure 5: Topography of the Dominican Republic[5]

The eastern third of the Dominican Republic is the most developed, and Punta Cana lies in La Altagracia, the most eastern province of Hispaniola.[6] Punta Cana is recognized for its sandy beaches, which attract many tourists to the area. Consistent weather averaging around 86°F (30°C), abundant sunshine, and little rainfall also contribute to year-round tourism.[7] Punta Cana has thin soil covering a hard limestone base, making agriculture difficult.[8] The regions surrounding Santiago and Barahona are fertile agricultural zones with less development than Santo Domingo, the capital, and the tourist regions.[9] Punta Cana and other developed areas of the Dominican Republic have aimed to increase tourism, boost processing industries for exports, and diversify the economy beyond their former mono-economy of sugar.[10] Tourism has been instrumental to provide employment and resources to local residents in Punta Cana.

Punta Cana must balance its interests in increased tourism with biodiversity and ecological initiatives. Development can cause natural habitat destruction, which is a primary cause of decreased biodiversity. The ecosystems of the Dominican Republic have already faced great damage from local improper land use, international exploitation, and natural disasters. Despite the destruction of over 90% of the Dominican Republic's original forests, biodiversity remains high in Hispaniola. The remaining ecosystems support mosses, liverworts, orchids, mosses, ferns, fungi, bamboo, and pine forests, 45% of which are endemic species. In addition to plant life, Dominican ecosystems accommodate many rare birds, monkeys, rodents, sloths, and insects. Of the Dominican Republic's 217 identified species of amphibians, 209 are found nowhere else in the world, highlighting the need for protection.

In addition to preserving the value of biodiversity, Dominicans fear the links between the elimination of forests and increases in erosion, flooding, soil infertility, and poverty. To protect ecological, social, and economic interests, the Dominican government has established several large national parks. However, private interests continue to threaten preservation efforts. Jaragua National Park, the largest protected area in the Dominican Republic at 1,374 square kilometers, has been debated due to its economically valuable beach real estate.[11] Such conflicts of interests reveal the need for established protections to prevent environmental degradation from past, current, and future development.

Like the land regions of the Dominican Republic, the Dominican people are not easily generalized by race, social status, or customs. Dominican diversity spurs from a long history of imperialism and international contact. The majority of the Dominican population is mulatto, a mixed heritage of Spanish and African ancestry. Very few descendents of the Taino Indians, who populated the island prior to Columbus's arrival, exist due to Columbus's intentional and unintentional exploitation and extermination of the tribe. The subsequent Spanish colonization, importation of African slaves, rise of buccaneers, and French Revolution dramatically changed the cultural practices of the Dominican Republic. Series of imperialistic interventions by France, Spain, and the United States caused political, social, economic, and cultural unrest. When the Dominican Republic gained their independence from Haiti in 1844, the country's identity was unstable.[12] This instability has made the Dominican Republic vulnerable to international influence throughout the 20th century despite its ostensible independence.

Due to these contacts, Dominican culture remains a mix of Spanish, African, Taino, and various European and American influences.[13] Spanish culture generally predominates in language, architecture, religion, agriculture, dress, and institutions. While slaves underwent deculturation processes to weaken uprisings, African culture remains present in the arts, religion, some social and economic structures, and food, mostly in less affluent populations. Taino culture also persists in language, agriculture, food, religion, and art. Religious beliefs are generally linked to class; the middle and upper classes commonly practice Catholicism, the national religion, while the rural poor often practice traditional voodoo rituals.[14] Skin color is also linked with power and class. The middle class consists of the mulatto majority, the white minority dominates the upper class, and dark skin signifies the lower class.[15] Racism exists within all classes of society, presenting further divides beyond their disparate beliefs and practices.[16]

A social rift also exists between the Dominican Republic and Haiti. While Haiti and the Dominican Republic share instability, political corruption, and a lack of international power as commonalities, they have strong conflicts from different histories, social patterns, ethnicity, language, and culture.[17] Many Dominicans consider Haitians and their goods and practices as "dark and barbaric." The shift toward tourism has cultivated a stigma against cutting sugarcane, and imported Haitians are employed to work the fields.[18] Most of these field workers live in *bateyes*, or Haitian ghettos in the Dominican Republic that are isolated culturally, socially, and economically due to racial prejudice and discrimination. While conditions vary with region, bateye houses are often one-story, wooden structures with small rooms and crude sanitary facilities. Few bateyes have access to medical services, schools, electricity, and running water. Consequently, disease, malnutrition, and illiteracy predominate and degrade Haitians' quality of life.[19]

Saskia K.S. Wilhelms details the poor working conditions for Haitian cane workers, which include the denial of food and water, low wages, inhumane treatment by the military, and child labor. Workers are also commonly paid by output, have no opportunities for advancement, and lack retirement benefits, causing them to work long hours into old age. As a result of poor treatment, stereotypes between Haitians and Dominicans are mutual. Some Dominicans accept Haitians while others practice discrimination. Haitians may believe

Dominicans are lazy, cruel, or greedy. In both groups, people can choose to be accepting, hostile, or condescending, causing varied relations between the two nations.[20]

Dominican living conditions vary widely throughout the country. Santo Domingo features modern development around its colonial center, but the city is surrounded by shanty towns. Rapid and uncontrolled growth results in noise, pollution, overcrowding, a lack of infrastructure, and high crime.[21] However, the insufficient housing and services available to urban workers is generally preferable to the conditions in the poorer countryside. Due to the remote locations of the huts constructed of mud, sticks, and thatch, 65% of the rural population lacks potable water, 25% lacks electricity,[22] and illiteracy and malnutrition rise as in the bateyes.[23] Veron, an impoverished town where many workers of the Punta Cana resorts reside, faces similar challenges of poor sanitation, overcrowded schools, crime, and insufficient medical attention.[24] However, the improvements in Veron above highly urban or rural locations demonstrate the possible benefits of First World development in the Dominican Republic.

Many of the current conditions in the Dominican Republic present opportunities to improve residents' quality of life. Of its population, 42% lives below the poverty line, 14% is unemployed, and laborers have few rights.[25] Most farmers produce cash crops and must rely on storeowners to sell their crops, preventing self-sufficiency. The gaps in healthcare could be filled with more healthcare facilities and practitioners. Similarly, only 17% of rural schools offer the required six years of primary school; students need more educational opportunities. However, with increased education, the Dominican Republic has experienced "brain drain," with many young Dominicans emigrating to live in New York City.[26] Some older Dominicans fear emigration is eroding Dominican family values in favor of consumerism, threatening their cultural identity and preventing localized development. In order to retain young, educated citizens, more attractive opportunities must be available to Dominicans, and social norms of negrophobia, conservatism, misogyny, homophobia, Eurocentrism, and upper-class biases must be counteracted with understanding and equality.[27] Wiarda and Kryzanek also support privatization, as the government is the largest landholder, further democratization, as power remains concentrated in the hands of a few, and increasing exports and foreign investment to strengthen livelihoods and maintain young citizenship.[28]

However, when facing development from external stakeholders, the Dominican Republic struggles to maintain the core values of its society due to the vulnerability of both its institutions and identity. Dominicans are characterized as gentle, friendly, generous, hardworking, and loyal people. In business and daily living, Dominicans are known for impulsivity, choosing to live in the moment instead of formulating careful plans.[29] It is a family-oriented society that values close interpersonal relationships, trust, and confidence. However, migration, urbanization, feminization of labor, and international influence have already begun to shift these core values, traits, and traditions.[30] While families used to enjoy and take pride in lengthy, prepared dinners, many families now order fast food. New working hours now exclude the traditional, long afternoon siesta.[31] Many of these shifts in practices suggest that Dominicans are adopting a more global perspective that equates time with money, speeding up their former unhurried lifestyles.

Vernacular and development

Throughout history, the Dominican Republic has relied heavily on its natural resources for building materials. Supplies of stone, marble, limestone, pine, ebony, and mahogany provided ample material for centuries. Prefabricated materials and modular components were not used in Dominican architecture until the late 1800s.[32] While reinforced concrete is influential in current architecture, palm trees remain popular in home construction due to their ubiquity, suitability, and traditional use by the Taino.[33] Builders slice palm trunks into thin planks to construct walls, paint the boards vibrant colors, and use fronds as roof coverings.[34] Industrial practices have displaced the use of some traditional materials, but many residents continue to rely on local resources for building construction.

To chart architectural evolution more closely, Isabel Zakrzewski Brown identifies four periods of Dominican architecture, and each is a direct result and symbol of important stages in Dominican development. First, colonial architecture began with Columbus and fulfilled needs for religion, health, defense, residence, and sugarcane production. Most buildings were built of stone or brick, and many displayed Spanish prestige. Secondly, Republic era buildings provided homes and structures for the rising urban middle class, which developed from the success of the sugar industry. The newer residences of the 1800s were similar throughout the Caribbean and New Orleans and were light, open, and airy in response to the warm climate.

Thirdly, the Trujillo style marks an abrupt shift into modern industry and contemporary international style.[35] Industrialization and mass urbanization began under Trujillo and continued to build infrastructure throughout the 1970s and 1980s. Despite corruption and vast social injustices, the government invested in extending electricity and factories to process raw materials and produce consumer goods during Trujillo's reign from 1930-1961. In contrast to the original monoculture of sugar, new production featured manufactured cement, paint, wire, printing, paper, footwear, textiles, cotton, salt, gypsum, dairy, chocolate, tobacco, beer, rum, batteries, and furniture.[36] Today, less than 33% of all construction materials are imported due to domestically produced tiles, cables, gravel, sand, clay, piping, metals, paint, and cement. New production allowed Dominican builders to use a greater amount of industrial materials, such as cement block, in Dominican buildings. Increased construction also employed many unskilled laborers, and infrastructure allowed tourism to grow in the 1980s, which in turn spurred more construction.[37]

The Industrial Incentive Law of April 23, 1968 also encouraged investment in new industries with the objective of creating lasting employment, income, and diversity. The law established free zones and business categories as incentives. Free zones have been more effective at creating jobs than other industrial sectors but are more vulnerable to global trends and encourage low wages to attract investment. Others caution that, although industries in free zones must be light and environmentally clean, factories are capital intensive and promote only consumer goods, not the production of capital goods.[38] Many residents also debate whether funds and attention should be allocated toward industry or agriculture. Agriculture declined in significance during the 1970s and 1980s as tourism, manufacturing, and mining grew. Farming accounted for 60% of the labor force in the 1960s,[39] but today agriculture provides only 15% of employment. Sugarcane, coffee, cotton, cocoa, and tobacco are the Dominican Republic's most prevalent agricultural products, and foodstuffs are the country's primary import, indicating a lack of self-sufficiency.[40] Without the ability to provide for basic needs, the Dominican Republic is liable to trade deficits and international dependencies.

As the fourth and final established Dominican stylistic period, contemporary architecture is more modern and sleek. Many current developments feature multi-story buildings with glass windows. Such buildings follow a modern international style that rejects local history. However, other contemporary buildings are postmodern and reflect various contextual influences in an eclectic style. Postmodern architects strive to capture individual expression and the local flora and fauna of the Dominican Republic.[41]

However, a study by Maria Eugenia Palacios Guberti reveals more lasting vernacular traditions in Dominican housing construction. The majority of Caribbean architecture is very heterogeneous and cannot be captured under a single style, retaining Spanish, British, French, Dutch, Danish, Taino, and African influences. In Guberti's study, rural Dominicans were relocated from their vernacular dwellings, made of palm wood walls with cement floors, to modern, concrete block housing designed by specialists. Despite the altruistic intentions of the project, residents expressed greater dissatisfaction with their new dwellings. Specifically, the concrete could not withstand natural disasters and crumbled with age, and the buildings' standard form and layout provided little shade to sit outside and less air circulation to cool the interior. In addition, residents perceived indoor bathrooms as unsanitary, conveying a divide in cultural interpretations. Most importantly, residents were not consulted during planning, design, or construction, and the new houses were not flexible to changes. Guberti says, "Housing is not only a noun but a verb, for it involves the process by which a community/society builds its dwellings." In order to build appropriately for users and their contexts, designers must consult residents to fulfill their requirements and employ the wisdom and experience accumulated from local living over time.[42]

Guberti's study is only one example of the Dominican Republic's varied relationships with external developers, particularly the United States. The United States' interference in the Dominican Republic dates back to Roosevelt's corollary to the Monroe Doctrine, proclaiming the United States as global police. The United States acted in the Dominican

Republic from 1900-1903 to combat its near-bankruptcy and continued under Taft and Wilson. The United States' strong presence has brought economic benefits and protection but also exploitation and unwanted intrusions, raising mixed sentiments regarding international relations within the Dominican Republic. Dominicans seek independence but also desire international support. With limited resources, decision makers often must choose to satisfy immediate needs or invest in the future, and external assistance can ease their sacrifices. While the United States dominated Dominican banking and transportation to its own benefit, its actions also helped stabilize Dominican finances and improve infrastructure.[43] Likewise, the United States put pressure on the Dominican Republic to democratize, which gave citizens more power against dictatorship, but Dominicans were unsure of the suitability of democracy for their culture.[44]

Sugar production particularly epitomizes the Dominican Republic's vulnerability to outside forces. The Dominican sugar industry started under Columbus as a profitable export but resulted in seasonal unemployment and health problems from workers' hard labor.[45] The production of exports also makes the Dominican Republic very economically reliant on other countries, particularly the United States, its largest trading partner. The importance of trade relations gives the United States considerable influence in the Dominican Republic, affecting its politics, military, economy, culture, and daily life with many benefits but also many costs.[46] However, regardless of the advantages and disadvantages of interference, which vary between specific actions, interventions indicate a lack of independence and the perceived lower status and agency of the Dominican Republic by First World nations. While the United States has brought Western initiatives to the nation, it has not solved its underlying problems of poverty and inequality, leaving the Dominican revolution unfinished.[47]

Consequently, international relations are a key source of debate within the Dominican Republic and other Third World countries. Other Latin American countries see the Dominican Republic as an unfortunate example of small countries' vulnerability to giant powers. "Suprasovereignty" describes an unequal partnership between nations, where the United States is the main beneficiary and the Dominican Republic is the pawn. However, proponents have caused the Dominican Republic to expand trade, diplomatic, and international relations in Western Europe, the Middle East, and Asia. As a member of the United Nations, the Dominican Republic is likely to continue its involvement in international affairs. However, it is uncertain whether globalization will increase the Dominican Republic's influence and amicable relations or threaten its independence.[48]

Tourism and ecotourism

While a history of imperialism, exploitation, and suprasovereignty creates skepticism regarding global exchanges, international assistance and tourism can provide many benefits to the Dominican Republic. Today, service industries account for 68% of the Dominican Republic's GDP and 63% of its employment, and many of these services cater to hospitality.[49] Campaigns for tourism began with Trujillo; he commissioned the Embajador Hotel in Santo Domingo to encourage visitors. Civil war following Trujillo's reign deterred tourism, but the 1960s brought renewed interest in tourism to balance the trade deficit. In 1971, the government issued incentives to stimulate the development of hotels, recreation facilities, and cultural experiences to provide more attractions beyond the beaches. The United States primarily responded to these incentives and remains the prime developer today.[50]

Tourism continued to grow throughout the 1970s. Santo Domingo became a stop for cruise ships, and La Romana and Puerto Plata emerged as secondary tourist locations. As with almost all Dominican exports, the United States was and is the largest tourism customer. Americans were 72% of all tourists to the Dominican Republic in 1977,[51] compared to 48% between the United States and Canada in 2011.[52] Consequently, the Dominican Republic has great interests to maintain political stability and goodwill with United States patronage in order to protect its tourism livelihood.

However, many critics of the tourism industry recognize the inequalities present in the growth that tourism brings. While economic growth is positive overall, it is concentrated in tourism, free trade zones, and telecommunication industries. Tourism counteracts chronic unemployment, underemployment, and seasonal unemployment, but many residents remain without potable water, electricity, sanitation, healthcare, education, and infrastructure in rural areas.[53] Tourism has been one of slowest industries to adopt social responsibility practices, and most hospitality businesses cite increasing profits as a far superior goal to reducing environmental impacts.[54] However, advocates recognize that tourism can either be a tool or threat to local interests and global sustainability, depending on the type, size, location, and methods of its implementation.[55] The concept of ecotourism seeks to correct the inequalities that mainstream tourism can foster, creating businesses that are beneficial to all stakeholders, and, therefore, sustainable.

The definition of ecotourism has evolved over time and currently lacks unification, causing confusion and misconceptions regarding its intents and effects. Hector Ceballos-Lascurain coined the term *ecotourism* in 1983 to signify "travelling to relatively undisturbed natural areas with the specific object of studying, admiring and enjoying the scenery and its wild plants and animals, as well as any existing cultural aspects (both past and present) found in these areas." Stated interests in nature and culture cause confusion between sustainable tourism, nature-based tourism, and ecotourism. These terms are not synonymous but are linked in ideals. Dowling categorizes ecotourism as a specific subset within alternative tourism, natural tourism, and finally sustainable tourism (Figure 6).

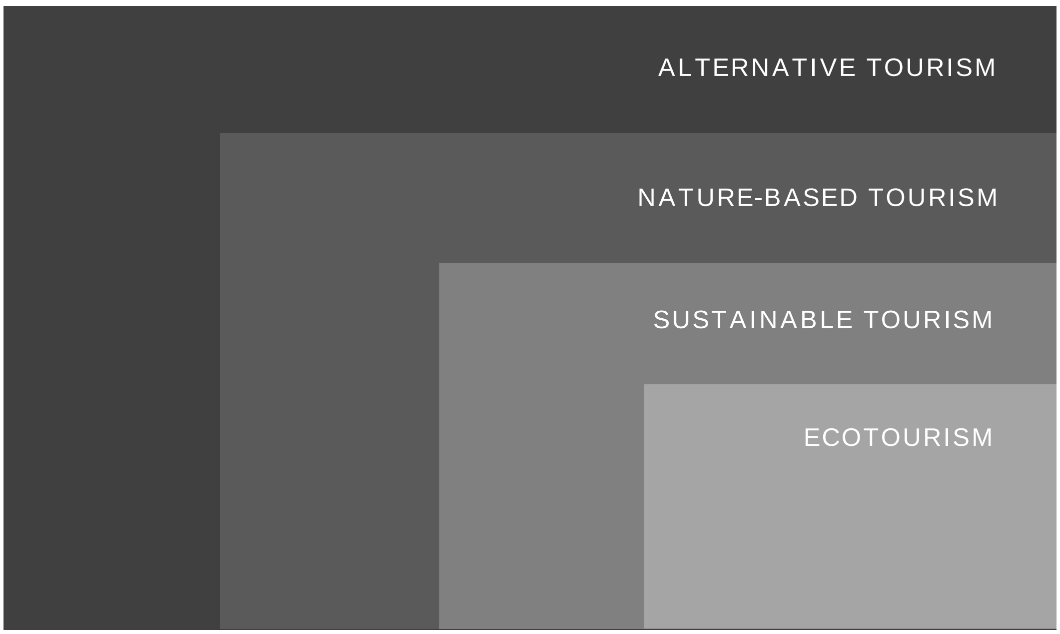

Figure 6: Hierarchy of tourism categories[56]

In an analysis of various organizations' definitions of ecotourism, Fennell (1999) found an interest in nature, contributions to conservation, reliance on protected areas, and local and long-term environmental and community benefits as the most prevalent traits.[a] However, other common, distinguishing tenets of ecotourism include an educational component, low-impact travel and activities, and ethics regarding external resources and internal operations.[57]

While sites vary in the balance of these components due to their activities and interests, the level of commitment to ecotourism values is also not constant across ventures.

[a] See Fennell (1999) for a full chart of ecotourism definition components.

Page and Dowling recognize the hijacking of ecotourism into the realm of greenwashing and buzzwords. International travel that implements a few features to increase efficiency or decrease waste does not fully embody the holistic goals of ecotourism but is often marketed as such to build desirable, green images. Likewise, resorts that provide access to natural areas without ensuring the continued health of the ecosystems and local communities are simply unsustainable forms of nature-based tourism. Such ventures that claim to be ecotourism damage the image of efforts to spread sustainable ethics and practices through tourism.[58]

Greenwashed claims of ecotourism are prevalent because ecotourism's fragmented definition relies on value judgments, rather than unified, factual evidence.[59] For example, what links distinguish nature-based tourism? Must ecotourism exceed minimum legal requirements to support host regions' natural and cultural interests and/or surpass the efforts of less sustainable competitors? What criteria must tourism meet to earn the title of ecotourism? Should criteria vary with scale, remoteness, organization, etc.? Tensions arise between nature and culture as tourism commodifies environments; how can ecotourism mediate human contact and protections? These uncertainties highlight a need for oversight, standards, and metrics to convey quality to consumers and increase business accountability.[60]

Several organizations have already begun to gather international support and collaboration to define and enforce ecotourist goals. The rise of environmentalism in tourism publicly began at the United Nations Stockholm Conference in 1987 and continued at Earth Summit in 1992 with the Rio Declaration and Agenda 21.[61] The World Tourism Organization also identified a set of relevant indicators for sustainable tourism in the 1990s.[b] Subsequently, various ecolabels and certification programs, such as Green Globe 21, have

[b] See page 30 in Weaver (2006) for a full list of sustainable tourism indicators.

emerged to specifically indicate sustainability within the tourist industry.[62] These developments could greatly contribute to further definition, standards, and Corporate Social Responsibility (CSR) within the ecotourism industry.

Orams (2000) also links variations in environmental and community initiatives to the ethical component of ecotourism. With anthropocentric ethics, humans perceive all tourism to be ecotourism because they have no responsibility to nonhuman entities. In contrast, a high level of human responsibility demands infinite active participation to protect resources and wellbeing. Therefore, the way humans perceive their relationship to nature is closely tied to the actions they undertake, including tourism. In addition to the ethics of hotels and resorts, the ethics of individual tourists vary as well. Consequently, ecotourists vary across society, including rustic adventurers, groups of students or scientists, and "ego-tourists" who visit remote locations to brag and differentiate themselves, among others. The belief that all ecotourists are environmentalists or highly educated is a common but risky misconception; all tourists have varied motivations for travel, behaviors, and values. As all ecotourism cannot be generalized as a group, critics and advocates must also consider the actions of individuals on a case-by-case basis.[63]

Due to disparate guest motivations, ecotourism, ironically, can potentially be more harmful than mass tourism. Tourists who feel entitled to experience rare, fragile ecosystems and communities without a stewardship ethic can threaten local stability.[64] Critics also identify privation that excludes or dislocates local societies, the use and extraction of scarce resources, the clearing and wearing of land for transportation and foot travel, the spread of exotic pathogens and species, and the ability of laudable practices to mask degradation as weaknesses of ecotourism.[65] Many sociologists remain cautious of increasing developing countries' dependencies on the demand of developed nations. Reliance may allow low-wage and unstable employment, exploitation, and revenues that erode with competition.[66]

However, ecotourism continues based on the justification that the benefits can outweigh the risks. Alternative tourism, which includes homestay, volunteerism, and ecotourism, generally contrasts conventional mass tourism by claiming no distinct seasonality, no dominant markets, less commercialization, a smaller scale, lower density, more dispersal, local ownership, a higher multiplier effect, community control, and long-term planning.[67] Ecotourism is more likely to provide stable opportunities for enterprise, employment, and investment by interacting with local populations, improving communication and transportation, providing markets for their natural and cultural resources, and increasing intercultural understanding and peace.[68] Ecotourism specifically can teach visitors about foreign ecosystems and communities, instill a sense of ecocentric, global ethics, and facilitate preservation, rehabilitation, and social activities through increased funding, revenues, and donations.[69]

Many works outline recommendations or criteria to balance the benefits and costs of ecotourist ventures between all stakeholders and create sustainable operations. The United Nations Environment Program (UNEP) recognizes tourism enterprises, local communities, environmentalists, and tourists as stakeholders within ecotourism, each with different goals and intentions. Governments must play a strong role to regulate and mediate conflicting values, build networks, and disseminate information, as well as set priorities, implement and monitor strategies, and manage growth, conservation, health, and security to reap positive benefits.[70] However, rather than government regulation alone, planning processes must be participatory. The presence of tourists can cause disputes if other groups do not accept their visits; communication is key to increasing understanding and consideration between them.[71] Since the 1980s, ecotourism has counteracted the development of tourist ventures that do not consult local populations. However, decision makers still often fail to address local needs and concerns, indicating opportunities for improvement.[72]

In addition to stakeholder involvement, UNEP calls for a broader, long-term view for ecotourism. With its interests in nature conservation, ecotourism was built on the need to consider, monitor, and adapt to changes in ecosystem life cycles.[73] Over time, increasing emphasis has been placed on consumer behavior, encouraging tourists to reduce, reuse, and recycle as well as instill ethics and respect for their environments. James Sweeting, however, demands further consideration of the design, construction, and operation of ecotourist facilities and infrastructure, which often change the daily life and future of the community.[74] Facilities present another opportunity to support the local community by working with local architects and knowledgeable residents, using locally sourced, renewable resources, and planning to reduce waste at the end of buildings' useful life.[c]

The need to maximize benefits and minimize costs is especially imperative for current times because ecotourism is recognized as the fastest growing segment of tourism, particularly in tropical regions.[75] The majority of tourists traditionally visited developed European or North American locations, but tourism to the less developed tropics, including East Asia, Latin America, and Africa rapidly increased in the 1980s and 1990s due to increased political stability and safety, reduced flight costs, and more airline access.[76] International tourism increased 30 fold between 1950 and 2004, and spending increased by a factor of 235.[d]

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[c] See page 78 in Sweeting (1999) for a full list of facility design and construction recommendations.

[d] 23 fold increase in spending when accounting for inflation.

Concurrently, awareness of sustainability issues within environmental, social, economic, and cultural spheres increased and spurred First World desires to assist those in need. These changes illuminate both the opportunities and risks of partnerships between the developed and developing world, and the impacts of the outcomes are elevated due to the fragile conditions of many tropical ecosystems and local communities.[77] This rapid growth also suggests that alternative tourism may emerge from its niche to become mainstream.[78] The possible influence of ecotourist ventures to cause mass tourism to become more sustainable could have far-reaching benefits beyond local sites and communities.[79]

Grupo PUNTACANA

The developments of Grupo PUNTACANA provide an exemplary model for tourism to create environmentally, socially, and economically beneficial solutions for all stakeholders through increased consideration and collaboration. Once a poor fishing community that burned wood to sell charcoal, Punta Cana is now home to schools, shops, biodiversity labs, and the third busiest airport in the Caribbean.[80] Punta Cana also boasts the highest per capita income in the Dominican Republic and a zero unemployment rate. The private sector funded virtually all of this development, reducing pressure on public resources.[81] Current tourism in the Dominican Republic and Punta Cana includes both mass tourism, which primarily consists of all-inclusive resorts and cruises, and sustainable tourism, which follows standards promoted by the Caribbean Alliance for sustainable tourism. The tourism industry in the Dominican Republic has surpassed all other Caribbean tourism in recent years, proving its economic viability. The number of hotel rooms increased from 1,600 with $55.4 billion in expenditures in 1997 to 59,000 rooms with $3,127 billion in expenditures in 2004. In 2006, tourism generated 50,000 direct employments and 30,000 indirect employments in the Dominican Republic. Of these employees, 97% are Dominican, and 30% are female, generating livelihood for local citizens.[82]

Despite increases in local income, mass tourism in Punta Cana has significant costs for the local community. Resorts that are all-inclusive divert business from local restaurants, small businesses, and cultural centers, causing them to fail and restricting sources of employment. In addition, the substantial resources that resorts consume to accommodate large volumes of guests can damage and pollute the area without careful planning. However, Grupo PUNTACANA recognizes the possibility for symbiosis through ecotourism, where the preservation of nature and cultural assets can build a profitable and enjoyable business. Their venture is not solely aimed at building a successful business for a few but "learning how to build a community that is lasting where there is a future for everyone."[83]

When Ted Kheel, an American labor lawyer, and a group of American investors purchased thirty square miles at Punta Cana in 1969, the area had no sanitation or drinking water, low literacy, no infrastructure, inadequate housing and education, and a government without means to support communities in need. Through a partnership with Frank Rainieri, a Dominican restaurant owner, Oscar de la Renta, and Julio Iglesias, Grupo PUNTACANA sought to bring development, employment, and services that would improve the quality of life of the local people. Punta Cana needed social development and the means to live sustainably to avoid destruction from within, as threatened by the deforestation from charcoal production. Grupo PUNTACANA's mission and master plan serve three purposes: to provide a safe and enjoyable environment for tourists, to protect the living environment, and to contribute to human welfare. As nature is the greatest attraction of the area, businesses must preserve nature's health and beauty not only for local sustainability but also the continuity of their business; like all sustainable planning, the tenets of Grupo PUNTACANA's mission are inherently linked for success.[84]

To construct their facilities, Grupo PUNTACANA hired Dominican architect Oscar Imbert to incorporate Dominican, Spanish, and Awark Indian themes and use local materials where appropriate. Imbert's talent to meld modern and traditional influences was ideal to present the unique culture to high-class clientele. Through Imbert's designs, the traditional thatched roof of the Taino Indians reemerged after almost disappearing from use in the Dominican Republic from the 1930s to 1950s. The thatched roofs and Cana tree supports chosen for the hotels and airport are renewable, local, and inexpensive materials, making them regionally appropriate, historical, and sustainable choices. The use of local builders through a bid process also increases local employment beyond the hospitality industry.[85]

Over its 40-year life, Grupo PUNTACANA has undertaken many sustainable initiatives. In 1972, Rainieri built the first school at Punta Cana for workers' children. Later improvements include staff housing, a church, a plaza, various infrastructure, Punta Cana International School in 2000, and the Ann & Ted Kheel Polytechnic School in 2004,[86] in which Grupo PUNTACANA invested $785,000 to supply computers, science labs, a library, additional classrooms, and workshops.[87] As tuition is prorated according to parents' salaries, these schools are egalitarian and mix children of different social classes. These projects have brought significant changes to unite the community and improve the standard of living. In the long term, rather than suffering the "brain drain" present in other parts of the Dominican Republic, Rainieri hopes to create advanced jobs in Punta Cana similar to the ones currently sought in the United States. Many of these jobs may focus on environmental rehabilitation and health to continue the mission of the PUNTACANA Ecological Foundation (PCEF) and Punta Cana/Cornell Biodiversity Center. American and Dominican students already study the flora and fauna of the region through the Biodiversity Center. Dominicans are beginning to recognize the need for scientists in sustainable tourism and environmental management to provide the proper tools and research for decision making, promoting the growth of scientific fields in Punta Cana.[88]

PCEF's biodiversity research has also developed new crops, farming methods, water treatment, coral remediation, education, and flora and fauna protections. To remedy the thin, poor soil and support their zero waste initiative, PCEF has launched "Lombricompost" to convert solid waste into rich soil through vermiculture, or worm composting. Composting processes 200-500 pounds of organic waste monthly without additional inputs, making the process well suited to Third World applications. The resulting soil supplements PCEF's Sustainable Agriculture program to grow and sell produce to local restaurants and residents. Similarly, a beekeeping program produces honey for the hotels' use. Lastly, while Punta Cana's golf courses would normally be a symbol of unsustainability, PCEF has developed a hybrid grass to minimize its chemical treatments and irrigates with hotel grey water output.[89]

In addition to initiatives that connect the organizations to the environment and community, Grupo PUNTACANA also seeks to engage their guests and workers in sustainable activities to avoid the common schism between tourists and the surrounding community. In addition to the research labs available for visit, PCEF maintains a 1,500 acre reserve with trails, freshwater lagoons, a petting zoo, and educational information. Guests are also informed of the zero waste initiative and are persuaded to conserve.[90] Management encourages workers to contribute ideas to improve initiatives and guest experiences, building interpersonal support within the company. Worker satisfaction builds community pride and attachment, which is vital to the health of the environment and organization.[91]

Most importantly, Grupo PUNTACANA considers sustainability as a process, not a destination. The resort and its programs are unfinished experiments, and Grupo PUNTACANA continues to add responsibilities to its mission. Kathleen and Udayan Gupta state, “There is a school of thought in development that argues that economic change- especially in developing countries- cannot happen without wiping the old slate clean and starting afresh. Punta Cana is proof that there is another way.” Grupo PUNTACANA has successfully built on the tradition and originality of the area, utilizing and protecting human culture and nonhuman environments as fuel for enterprise and security. As a result of both preservation and change, “Punta Cana's culture is not Dominican... Punta Cana has a culture of its own, a culture that has come from the many influences that have shaped it.” While some may lament the loss of certain traditional practices, no culture persists statically in isolation, and changes that allow the residents of Punta Cana to live healthier and more sustainable lives should be welcomed and celebrated. Punta Cana, as a case study, proves that sustainable development is possible, but it must arise from internal resources and assets, not externally imposed ideas and technologies. With its success, Punta Cana will likely serve as a catalyst for further development, easing future sustainable development with its experiences and knowledge to overcome the common tension between development and sustainability.[92]

Conclusion

The Dominican Republic presents many challenges and opportunities for sustainable development. No single factor can explain the Dominican Republic's problems as a nation.

Beyond the international conflicts it faces, Hispaniola is not united from within itself; classes are deeply divided in terms of race, wealth, values, concerns, and opportunities. Particularly in Dominican cities and resort areas, the poverty of lower classes is juxtaposed with the wealth of the upper class and tourist industry. Wiarda and Kryzanek recognize the tensions of these incongruities as they state, "The Dominican Republic represents an uneasy joining together of tradition and modernity, conflict and stability, wealth and poverty, idealism and cynicism." The Dominican Republic has often handled its contradictions with uncertain surges and throwbacks, rather than gradual, evolutionary succession.[93]

Sustainable development provides a possible path to overcome the immense poverty that weakens all sectors and facets of Dominican life. As a small and vulnerable country that has been forced to adapt to global changes, the Dominican Republic may be understandably cautious of further interventions. Past globalization has had mixed impacts; some changes weakened popular organizations and fostered further inequalities while other effects strengthened support and democracy.[94] In Punta Cana, ecotourism has helped build community, health, education, vitality, and local equality; these effects would be desirable throughout the Dominican Republic. Further research should identify the array of factors that promote social equality through sustainable tourism and development.

Subsequent chapters will explore philosophical and material questions regarding tourism in Punta Cana. For example, how could Grupo PUNTACANA extend their zero waste initiative to include their buildings? How does the choice of building materials affect the environment, society, and economy of Punta Cana? Gupta and Zaborowsky provide a useful history of Grupo PUNTACANA, but the narrative could benefit from more detailed analysis that directly compares the benefits and costs of their programs to less sustainable, mass tourism. In "Investigation of Material Application in Punta Cana," a comparative analysis of bamboo and concrete will illuminate tradeoffs within all three Es of sustainability. In addition, the variations in underlying values between stakeholders in Punta Cana are apparent but have not been fully analyzed in their relation to sustainable tourism and development. What are the values of stakeholders in Punta Cana that drive successful sustainable development, and how can these values be fostered elsewhere? When confronted with sharply different values and backgrounds, how are opposing viewpoints mediated and represented? Such questions deserve further investigation to apply the lessons of Punta Cana to locations with different contexts and criteria.

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[92] Ibid. 9, 87-101.
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M E T H O D O L O G Y

The intention of this thesis is to promote further qualitative analysis among designers when making material selections for exterior and interior building applications. By considering human and nonhuman needs as an integrated system within the design process, the building industry can produce more sustainable structures and development. This exploration has a theoretical basis with a practical application. The theoretical foundation consists of environmental logics and philosophies that define sustainable actions, each with distinct concerns and goals. The application of a broad conceptual framework to a specific time and place will clarify both the abstract content and its relevance for modern society.

Objectives

- Analyze the rationales that divide green advocates among technological, regional, and stylistic logics and present a foundation for less dualistic thinking regarding the construction of new, sustainable buildings.
- Justify zero waste as an appropriate, sustainable goal that can overcome mainstream assumptions and broaden designers' receptivity to unconventional closed-loop materials.
- Compare the environmental, economic, and social advantages and disadvantages of bamboo and concrete in their proposed applications in Punta Cana, Dominican Republic.

Hypothesis

Zero waste, as an interpretive framework, can overcome the complications that arise from conventional dualistic thinking and provide appropriate criteria to aid sustainable material selection.

Research Design

This research employs reflexive methodology in order to explore the underlying conceptions that guide human actions within their environment. Reflexivity is a subset of reflective research, assessing "the relationship between 'knowledge' and 'the ways of doing knowledge.'"[1] Rather than data-oriented or hermeneutic approaches, the "Results" chapters are interpretations with reflective themes that identify underlying meanings, analyze why certain interpretations predominate, and present the possibility of counter-images.[2] According to David Wang, interpretations explore the assumptions of a coherent world rooted in past or present social situations, and social situations are equally products of human assumptions. The narratives that humans construct not only perpetuate certain ways of thinking but also shape the physical, social, and cultural environment, signifying their importance.[3] Therefore, an epistemological study of environmental building materials is critical to understand the mechanisms of knowledge production and inspire new material ideologies and actions in the design field.

Interpretive research also indicates the exploration of a wide scope to explain common ideologies. Wang defines interpretive research as "investigations into social-physical phenomena within complex contexts, with a view toward explaining those phenomena in narrative form and in a holistic fashion."[4] The final narrative product employs both careful interpretation and reflection.[5] Consequently, each "Results" chapter will contain a reflexive interpretation of the epistemology of a given dualism within the context of sustainable architecture and development, exploring environmental, social, cultural, political, and institutional factors and impacts on a variety of levels. Each reflection will present the possibility of counter-images, or more sustainable alternatives for conceptualizing human-environment and interpersonal relationships.

In addition to the conceptual framework of critical interpretations, the "Results" chapters will integrate an analysis of the environment, economy, and culture of the Dominican Republic into a critique of dualistic thinking regarding building processes. Although the dualisms chosen to investigate are extracted from Simon Guy and Graham Farmer's "Reinterpreting Sustainable Architecture: The Place of Technology," each set of dualisms was intended to relate to specific confrontations present in the current time and place of Punta Cana. In Linda Groat's terms, the combination of theory and context is designated as an emancipatory system of inquiry with historical situatedness.[6] The synthesis of dualistic theory and the conditions of the Dominican Republic employs both research and design inquiries. The research inquiry is "an explanatory system with use beyond the confines of one place and time," whereas the design inquiry is situated within a given context.[7] Accordingly, each "Results" chapter will detail theoretical grounds and draw upon the Dominican context to illustrate and apply the discussed concepts.

Upon conveying the history and rationales of the three sets of dualisms, this thesis will present a resolution capable of overcoming problematic ideologies. An examination of zero waste ideals will reveal the advantages of supplanting dividing dualisms with a shared goal. While other initiatives may serve as common, uniting goals, this thesis chooses to study zero waste due to its relevance for current times and the Punta Cana region of study. The benefits of zero waste are critical in Punta Cana, which relies on the beauty and health of its ecosystems for tourism and subsistence. Grupo PUNTACANA has already identified zero waste as one of its missions, and as waste is a key concern of tourism, zero waste initiatives indicate intentions of ethical and symbiotic resource use in support of sustainable development. In addition, this thesis investigates the realization of zero waste, a strategy popularized by William McDonough and Michael Braungart's 2002 book, *Cradle to Cradle: Remaking the Way We Make Things*. Cradle to cradle design has inspired many professionals over the past decade, yet it has met criticism due to the lack of concrete examples demonstrating its feasibility. By supporting the ideology of zero waste with a relevant case study, designers may recognize the potential pathways and value of zero waste interventions.

Finally, "Investigation of Material Application in Punta Cana" will contain comparative, qualitative life-cycle analyses of bamboo, a crop-based and zero waste material suitable for construction in Punta Cana, and concrete, the prevailing construction material in the Dominican Republic. The case study will apply and illustrate the concepts of the analyzed dualisms and the zero waste resolution and make tentative recommendations for materials for new construction in Punta Cana. The analyses will compare the environmental, economic, and social impacts of each material's extraction, production, transportation, installation, operation, and disposal. The intended applications of the study include hospitality structures for PUNTACANA Resort and Club and housing for residents of various income levels in Punta Cana's region. While the analyses will include quantitative data where appropriate, the study will emphasize less quantifiable aspects of material usage within and beyond the project site, such as ecosystem integration and health, social dynamics, and cultural receptiveness. The information gathered in this study may be helpful to direct ongoing residential construction in a safe and sustainable manner and to guide Grupo PUNTACANA's future developments as parts of their property holdings, such as Playa Sorena (18.522°N, 68.365 °W), currently remain undeveloped.

All chapters will utilize relevant written and digital sources to inform both philosophical and applied arguments. In addition, a site visit undertaken at PUNTACANA Resort and Club, Veron, and the surrounding area in January 2011 will provide insights into current cultural practices, ideals, and user and environmental needs excluded from textual sources. Only by experiencing the local environment and users' interactions within it can designers properly anticipate the implications of their designs; therefore, a site visit was imperative to the success of the project. Observation and discussion of the resort and landscape revealed factors imperative to consider in design planning and execution. During the site visit, members of PUNTACANA Foundation voiced a zero waste goal for daily consumption at their eco-resort. Due to the specificity of these material investigations to their resort, the data and analysis provided within this thesis are likely to appeal to the Foundation to expand their zero waste goal to include future buildings and renovations, supporting sustainability and other benefits in the wider community.

Precedents

Many precedents for interpretive study exist within the fields of architectural theory and sustainable development. Architectural theory, in general, has moved away from its origins of observing, recording, and professing the value of specific strategies and patterns toward analyzing the underlying values that guide actions. Contemporary architectural theory studies changes in values and practice over time, connecting architecture to its wider cultural contexts. In particular, Gottfried Semper, a prominent architect and critic of the 19th century, provides exemplary analyses that link inner conceptions to manifestations. Like this study, Semper's renowned book, *The Four Elements of Architecture*, largely centers around materials employed in architecture. While Semper's key interests for materials are stylistic and aesthetic, the interpretive framework Semper employs can translate to guide current research of sustainable materials.[8]

In *The Four Elements of Architecture,* Semper identifies the hearth, roof, enclosure, and mound as the four elements. Each element corresponds to a material category: ceramics, carpentry, weaving, and stonemasonry, respectively. By stating this correspondence, Semper appears to argue that architecture is reducible to its physical materials and the processes associated with their use.[9] However, the use of the term "elements" is misleading; rather than referring to material elements and the forms they assume, Semper clarifies that "elements" signify the motives and ideas that shape physical means.[10] Concepts of science, art, and society embody a powerful context that influences the form and use of materials. In addition, various groups privilege different types of ideas and instruct others according to their opinions. Semper recognizes the scientific interests of materialists, the historical emphasis of historicists, and the philosophical preference of schematicists. Each bias or combination of ideologies has different consequences for action, and Semper encouraged the study of these underlying values to reveal a proper course for material usage.[11]

While Semper recognizes the importance of ideologies within the architectural community, W.C. Adams identifies dualisms shaping the conceptions and actions of sustainable development. When interpreting civilizations worldwide, Adams encounters the use of dualistic terms to descriptively compare groups and regions. Common dualisms include modern/nonmodern, producer/consumer, capitalist/non-capitalist, traditional/progressive, First World/Third World, primitive/civilized, material/existential, and centralized/decentralized. From these dualistic traits, Adams defines the "green strategy of development," which resists technological culture in a similar manner to communist, or the "red strategy of development," resistance of capitalism.[12] Upon defining these strategies for conceptual purposes, Adams recognizes the shortcomings of narrow-minded approaches. As the terms *technology* and *capitalism* group diverse actions under a simple title with its own associations, developers need to challenge assumptions, consider ideas individually, and make informed decisions. By realizing the unique traits and contexts of solutions, individuals can better understand the relationship between development and nature.[13]

Adams also provides critiques of environmentalism, which serve as models for the critiques of current ideologies shaping sustainable material selection within this thesis. Beyond his concerns of dualistic thinking, Adams names neo-Malthusianism as "ecofascist." The neo-Malthusian ethic must be approached with caution, as inflexible controls limit innovative possibilities globally and development to support the Third World.[14] Due to Adams' close alignment with the topics of innovation, globalization, and indigenous cultures represented in this research, Adams' critiques provide a guide to approach interpretation of these topics conceptually and within applied contexts.

Lastly, this thesis will directly reference the green building and ethical logics presented in Guy and Farmer's "Reinterpreting Sustainable Architecture: The Place of Technology." Guy and Farmer outline "six competing logics of green building," which they label as eco-technic, eco-centric, eco-aesthetic, eco-cultural, eco-medical, and eco-social. Within this series of ideologies, each logic is set in opposition to another, and each pair of opposing logics is explored within a "Results" chapter in this thesis. The use of Guy and Farmer's logics as a framework will clarify the nature of dualistic thinking within sustainable design, elucidating the conflicts and synergies between philosophies.[15]

Limitations

Due to the highly contextual nature of interpretive research, the assertions and findings within this thesis cannot be applied universally. First, the analyses of underlying assumptions fueling dualistic thinking are derived from observations and sources describing First World, Western ideologies. The patterns of thought prevalent in the United States and Europe cannot be generalized without further investigation. Environmental building philosophies are not likely to hold in divergent cultures due to varying traditions, practices, and social and physical conditions. Similarly, the materials under analysis, bamboo and concrete, can be neither glorified nor vilified for all building construction. On the contrary, materials must meet site and region-specific criteria that vary their suitability across time and place; no universal building material exists.[16] Even within Punta Cana, the area of study, bamboo and concrete were not chosen as exemplars of the "best" and "worst" materials. Bamboo and concrete were selected due their relevance for the specific time, place, dualisms, and goals highlighted in the research, not as absolute recommendations or admonishments above all other solutions.

Consequently, this thesis raises questions and offers possible conceptual alternatives, rather than asserting polemical theories of design and materials. Architectural theory has a long tradition of polemics, such as Laugier's "theories of the hut" and Loos' chastisement of ornament.[17] The limited scope of study and dynamic nature of interpretation prevent firm material recommendations in all cases. Like the endless variety of materials, zero waste is also simply a strategy among many for sustainable building and may not be suitable for all applications. Certain circumstances, such as hostile climates, may dictate high-performance, rather than low-impact architecture, to meet the functional requirements of users. Currently available materials may not meet zero waste, safety, and performance criteria. Therefore, zero waste building should be pursued to the extent that the building continues to meet the structure's functional requirements. Nonetheless, if zero waste is deemed a desirable, albeit unattainable goal, for all climates, innovators should not be deterred from exploring new material possibilities to meet all desired criteria.

These limitations highlight the need for a conceptual framework that can remain flexible, guiding actions without dictating methods. Michelle Murphy develops the concept of "regimes of perceptibility" to indicate the risks associated with defining an inflexible scope. According to regimes of perceptibility, a specific focus on a given topic or strategy will inevitably reduce attention to other topics or strategies.[18] Within this research, a primary focus on zero waste risks overlooking other environmental impacts. Embodied energy, carbon footprint, and land use implications may be equally important concerns; however, these factors are not the subjects of this study. Therefore, the limited scope of this study precludes the ability to judge and generalize the value of a given object in terms of "most sustainable" use; materials can only be compared based on the measures presented.

Regimes of perceptibility are also helpful to consider the study of metaphysics. Investigations of metaphysics inevitably remove analysts from the details of threats to human and nonhuman wellbeing, but metaphysics is not meant to mask the reality of degradation and suffering. On the contrary, metaphysics is imperative to understand reality by avoiding a focus on ideas in isolation. A broad approach of material and immaterial issues is particularly important when approaching sustainability from a critical viewpoint. Carl Mitcham speculates, "Just as Socrates taught us that the good that is our own calls for philosophical criticism to save it from popular misunderstanding, so now does the idea of sustainability."[19] Therefore, humans must consider the meaning, values, and goals associated with sustainability before taking sustainable action. As Aiden Davison claims, "the end cannot be adequately characterized independently of a characterization of the means."[20]

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[2] Ibid. 250, 255.
[3] Linda N. Groat and David Wang, *Architectural Research Methods* (New York: J. Wiley, 2002). 88.
[4] Ibid. 136.
[5] Alvesson and Sköldberg, *Reflexive Methodology : New Vistas for Qualitative Research*. 5.
[6] Groat and Wang, *Architectural Research Methods*. 40.
[7] Ibid. 49.
[8] Semper, *The Four Elements of Architecture and Other Writings*. 265.
[9] Ibid. 103.
[10] Ibid. 24.
[11] Ibid. 189-190.
[12] W. M. Adams, *Green Development : Environment and Sustainability in the Third World* (London; New York: Routledge, 1990). 73-75.
[13] Ibid. 86.
[14] Ibid. 76-78.
[15] Guy and Farmer, "Reinterpreting Sustainable Architecture: The Place of Technology."; Fox, *Ethics and the Built Environment*.
[16] James Marston Fitch, *Architecture and the Esthetics of Plenty* (New York: Columbia University Press, 1961).
[17] Groat and Wang, *Architectural Research Methods*. 82.
[18] Michelle Murphy, *Sick Building Syndrome and the Problem of Uncertainty : Environmental Politics, Technoscience, and Women Workers* (Durham, NC: Duke University Press, 2006). 10.
[19] Davison, *Technology and the Contested Meanings of Sustainability*. 63.
[20] Ibid. 164.

RESULTS, PART 1: DUALISMS

Introduction: A Call for Ethics of the Built Environment

Dualisms, or perceived oppositional traits, are ubiquitous within Western modes of thinking. Like other schemata, dualisms help humans comprehend and organize the entities they encounter by highlighting certain characteristics and discarding others. The simplification of complex concepts into two static poles eases mental categorization, communication, and judgment. While ignorance of some factors may dangerously mislead decision making, humans do not have the capacity to live with the unlimited data and stimuli with which they are confronted. Therefore, schemata, such as dualisms, are essential for humans to fulfill their needs and live efficient and effective lives.

However, the use of dualisms does not cease at objective categorization. Humans have evolved their psychological tools to judge alternatives and make decisions, and dualisms allow humans to attach normative ideals and sentiments to dualistic poles to guide their actions. Despite the utility of these mechanisms, the normative aspects of dualistic thinking can have severe detriments and limits. The privileging of one pole can diminish the perceived value of the opposing pole and limit human creativity to produce hybrids. Dualistic thinking misunderstands practical reasoning, which is essentially nondualistic.[1] In material culture, a variety of available solutions is generally preferable to tailor selections directly to unique applications. However, a mindset that assumes certain traits are superior in general encourages uncritical applications of “the best” materials, regardless of their contexts. By exploring the hybrids that dualistic thinking often precludes, humans may discover more appropriate and sustainable solutions to protect human and nonhuman health.

Humans may gravitate toward dualistic thinking due to its utility, but their values and tendencies may also be hardwired by humans' DNA. The goals of sustainability, which seek long-term stability for the greater good, often conflict with instincts to maximize resources for the individual and its relatives, causing resistance to sustainable change. For example, all species are hardwired to reproduce; the trait has persisted because it supports the continued survival of the species. However, unlimited or uncontrolled reproduction may threaten survival in conditions of scarcity; instincts do not always product individual, species, or global security. Therefore, humans must be critical in their decision making, questioning their desires through established ethics. As instincts are difficult to combat, the magnitude that human values can be altered may be limited, and when humans feel content, they may not realize their lifestyles are problematic. Consequently, before sustainable change can occur, society must realize its innate, or at least habitual, patterns of dualistic thinking are a hindrance to long-term survival and question the assumptions that guide their actions in unsustainable paths.[2]

In Western building cultures, dualisms prevail that require investigation. Mainstream architectural and interior designers tend to privilege materials exhibiting strength, durability, technological innovation, modernity, and international sophistication. Each valued trait has history, reasoning, and consequences of its perceptions worthy of inquiry. However, this study identifies three categories of dualisms that are specifically applicable to the material culture and selection process in the Dominican Republic. These dualistic categories include eco-technic vs. eco-centric, eco-medical vs. eco-social, and eco-aesthetic vs. eco-cultural. These dualisms are not fully distinct from each other; there is much overlap in their considerations and effects. However, it is useful to focus on main ideas individually to grasp and clarify details, as long as analysts acknowledge the complexity of the broader scope. In sustainable material selection, each dualism category relates to specific considerations. Often, the “natural” is considered more sustainable than the “unnatural,” but each dualism has different criteria for judging the natural. Eco-technic and eco-centric logics correspond to material renewability and connections to natural cycles. Eco-medical vs. eco-social views may dictate the distance of material origins from building sites. Lastly, eco-aesthetic vs. eco-cultural perspectives consider material familiarity, status, and aesthetics.

Processing is a key factor that unites all three of these dualisms. Increased processing tends to remove materials from a closed loop, increases distances between sources and sites, and makes materials less recognizable and honest. In addition, as processing is synonymous with human interventions, either through manual labor or machinery, each dualism relates to the human vs. nature dualism that guides broad human-environment relationships. Therefore, each dualism is governed by the assumption that human manipulation makes materials less natural, sustainable, familiar, and primitive than less processed alternatives. Simply put, many designers assume that materials that require advanced technology in their production are less sustainable but more modern than their raw counterparts. Western designers feel conflicted by perceived tradeoffs in modern aesthetics, cultural symbolism, and environmental-friendliness. The following chapters will explore the contradictions that arise from Western material assumptions and suggest helpful mediations or hybrids that dualisms overlook. Active work to dissolve oppositions between humans and nature, nature and technology, and individuals and collectives will drive a new order to represent sustainable globalization, ethics, and knowledge-based economies.[3]

Dan Imhoff recognizes the impacts of these dualisms as designers strive to produce new, innovative materials to advance sustainability, performance, or their own creativity. Imhoff states two common courses of action to change "building as usual." Some designers pursue highly processed and/or prefabricated building components, such as steel studs, recycled plastics, and engineered wood products. A less popular course explores traditional and vernacular building methods, such as straw bale, rammed earth, and clay, in a modern context. A strict philosophy toward the former or latter restricts consideration of certain materials due to assumptions, sacrificing possible alternatives suited to green goals. Imhoff is encouraged that these seemingly opposing camps have begun to combine techniques into hybrid structures of industrial materials and natural approaches; physical successes will likely spread the need to question assumptions more effectively than pedagogy alone.[4]

Quantitative analyses and scientific data dominate contemporary sustainable material selection, but materials are not solely technical issues with technical solutions. Technical performance is important, but study primarily through science detracts from social and contextualized understandings of building issues. No simple change in levels of technology, miles of shipment, years of practice, etc. will provide a proper standard to guide sustainable material applications due to the complex and dynamic interplay of considerations and values. In addition, policies and innovations can decrease harmful impacts, but change in underlying cultural values and lifestyles is also needed to sustain societies in the long run. Warwick Fox states, "achieving a sustainable way of living is not only a technical issue (although it is often discussed as if it were) but also (and fundamentally) an ethical one." Because "technical solutions" cannot guide material applications across diverse circumstances, designers need an ethics of the built environment to raise relevant questions and concerns.[5]

Whereas laws state what citizens must and must not do in general, ethics dictate what human should and should not do to tailor behavior appropriately to specific situations.[6] Ethical action, like design, is "first and foremost an attempt to open up possibilities, to enrich the world."[7] Designers need a reminder of what design is; according to Manzini and Cau, "conceiving of the possible is the basis of every design activity."[8] Design demands no single correct solution. Instead, design is complex problem solving that applies knowledge, techniques, and materials to a specific problem and context. By remaining cognizant of the nature of design in the face of technology, globalization, and postmodern aesthetics, which tend to have more analytical, quantitative, and scientific emphases, designers are likely to challenge their assumptions to consider a wider range of material and ethical solutions.

Many building professionals may claim a set of ethics for the built environment already exists. However, Fox argues that no framework is coherent and established to analyze the ethical issues of building. Architectural organizations, such as the American Institute of Architects (AIA) and the National Council of Architectural Registrations Boards (NCARB), attempt to establish ethics for architects. However, these ethics are largely focused on business practices to avoid lawsuits, and most fail to address the ethical issues of design itself. Professional codes are presented as rigid, as architects must agree to the statements in their entirety for membership. Unlike moral codes, they do not encourage questioning or criticism of their authority, which is imperative to update ethics to current circumstances, and they often neglect the role of others who should be partners in building processes. Past green professionals have been cautious of critiquing their profession or sustainability in fear of fueling the arguments of their opponents. However, their hesitation to reveal flaws disregards the need to establish clear, adapted principles to guide building practices.[9]

Others may claim that buildings, as part of the environment, are included in general environmental ethics. Environmental ethics were sparked by the environmental movement and became recognized as a field in the 1970s to contemplate and govern human interactions with all aspects of their surroundings.[a] However, environmental ethics currently maintain a bias toward the natural environment to redress past anthropocentric actions. Architecture is a distinctive practice of that combines utility, art, society, and ecology with implications that exceed most other disciplines; its unique issues cannot be adequately captured in a general ethics. Fox recognizes early developments to tackle building ethics, but most either emphasize architecture and design *or* environmental philosophy. Dale Jamieson states, "We often speak of the environment as if it is everywhere except where we live." Environmental, cultural, and technocratic sustainability are often understood on different terms, and the links between them pass uncontested. It is important to develop a moral code to ensure symbiosis between human and nonhuman entities and guide specific actions within the building process, such as material selection.[10]

Ethics, or a lack of ethics, impact all aspects of sustainability. Aiden Davison claims that the exclusion of morals is at the core of unsustainability as he states, "unsustainability and unsociability cultivate each other." As the Earth's resources become commodities, citizens and organizations trade culture and nature for personal gain. Divisions and distrust between social groups foster competition over cooperation, preventing the sharing of knowledge necessary to devise proper social solutions and plans for resource use. The ethical dimensions of the built environment would include place identity, economics, community

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[a] See "Environmental Philosophy, Philosophy of Technology, and the Human vs. Nature Dualism" in this thesis for a more detailed history of environmental ethics.

empowerment, professionalism, and ecosystem integration. User involvement is imperative to create socially and ecologically responsible architecture with respect for the values, experience, and wisdom of cultures.[11]

In contrast to dualistic thinking, ethics can avoid uncritical assumptions and require contemplation and ongoing reflection. In addition, ethics resist the inflexible categories of dualisms by analyzing circumstances and tailoring judgments and actions to situations accordingly. With consideration of ethical complexities, designers can employ a more comprehensive view in their design processes. According to the Law of Ecological Design, designers must analyze component parts, their interactions with each other, and their impacts on their supporting environment.[12] Kenneth Yeang details external dependencies, internal dependencies, external-to-internal exchanges, and internal-to-external exchanges of building systems. Buildings are not self-contained; their impacts on their surroundings necessitate an understanding of ecosystems and global changes over time and space. With a broader view of considerations, humans are better equipped to anticipate changes and learn from their mistakes. Rather than perceiving only options to control or succumb to nature, designers can explore more symbiotic solutions of cooperation.[13]

Deyan Sudjic claims an architect's disregard for sustainability is "professional suicide," conveying the importance of sustainability in the Western building community. However, the diverse impacts of newly constructed buildings are "material embodiments" of the varied ecological and ethical values of their builders. Guy and Farmer's six logics compete for consideration in green buildings, which, when paired, each describe various technical, socio-cultural, or percepto-cognitional values. These logics are not exclusive nor exist in isolation, but they illuminate many of the key tradeoffs green designers perceive in their work.[14]

First, designers must select their techniques, which are regulated by the dualistic *eco-centric* and *eco-technic* logics. Eco-centric buildings strive for holism by accounting for local ecosystems, reducing waste, and limiting operations to a small scale. Dramatic reductions of buildings' ecological footprints require a paradigm shift in values, abandoning conveniences of modern society. In contrast, eco-technic techniques build on existing technocratic frameworks, implementing incremental changes that increase efficiency and control.[15] This conflict will be explored in further detail in the "Eco-technic vs. Eco-centric" chapter.

Designers must also balance social concerns in their works. The *eco-medical* logic focuses on benefits for the individual. Eco-medical designers seek to maximize the health and comfort of building occupants, often by increasing barriers between interior and exterior environments. *Eco-social* designers, however, highlight the welfare of communities in their designs. Under this ideology, buildings are social processes that demand flexibility and user participation, which cultivate pride, functionality, and empowerment. The "Eco-medical vs. Eco-social" chapter will address the tradeoffs and intersections of wellbeing on different scales.[16]

Finally, designers' formal strategies vary between *eco-aesthetic* and *eco-cultural* categories. Both seek to function and appear as ecological but employ vastly different methods to achieve their similar goal. Eco-aesthetic buildings' modern images convey increasing knowledge of the nonhuman world through scientific exploration. Contemporary organic architecture applies inspiration from nature to create visual continuity between human and nonhuman forms. Alternatively, the eco-cultural logic values tradition, employing authentic emblems of regional culture. Buildings must be accepted by the community to remain viable, and eco-cultural builders believe links to the past, rather than continual transformations, are best to form lasting community connections.[17] The "Eco-aesthetic vs. Eco-cultural" chapter will explore the intricacies of this topic.

Graham and Farmer's descriptive ethics, as well as other ethical developments, provide insights to resolve many contemporary challenges of rapid environmental, social, and economic change in the Dominican Republic. At the intersection of technological, modern, First World influences and traditional methods based in local materials and labor, designs for the Dominican Republic must tackle the technical, socio-cultural, and percepto-cognitional values that Graham and Farmer introduce in fairly equal measures. One significant challenge recognizes that past urbanization was largely restricted to the global North, but now the global South holds the fastest rates of industrialization and fossil fuel increases. Architects and designers will play significant roles to answer the complicated questions raised by sustainable development. How can buildings minimize resource consumption and environmental destruction without restricting developing economies? How can Third World residents enjoy needed improvements in their quality of life without sacrificing their own autonomy or nonhuman health? How can the burdens of modern living be shared equally between societies of varying affluence and traditions?[18] Sustainable development must start with changes in mindsets and ideologies, but ultimately actions are of key importance. As Manzini and Cau relate, "The spirit, per se, can do nothing - its value lies in the mediations it generates and through which it passes."[19]

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[1] Ibid. 163.

[2] Harry Francis Mallgrave, *The Architect's Brain : Neuroscience, Creativity, and Architecture* (Chichester, West Sussex, U.K.; Malden, MA: Wiley-Blackwell, 2010).

[3] Abley and Heartfield, *Sustaining Architecture in the Anti-Machine Age*. 64.

[4] Imhoff, *Building with Vision : Optimizing and Finding Alternatives to Wood*. 12.
[5] Fox, *Ethics and the Built Environment*. 6, 28, 74.
[6] Ibid. 181.
[7] Davison, *Technology and the Contested Meanings of Sustainability*. 163.
[8] Ezio Manzini and Pasquale Cau, *The Material of Invention* (Cambridge, Mass.: MIT Press, 1989). 48.
[9] Fox, *Ethics and the Built Environment*. 10, 54, 172-173.
[10] Ibid. 1-4, 171.
[11] Ibid. 9, 38, 206-207.
[12] Braham, Hale, and Sadar, *Rethinking Technology : A Reader in Architectural Theory*. 394.
[13] Yeang, *Designing with Nature : The Ecological Basis for Architectural Design*. 35-36, 79-85.
[14] Fox, *Ethics and the Built Environment*. 75, 162.
[15] Ibid. 78.
[16] Ibid. 81-83.
[17] Ibid. 79-80.
[18] Ibid. 15, 61.
[19] Manzini and Cau, *The Material of Invention*. 16.

Eco-technic vs. Eco-centric

Introduction

Despite the clear purpose of technology to resolve human challenges, designers, environmentalists, economists, and political scientists debate the appropriate use of various technologies in the built environment. While eco-technics favor highly technological, scientific, and performance-based solutions to exert maximum control over the built environment and alleviate scarcity, eco-centrics idealize local, traditional, and unprocessed building solutions to minimally impact and respect the limits of the natural environment.[1] Society and practitioners, in response to ongoing debates, commonly view these strategies as oppositional, paradoxically pursuing divergent means to achieve the same end of ecological sustainability. To further the divide, stakeholders simplify ideologies to pro-technological or anti-technological views, which render compromise untenable and hinder transitions toward their common goal.

In order to guide contemporary development in Punta Cana and support a unified, productive green building movement, it is necessary to rethink the concepts of "technical" and "natural" as used in Western cultures. Both in theory and application, "technical" and "natural" building strategies have shared roots, processes, and outcomes. The comparison of the famed Crystal Palace, built in London for the Great Exhibition of 1851 and modern, vernacular structures in the Dominican Republic, will reveal the ambiguities and consequences of eco-technic and eco-centric categorizations. As an intended symbol of industrial strength, modern prosperity, and environmental control, the Crystal Palace appears to contrast and threaten the traditional knowledge, local handcraft, environmental-responsiveness characteristic of many Dominican shelters.[2] Despite their seemingly oppositional approaches and values, further investigation will reveal that defining the Crystal Palace as purely technical and Dominican buildings as purely natural oversimplifies the complex dynamics of their contexts and relationships to nonhuman nature. A middle ground between ideological poles may present more favorable design solutions in Punta Cana and ultimately beyond. By analyzing the assumptions of environmental dualisms, the definitions of nature, technology, and their hybrids, and the dynamics of technology as a mediating force, practitioners can overcome barriers erected by past preconceptions of technology to expose a wider array of favorable methods for unique projects and their contexts.

Assumptions of eco-technic and eco-centric perspectives

Perceptions of human separation from nature have existed for centuries and contributed to later oppositional conceptions of technological and natural processes.[a] Descartes famously publicized the separation of mind from matter, where the mind represents humans and matter signifies the nonhuman environment. While Descartes proclaimed the superior capabilities of humans to manipulate their environment through innovative, technological solutions that nonhumans lacked, nature provided a different set of anthropocentric values, including beauty and leisure.[3] As William Cronon relates through the concept of wilderness, policy makers perceived the superior cultural value of "untouched" lands relative to developed terrain and promoted the preservation of wilderness with less regard to delineated civilization. The dichotomy of nature and civilization strengthened with the celebrated use of technology in developed areas and its protested use in the wilderness. Western cultures sought to conquer nature within human civilization and employed

[a] See "Environmental Philosophy, Philosophy of Technology, and the Human vs. Nature Dualism" in this thesis for further detail.

technologies as means of environmental control; in contrast, any manipulation of wilderness tragically spoiled its supposed purity, forming an antithetical relationship between nature and any human intervention.[4] "Technology replaced or modified nature, but nature was not technology… nature [had] to be dead to be technology."[5] This view vilified technology and industry in the eyes of many environmentalists, promoting the tensions between ecological and economic goals that persist today.

However, the eco-technic perspective questions the antithetical relationship between technology and ecological health. By viewing technology as key to sustained ecological health, eco-technics suggest that humans can live symbiotically with nature, counter to historic ideologies. In support of sustainability, eco-technics seek to reduce energy and nonrenewable material inputs of high performance architecture to prolong the availability of resources and reduce toxic inputs to increase safety. The Bauhaus played a significant role to incorporate engineering values into architecture; whereas architecture historically sought to implement integrated solutions based on people and their experiences, engineering introduced efficiency, forces, parts, and material performance as primary considerations.[6] However, technocratic sustainability is not exclusively a post-war phenomenon. Ideals of managing nature to prevent declining productivity date at least back to the 18th century German concept of "sustained-yield" in forestry.[7] However, preoccupations with science and technology have grown over time to strengthen eco-technic arguments in the 21st century.

Julian Simon expresses an eco-technic theme of limitless abundance through science as he stated in 1970s and 1980s that "there is no ecological crisis and no limit to growth that human ingenuity cannot overcome." Eco-technics commonly believe that increasingly efficient technology will sustain current lifestyles indefinitely. Elizabeth Dowdeswell, Director of the UNEP in 1996, proclaimed a five- to ten-fold increase in efficiency would be sufficient to achieve sustainability.[8] Therefore, eco-technics envision nature as an orderly construct that can be managed and used as inputs to meet human needs.[9]

While eco-technic views seem to find symbiosis by naturalizing technology and structuring nature, eco-centrics perpetuate the idea of inevitable conflicts between humans and nature with their low-impact architecture. Technology, which includes most human environmental interventions, allows current, ecologically damaging lifestyles to continue. Semper claims, "Necessity was the mother of science"; technology emerged to overcome natural limits.[10] However, eco-centrics argue that natural limits indicate a sustainable level of consumption and must be respected for long-term survival. From this view, ecomodernism ignores the moral meaning of sustainability altogether.[11] Technology fosters the belief that humans can transcend their natural heritage, and this dangerous illusion leads to environmental degradation.[12] Rather than the incremental technical change and optimism of eco-technics, eco-centrics call for a dramatic shift in values and practices, attacking the roots of ecological problems, not simply the effects.[13] With a broad view of ecosystems' complexities, eco-centrics believe technology is prone to oversimplification, disregards local conditions, and fails to replace nonhuman nature's functions. No single "technological fix" or universal approach can solve all environmental problems, nor can sustainable solutions be purely technical. By increasing the saturation of human-made controls, humans are decreasing the complexity and resiliency of the environment, according to eco-centrics.[14]

Eco-centrics also caution against the momentum of science to become an object in itself, separated from the goals of human welfare. Science provides directions for desired material improvements based on empirically derived facts, boosting consumer confidence in its recommendations. However, too much faith in science can lead to blind obedience to its proposals. Eco-centrics fear the public relies upon science as an absolute source of guidance, failing to realize that models' outcomes are not completely objective but vary with their founding functions, variables, and assumptions, can yield flawed data, and cannot predict long-term results with certainty.[15] In the interests of control, the sciences also inevitably simplify conceptions of nature through models, and these representations reconfigure human understandings of nature and nature itself.[16] Bruno Latour discusses the ability of perceptions of neutral, autonomous, scientific "fact" to discredit and silence alternative, less quantitative forms of knowledge, which science deems as subjective.[17] Consequently, humans may encounter difficulty imposing limits on "objective" technology. While science should enrich human lives with knowledge and superior methods, Semper claims inventions are no longer a means for enjoyment. Rather, enjoyment fuels the market for invention with created needs, exacerbating the consequences of consumption.[18] "Science push" and "market pull" become blurred to fuel material development, and each sector must evaluate its ethics and values to ensure critical and appropriate action.[19]

As Punta Cana becomes increasingly entrenched in American models of business and industry, it will likely also adopt the authority of science that Western designers value in their decision making. Traditionally, Dominican builders employed eco-centric ethics, relying on natural cycles to provide the materials they needed without desires for machines. However, the rise of Western tourism in Punta Cana challenges traditional values with eco-technic practices. In order to reap the benefits of both perspectives, scientific objectivity must be questioned, rather than blindly accepted. Dominican knowledge gained through experience with local materials, which have provided effective means for centuries, may be an important complement to the scientific, Western recommendations that Punta Cana encounters. Innovations may improve economic productivity, reduce health strains, and protect resources, while Dominican practices may realize synergetic and dynamic effects that the Cartesian method neglects and can only be observed through application.[20] Each approach introduces different considerations for material applications, and designers may benefit from utilizing both in tandem.

However, the rise of concrete and other industrial building materials in the Dominican Republic illustrates a growing preference for international and scientific materials without balancing respect for traditional knowledge. Kennedy notes:

> Ironically, natural building materials, once the norm for us and still the norm for the majority of humankind, are viewed with great suspicion and skepticism in current mainstream building culture. Even though people have surrounded themselves with natural, permeable materials throughout human history, and even though enduring models of these buildings are found throughout the world, mainstream building practices and codes promote manufactured building commodities that are laboratory tested, standardized, stamped, packaged, and shipped.[21]

Despite preferences for the flexibility and familiarity of organic building materials by rural families,[22] many Dominicans are drawn to industrial materials to mimic Western culture. The assumption of betterment and prestige associated with concrete disregards its shortcomings for the landscape and lifestyles of the region.

While the current blend of Western technology and Dominican tradition is less than ideal, innovations can offer many benefits to the Dominican Republic that should not be abandoned. The former economy in Punta Cana relied on the harvest of renewable resources, i.e. trees to make charcoal, but these “natural” practices led to unsustainable deforestation. Industrialization brought employment and goods to increase Dominican self-sufficiency and protect exploited resources. Therefore, the current tradeoffs of innovation and tradition have potential for symbioses with further exploration and integration of human and nonhuman activities. Eco-technics and eco-centrics need not resist "low-tech" and "high-tech" interventions respectively, but battle any unsustainable, consumptive values each embodies. In other words, environmental ideologies do not oppose specific practices but rather the typical values and effects of varied technological levels, and these assumptions preclude the consideration of solutions of opposing ideologies. With this realization, various practices and technologies can be used not to justify current lifestyles in Punta Cana and abroad but as tools to implement locally appropriate solutions for environmental, social, and economic benefits.[23]

Consequently, it is the assumptions designers make about materials that must be questioned in order to explore modern and traditional technological blends. Many of these assumptions relate to tenets of material categorization; common adjectives are attached to diverse materials to ease identification and understanding. In the selection of green materials, designers often reference natural, unnatural, organic, and inorganic labels. However, these terms often obfuscate human relationships to ecosystems. The idea of humans as part of natural systems overcomes the prior notion of separate human and natural realms and also questions the division of natural and unnatural objects. What are the implications of considering human actions unnatural and, conversely, natural? If all inputs are natural in origin, i.e. available on Earth, how do outputs become unnatural? Furthermore, how do designations of natural or unnatural inform sustainable material selection?

Limits of categorization

As previously discussed, human-environment relationships have varied over history.[b] Perception of humans as a part of, outside of, or antithetical to nature significantly impact the way designers and the public consider and apply materials. Eco-centrics' resistance to human interventions through technology indicates a belief that humans exist in opposition to ecological stability. As a result, eco-centrics favor materials that are less processed and locally based. Due to the reduction of human work, builders consider these materials more natural. In contrast, eco-technics accept technology as desirable and necessary solutions for ecological health, suggesting human actions are natural. Consequently, just as other species employ their strengths, humans should utilize their superior cognitive and inventive skills to serve the needs of their species and environment. Nonetheless, eco-centrics maintain the division that vilifies "unnatural" technologies and processed materials.

To categorize materials, the identities of various materials are consolidated and often simplified according to particular traits. These traits regularly include composition and physical properties; countless tree species produce variations of a single material, wood. When diverse entities are grouped under broad categories, "known materials" are defined by a system containing relatively few distinct materials that remain constant in properties over time. Only by establishing iconic, static traits to organize material conceptually could broad material names, such as wood, automatically communicate a basic understanding of the use, performance, and consequences of specific materials, such as Douglas fir or Scotch pine. In other words, designers can predict the behavior of materials based on collective memory.[24]

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[b] See "Environmental Philosophy, Philosophy of Technology, and the Human vs. Nature Dualism" in this thesis for further detail.

Like other generalizations, these categorizations can communicate information quickly, but they entail dangers because they do not always hold true. Specific materials may fit most of the characteristics of their group but vary in particular traits that are suited to divergent applications. Static categorization also hinders the acceptance of new materials; without collective memory, unique innovations lack recognition.[25] Plastics, as a category, has faced an identity crisis due to its novelty and diverse counterparts. Without a set shape, composition, or strength and with applications varying from cheap packaging to expensive aerospace technology, plastics may be excluded from appropriate uses due to misconceptions. Therefore, categorization produces a language that can sacrifice deep understanding and suitability for efficiency.

The assumption that materials can be universally and statically categorized fuels the rise of problematic terms, such as *natural* and *unnatural*. Sara Pritchard and Thomas Zeller argue that distinctions between natural and unnatural entities are both relative and culturally specific, discouraging broad generalizations across time and space.[26] For example, Crystal Palace's glass and steel seem inorganic when compared to Dominican wood, thatch, and clay-based materials.[27] In addition, despite the silica composition of both glass and brick, glass was considered less natural than brick in the 19th century due to its novelty, physical appearance, and technical demands. Are material developments deemed artificial due to their properties or because stakeholders do not recognize and understand them? Many factors can influence actors' and analysts' perceptions of building materials as natural or unnatural beyond composition, such as processing, extraction, installation, and disposal techniques, and these attributes should be considered in depth and in tandem to generate an extensive material profile.

In the design field, a common definition of natural materials "covers all materials that come directly from a plant or animal source," indicating the relevance of both origins and manipulation.[28] Accordingly, design norms deem bamboo and thatch that compose buildings in the Dominican Republic natural because they can be harvested and applied with minimal processing. However, at what level of manipulation are materials no longer considered "direct" from the source? For example, do clay bricks become unnatural when treated at high heat? Sunflower seed board is widely considered a highly natural material, but its treatment with binders and compression inevitably distances the final product from its source. In addition, when comparing types of bamboo and thatch used in different Dominican structures, materials that are imported and processed off-site may be considered less natural, although still organic; location also plays a critical role in material definition. Such intricacies indicate that the terms *natural* and *unnatural* reflect a subjective gradient of designations, rather than a sharp ontological difference. *Natural* and *unnatural* are not absolute or fixed categories; a variety of factors influence their application, and most of their meaning derives from their contextual embeddedness and relativity.

Designers often use the terms *organic* and *inorganic* as synonyms for *natural* and *unnatural* respectively, all of which operate on the assumed possibility of categorical dualisms. In order to avoid the subjectivity and prominent greenwashing of these terms, some manufacturers and sustainability metrics prefer to identify resources as *renewable* or *nonrenewable*, based on a quantitative regeneration time period.[29] Designations of time may be preferable to reveal variability of materials, in contrast to terms seeking to sharply affirm or deny categorical inclusion. In addition, thinking in terms of renewability connects all products back to the Earth. Dualistic terms of *unnatural* and *inorganic* mask the reality that all materials are organic at their source; it is only debatable if materials can become less natural or inorganic over time through technological manipulation. However, natural or unnatural material designations in abstract are less at stake than the implications of solutions either implemented or ignored according to such patterns of thinking and a priori ideals; particular practices vary in benefits and harms to specific peoples and environments. Recognition of the connections between the natural and unnatural in both theoretical and specific contexts is critical to reconceive of limiting dualisms.

While quantitative metrics may ground material sustainability claims more objectively than dualistic terminology, renewability and other measurements have limits as sole indicators, too. As *natural*, a common claim of sustainable materials, derives from many factors, the label *sustainable* entails even more considerations. For example, wood is a renewable resource, and steel is nonrenewable. However, steel is 100% recyclable, has possibilities for direct reuse, is more resistant to rot, fire, and insects, and is more dimensionally stable. If steel is better suited to a particular project, such as bridges, and can be fully recycled to prevent further extraction, steel, the less “natural” material, may be considered more sustainable. However, in other applications, such as housing, wood may be appropriate due to the lesser structural demands and its higher resistance to heat transfer.[30] In addition, the final form of the project also plays a role in material performance, as wood lasts longer when protected by an overhang.[31] This example illustrates the limits of static categories; application can play an equal or superior role to the physical traits and requirements of materials in determining appropriateness and impacts.

In addition, designers should not consider renewability as a static, universal number because renewability refers to the growth of resources over time. To ensure regeneration, crops and forests must be well-managed. If over-harvesting or soil depletion reduces productivity or crop health, the localized use of renewable resources is not sustainable. Numerical data or focus on any solitary measure can overshadow the methods and impacts of production, and designers must maintain an inclusive view of considerations to gauge material suitability.[32]

By conventional standards of naturalness, designers consider material science to be highly unnatural due to high levels of processing, composites, and synthetics. However, many of the processes humans undertake in material science parallel the activities of other species. Spider silk is a composite with impressive performance characteristics; do scientists consider spider silk natural simply because it is produced by nonhumans?[33] Humans are not the only engineers; other animals manipulate resources for their own ends but are considered natural. Should plastics be considered natural since they utilize inputs from the Earth and are transformed according to the laws of nature? Claims that changes to resources' chemical makeup and intrinsic qualities, rather than simply manipulating the physical form, yield artificiality do not hold as spiders work on molecular levels to produce their unique, yet natural, material.[34] Perhaps the material's production through metabolism with organic inputs and biodegradable outputs also plays a role in its categorization. According to this logic, if humans are natural beings, their products can also be considered natural if they utilize organic inputs and leave no residual waste. *By creating solutions that are integrated within natural cycles and yield high performance for applications, material development that satisfies both eco-technics and eco-centrics is possible.*

Many material developments already straddle the technological and natural divide. Biomimetics draws inspiration from nature's examples, such as spider silk production, to yield elegant, low-energy, and low-waste solutions through material science. Eco-centric beliefs that build upon the enduring wisdom of nature illuminate paths for environmentally compatible, adaptable, and high-performing solutions.[35] Biomimicry can achieve assumed high-tech traits with lower impacts, as shown through studies of lotus leaves and cicada wings to attain water and dirt resistance and chlorophyll to guide photovoltaic photosynthesis.[36] Bioprocessing is renewable, ubiquitous, and simple; enzymes are reusable catalysts that initiate reactions at room temperature and pressure with no solvents, and microorganisms digest products safety through biodegradation. Interest in biopolymers is increasing to maintain eco-technics' desired performance of plastic applications while integrating applied materials into the biosynthesis and biodegradation cycle.[37] Material science often studies how technology can improve upon nature, but biomimicry also reveals the merits of exploring how nature can improve upon technology.[38] Raw inputs present infinite possibilities for manipulation, and the intersection of eco-technic and eco-centric goals may provide a proper direction for future material science research.[39]

As the activities of material science are highly varied, no single "technology" variable exists; generalizations of the objects and effects of technology are gross and stereotypical. In order to judge individual technologies, designers must consider side effects, social changes necessary for implementation, the time period required to achieve goals, what limits will be overcome, and what limits humans are likely to confront next. Rather than arbitrarily excluding all "unnatural" technologies under a strict eco-centric perspective, designers should support technologies that minimize weaknesses and can work within natural cycles indefinitely. As not all human actions are the same in intent and effects, technologies also vary, and these differences matter to judge the viability of each technology's use for ecological vitality. In accordance with the Sierra Club motto, it is "not blind opposition to progress, but opposition to blind progress" to which designers should aspire.[40]

Other terms, such as *plastics*, *processing*, and *chemicals*, have acquired negative connotations that can prevent the use of benign counterparts within these categories. Thermoset plastics cannot be ground or melted, but many plastics, such as expanded polystyrene (EPS), are thermoplastic for complete recycling and CFC and HCFC free.[41] While these plastics are common symbols of synthetic material production, biopolymers, such as cellulose, celluloid, casein, cellophane, ebonite, rubber, and starch, occur in living organisms and have promise to bridge the nature-technology divide.[42] In addition, the low impacts of bioprocessing may challenge assumptions of high energy and material usage in processing plants. The negativity surrounding chemicals is even more problematic, as chemicals are essential for life.[43] As plastics, chemicals, and materials are not generalizable, designers must analyze the individual materials they encounter, rather than rely on categorizations alone to inform their decision making. This need may intensify in the future has material developments, such as composites, become harder to classify.

Consequently, society must question these assumptions that obscure the character of nature and technology to environmentalists. It is neither reasonable nor desirable to expect Western society to relinquish the modern privileges it enjoys. In order to enjoy social and economic goods that currently produce pollution and waste, such as automobiles, designers should change the way cars are made, not eliminate the benefits of the car.[44] Technological benefits may include less resource and energy use, more innovative forms, and saved time.[c] Technologies also afford more possibilities to tailor materials to their applications through

[c] See William J. Mitchell's "E-bodies, E-buildings, E-cities" in Braham, et. al. (2007) for further detail.

manufacturing and communicative means, melding science and other informative backgrounds with design. Some optimists of a technical and cultural future embrace the motto, "less matter, less energy, more information."[45] Despite fears that people are at the mercy of technology, humans are not passive victims when equipped with rationality, questioning, and criticism.[46] Technological determinism, or the belief that technology drives societal outcomes and cultural values, remains a concern only with ignorance and unchecked technological development and application. The following discussion will detail developing conceptions of nature, technology, and their intersection to overcome the problematic assumptions of current material descriptors.

Defining nature, technology, and hybridity

The meanings of nature and technology have shifted over time and place according to ethics, politics, human-environment relations, and other contextual factors.[47] From their Greek origins, the terms *organic* and *mechanical* had similar meanings as instrumental means, or tools. In late antiquity, however, the organic came to reference the artful use of instruments, while the mechanical involved their manufacture. The unprecedented results of new tools seemed unearthly, conceptually separating mechanical items and manufacture from nature. Later, technological construction during the Renaissance attempted to mimic the movement of bodies; this sought reconnection of machines and nature indicates their prior separation.[48] Despite the imagined boundary between nature and technology that persists today, technology and the environment are inseparable and interdependent.[49] To better understand the changing relationship between nature and technology, it is critical to explore the culturally contingent definitions, sentiments, and ethics of these terms over time.

Architects' concepts for their works reveal changing perceptions of buildings' relationships to nature over time. Frank Lloyd Wright claimed to produce organic architecture with passive strategies, while Le Corbusier professed a mechanical architecture with active strategies. However, the architects may not have seen architecture as strictly organic or mechanical as simple statements may indicate. Wright often discussed architecture in mechanical terms, and Corbusier interpreted buildings through life processes.[50] In addition, modernist architect Mies van der Rohe declared buildings as "machines for living," advocating maximum precision in the regulation of the internal environment. The conception of machines that support life indicates an intersection of technology, humans, and nonhuman nature. While no identifiable organic theory of architecture exists, the organism is a common theme in architecture with longstanding comparisons between buildings and botany, formal studies and morphology, and biotechnics (the building techniques of nature) and biotechniques (the building techniques of humans).[51] Despite historic divides between human manipulations and nature, architects have conceptually and physically linked their works to their environments.

However, the rise of systems of automation and control within buildings has obscured human ties to nature by allowing ignorance of "external" environmental conditions. The Crystal Palace, as a symbol of technological prowess at the Great Exhibition of 1851, displayed novel capabilities that allowed humans to live in controlled comfort, free from environmental concerns. Nonetheless, both modern and historic thinkers have maintained analogies between building and bodily functions that remedy the disconnects of mechanical thinking. Architectural machines mandate the cleaning, renewal, nourishment, and disease control that living beings require, but more importantly, the idea of a living building overcomes the idealization of precision and control. Living buildings are simply organs within a larger, bodily ecosystem, which they must respond to and support. Consequently, open-air buildings in the Dominican Republic exhibit greatly divergent forms, systems, and materials from the Crystal Place in London to harness unique and changing natural assets. Therefore, all buildings seek to fulfill similar functions, but ideologies influence the methods of building construction and operation.[52] To build upon these historic views and develop ideologies to guide sustainable building, how should current designers conceive of the buildings and materials they construct? How should the terms *natural*, *technology*, and *hybrid* be used within the building industry?

Donald Worster identifies nature as both a concrete and abstract entity. Nature is a part of the tangible environment that supports all life, but perceptions of nature have changed its societal value over centuries.[53] Contemporary Western cultures associate nature with "purity, simplicity and goodness," but these idealizations differ from past conceptions and also current perceptions in other cultural settings.[54] The vision of nature as a pre-existing ideal marks any intervention as destructive and undesirable, vilifying technology and most human actions. In *The End of Nature,* Bill McKibben asserts the need to rethink the definition of nature as pristine wilderness, which no longer exists.[55] By considering the contingency of physical conditions and cultural values regarding nature, humans would likely be more receptive to judging the benefits and costs of interventions, rather than dismissing options too quickly based on a priori distinctions that are assumed absolute.

The popular, Western idea of nature as a static, unified, vulnerable, and passive backdrop increases resistance to human manipulations. The attribution of agency to humans alone strengthens the divide between active humans and a submissive nature that can be conquered and destroyed. Under such views, as expressed in the Brundtland Report, technology must be regarded with caution to avoid environmental destruction. However, while nature lacks the mindfulness of human actions, some scholars call for new ways to consider the "agency of nature." Environmental history seeks to augment past historical accounts that identify humans as the sole actors by revealing synergistic, antagonistic, or complex relationships between humans and nonhumans.[56] Environmental determinism, like technological determinism, greatly oversimplifies the relationship; humans must recognize nonhuman nature as a partner in historical events. As humans recognize nonhumans as capable of effecting change, notions of nature as an entity without influence will disappear to reveal more complex relationships within a combined human-environmental history.[57]

Like nature, technology also has physical and abstract components. According to James Williams, "a technology is not merely a system of machines with certain functions; rather it is an expression of a social world." Technology is a zone of interaction that transforms nonhuman nature to suit human purposes. In other words, technology is an intermediary, defining humans' relationship to their environment while changing both parties simultaneously. Eco-technics and eco-centrics are less concerned with the meaning of technology than its performance and physical impacts, despite the impacts of metaphorical meaning on user experiences and selection. Other ideologies, such as the eco-aesthetic and eco-cultural perspectives, primarily analyze meaning; the "Eco-aesthetic vs. Eco-cultural" chapter will explore the metaphorical meanings of technology and progress in more detail.

Rather than analyzing the meaning of technology, eco-technics and eco-centrics assume all technology, or human interventions in the environment, is either desirable or undesirable. However, change, in evolutionary terms, is a basic feature of life and essential for survival; while not all changes are beneficial, change is not universally undesirable. According to Cronon, the trouble with the wilderness discourse is its reproduction of mutually exclusive categories of the *human* and the *natural*; if human presence destroys nature, and nature is ideal, humans have no place in the world they must live.[58] It is therefore necessary to rethink the assumptions and definitions that prevent society from embracing beneficial technological changes in pursuit of environmental sustainability. Any intervention will impact the environment by addition, alteration, or depletion; designers should not try to eliminate impacts and innovations but yield more benign or beneficial effects.[59]

Industrialization highlighted machinery as the key form of technology posing environmental threats. While the term *technology* was introduced in America by Jacob Bigelow's *Elements of Technology* in 1829, its use was not popular until the 20th century to refer to rapid invention and innovation.[60] The term *Industrial Revolution* conveys a great departure from previous practices, and like many critical changes, industrialization was met with an array of reactions. The substitution of machines for human labor provided optimism for new freedoms from work, precise quality, and diversity of materials. However, some parties identified shifts of geographic and temporal scales as industrial dangers. The use of machinery enabled changes of unprecedented range and speed in the air, water, land, and built environment. During the era of the Crystal Palace, citizens recognized mechanical processes as possible threats to their valued environments, and industrialization continues to raise particularly strong concerns for unintended environmental consequences in the Dominican Republic due to its heavy reliance on the health and beauty of natural resources.

Nonetheless, the revolution was not a complete break from the past, as resource extraction and cultivation date back to the Neolithic Revolution.[61] Industrial machinery emerged from a long diffusion and adaptation of ideas over time, an "accumulation of human inventiveness rather than a linear progression of measurable efficiency."[62] Mumford identifies the eotechnic, paleotechnic, and neotechnic stages of technological regimes.[63] Ancient eotechnic manipulations within architecture aimed to provide basic shelters; now the fundamental walls, floors, and ceilings of buildings are hardly considered technology.[64] Paleotechnics became less "natural" with transformations that were more visible than the slower, smaller-scale alterations of the past, and pre-established dualistic mindsets saw extreme human interventions as harmful to the environment. Neotechnic developments have the potential to break patterns of environmental damage through greater efficiency, materials, and skills, including dematerialization and detoxification. Future technologies can help realize human connections to nature through integration with local environments and effective measures, functioning more similarly to living organisms.[65]

While eco-technics and eco-centrics tend to consider technology as inherently favorable or detrimental, designers can explore the fullest range of possibilities by viewing the category *technology* as value-neutral. Langdon Winner recognizes the inability to generalize the values of technology as he states, "Technology 'has come to mean everything and anything; it therefore threatens to mean nothing.'"[66] As the motives of use, properties of application, and perceptions of culture shape positive and/or negative effects, individual technologies should be considered based on their merits.[67] In other words, *Technology*, as a category, lacks generalizable values, but *technologies* convey particular political and moral values based on their particular composition and context. Crystal Palace and Dominican vernacular both fall into technological categories, but each communicates differing policies regarding infrastructure, daily life, resource use, environmental actions, and societal goals.[68]

Examples of eco-technic and eco-centric material choices illuminate the need to consider the specific traits and applications of materials. First, inaccurate assumptions can prevent the use of high-performance crop-based materials by eco-technic designers. Straw bales provide greater thermal resistance than a typical cavity wall, last a century, and are easy to repair. Likewise, earthen architecture can survive centuries with little to no maintenance. Many eco-technics assume crop-based materials require synthetic inputs for high performance, but strawboard contains natural resins that bind strands when compressed and heated without additional adhesives. In addition, many manufacturers assume crops would require vast chemical inputs and care to meet demands for building. However, many crops, such as hemp, are resilient and fast-growing, absorb carbon dioxide, and require no synthetic fertilizers or pesticides, effectively improving soil conditions with minimal human work. Lastly, designers fear that crop-based materials will not meet building code without chemical retardants, but wool demonstrates inherent fire-resistance and self-extinguishment.[69]

Eco-centric preconceptions can also prevent the use of environmentally suitable, scientific materials. Some technologies can make materials more effective without worsening environmental effects. For example, glass tempering and annealing processes strengthen glass and increase its safety but do not change its ecological impacts. By considering material performance over the entire product life cycle, designers may find that some highly processed materials, such as triple-glazed glass and fiberglass, may offset their high initial energy use through energy savings in operation and durability. Likewise, smart materials respond to environmental conditions to reduce heating, cooling, and/or lighting loads. Dematerialization is also one of the goals of scientific materials, which decreases the amount of material required for given applications.[70] Translucent aerogels are composed of 88-98%

air but retain their structure under compression, allowing less material use in many applications. Other properties, such as hydrophobicity or strength, can increase material life spans, reducing material consumption over time.[71] Therefore, newly developed materials can accrue environmental benefits that must be weighed against their costs over time to accurately judge their overall environmental impacts.

Eco-centrics also must not assume that crop-based inputs are necessarily preferable to inorganics or synthetics. Some plants are toxic or require large inputs of synthetic chemicals or energy in processing, negating the benefits of plant-based materials.[72] In addition, not all natural materials are easier to use than industrial materials; cement is foolproof relative to lime, which requires deeper understanding to be used safely and successfully.[73] Consequently, "natural" and "unnatural" material categories cannot be defined and separated by their environmental and social impacts.

As the interface between humans and their environment, technology both shapes and is shaped by human-environmental relationships.[74] Consequently, the definition of technology should not be restricted to machinery alone. As Edmund Russell states, "all machinery is indeed technology, but not all technology need be machinery." Both living beings and nonliving things provide tools to resolve human challenges.[75] By recognizing the technological beyond the narrow context of machinery, society would be better apt to distinguish a zone that transcends the former technology and nature dualism. In this arena, the natural and the technological emerge as varying hybrids, results of the ongoing, intricate interactions within and between individual entities and larger assemblages. Designers may realize that all materials are both natural and technological by origin and manipulation respectively, forging ties across ideological divides. These hybrid tools cannot be studied in isolation, as they are both products and productive of a larger, complex, and dynamic system of cultural, political, and environmental elements.[76]

The concept of "technology as natural" denies the necessity for technology to replace nature.[77] To illustrate the possibilities of nature and technology coexisting, Arthur McEvoy identifies factories as ecosystems, or urban ecologies. With humans as a biological core, life becomes embedded in a technological realm, which in turn depends on natural resources, regional ecosystems, and global stability.[78] Like industrial factories, modern architecture, such as the Crystal Palace, regulates modern machinery and technologies, human occupants, pests, microbial life, energy inputs, and waste outputs in an environment that mimics a natural ecosystem. In fact, the key difference between a constructed ecology and a natural ecology is its original conception and creation by humans. Although factories and buildings tend to be more heavily managed by humans than natural systems, built environments remain subject to their interior and surrounding forces, including natural, social, political, and cultural influences. This interdependence is common to all ecologies.

Likewise, the notion of "nature as technological" also challenges the inherent separation of nature and culture by exposing the use of conventionally natural beings to resolve human challenges.[79] Edmund Russell, for instance, situates organisms, both part and whole, as technology, or biotechnology.[80] In the Dominican context, native plants are grown and harvested specifically for structural and roofing applications; buildings directly utilize living species to fulfill a technological requirement. Russell argues that, when harnessed, organisms can be conceptualized and/or utilized as products, factories, assembly lines, inventors, or workers, combining nature and technology into one fluid process.[81] In response to ecological concerns, some organisms can be used efficiently and symbiotically with few modifications by employing their evolved capabilities, such as environmental remediation. Russell also argues that anthropogenic evolution has been unavoidable for human survival and growth; disproving the novelty of biotechnology naturalizes human technological manipulations and "technologizes" nature more completely.[82] By affirming the necessity, mutual benefits, and possible costs of biotechnology, society can consider technological merits and choose a more harmonious relationship to nature through its actions.

Material movements have begun to explore the intersection of crop-based inputs and technological manipulation. Historically, chemurgy emerged as a movement seeking to use agricultural products to make industrial goods. George Washington Carver is renowned for his experimentation with peanuts, but many other efforts to develop crop-based products emerged in the 1930s with hopes of aiding farmers suffering from overproduction and inadequate markets. While contextual needs have changed dramatically over time, the environmental, social, and economic benefits of chemurgy are very relevant today. [83] In the 1980s, researchers renewed their interests in developing regenerative, biodegradable or recyclable, raw materials with equal performance to other products of material science. Nature-tech, or bionics, has produced many positive results, but few manufacturers undertake the risks of development.[84] However, with persistent research and implementation, chemurgic building materials have great potential to reduce embodied energy and toxicity, close material cycles, support local and domestic production and livelihoods, and provide new markets for low-impact agriculture.

In current chemurgic practices, technology facilitates new methods of processing pre-existing, crop-based materials. Most products change inputs' form to standardize and assemble. Some products also require alterations or additions to inputs' composition to improve capabilities. For example, the form and composite makeup of sandwich plate materials can display great strength, stability, rapidly renewability, and biodegradability. Biocomposites can utilize corn, wood, sunflower seeds, and cellulose to create biodegradable yet industrial products.[85] In these examples, technology can increase the functional performance of materials without compromising their environmental benefits. Fidobe, a mixture of recycled paper slurry and adobe dirt, remains low-energy and biodegradable with significant advantages over raw adobe. Fidobe weighs less, is a better insulator, can hold a screw, and can be painted.[86] Therefore, a middle ground generally opposed by "technological" and "natural" advocates should not be considered a less ideal compromise as solutions are possible without sacrifices in either ideology.

Several barriers to new sustainable material development exist and must be overcome, including standardization, social norms, zoning, and categorization systems. The CSI MasterFormat and building codes do not encourage innovation because unique materials are difficult to classify. However, denial of new material development is self-defeating as users demand materials better suited to their specific needs, and more sustainable options will promote global health for all beings. Multiple production methods and sources also offer flexibility and stability over economic cycles. New classification and regulatory strategies should encourage beneficial material adoption and exploration.[87] Schropfer and Carpenter state, "The development of different families of materials will reflect the concepts and desires of contemporary society. The way in which architects begin to consider new materials will determine the value with which society views them, and the longevity they will ultimately have as construction components."[88] Therefore, decision makers must align their policies with the values of a sustainable society or suffer the consequences of misaligned goals.

Categorizations must particularly cater to the idea of hybrids to overcome simplistic, dualistic norms because the interaction of human and nonhuman forces results in hybrid landscapes. The effects of human interventions in the environment prevent the possibility of clearly and physically delineating the technical from the natural.[89] The concept of *envirotechnical regimes* adds another layer of indistinguishable complexity, combining the institutions, people, philosophies, and technologies that shape these landscapes. The name *envirotechnical* acknowledges that nature arose first but is now co-produced with technology; environments are no longer limited to natural features.[90] This concept encourages scholars to consider a wider range of factors, or assemblages, that mediate human-environment relationships, and these new ideas affect actions and technologies.[91]

In conclusion, the definitions of technology and nature are overlapping, culturally contingent, and influential in designers' decision making. Many actors seek to sharply delineate a boundary between technology and nature but struggle to separate human and nonhuman entities that have become indivisible. Their search is futile and problematic because it assumes ahistorical views of nature and technology. Society and scholars must consider the dynamics and contexts of envirotechnical systems to judge proper solutions to the challenges they face. [92]

Understanding and applying technology

How should designers conceive of the materials they encounter and the buildings they create? Currently, the building industry privileges human comfort and wants above the needs of nonhuman entities, which has allowed unsustainable practices to persist. Consequently, the agency exerted by designers to choose their environmental relationships reflects more Western values and needs than aspects of nonhuman nature.[93] Due to the focus on human constructs, designers can consider the same physical conditions and challenges and yet devise vastly different ideas and approaches. Daniel Botkin explains two approaches to ecology, the arcadian and the imperialist, that dictate the proper use of technology ideologically. The arcadian view, like eco-centrism, is a romantic ideal of holism, harmony, and balance between all parts of ecosystems. Arcadians perceive "the power to mold nature" destroys the value of nature's function, transforming nature to artifice. The arcadian view relies on dualistic assumptions that technology and nature cannot coexist. Conversely, imperialist traditions promote domination of nature, like many eco-technic strategies.[94]

These ideologies easily translate into firm rules for technological use, in which arcadian followers seek to avoid all technology and imperialists glorify its power. Once again, the dualistic assumptions that prevent symbiotic relations between technology and nature are problematic. Arcadians must recognize that nature retains meaning due to its own agency; it cannot be rendered powerless or completely destroyed by human actions. Likewise, imperialists must appreciate the value partnerships with nature, rather than conquest, to ensure the regeneration of resources for continued human survival. The fears and aspirations of each opposing viewpoint (the destruction of nature, the conquering of nature, etc.) are largely symbolic and can cloud the issues most pertinent to sustainable design (environmental, economic, and social concerns). Designers must avoid firm ideological mindsets in favor of exploring the specific needs of their location and identifying appropriate solutions from the full set of envirotechnical alternatives at their disposal.

In order to broaden conventional modes of thinking, Michel Callon suggests methods of agnosticism, general symmetry, and free association. Respectively, analysts should avoid censoring actors' views of nature and society, generate a vocabulary to discuss society and nature on the same terms, and abandon preconceptions that fix separate roles of natural and societal events.[95] In the examples of the Crystal Palace and Dominican buildings, Western society and practitioners should not privilege scientific nor local methods but encourage equal openness to and skepticism of all strategies. After openly studying and discussing natural and social conditions under a unified vocabulary, the building community, and other technological fields, can make informed decisions based on contextual information.

While it is vital to consider contextual details for site-specific installations, Michelle Murphy introduces the concept of "regimes of (im)perceptibility" to reveal the tradeoffs of study. According to this concept, increasing focus on one factor, solution, or party decreases consideration of a broader field of possibilities. For example, the earlier discussion of renewability revealed its benefits as a method of material categorization and judgment, but renewability is not without its own disadvantages. Fixation on numerical data decreases the perceptibility of more qualitative, contextual details, which are imperative to develop socially appropriate solutions. Imperceptibility is one of the key disadvantages of dualistic thinking; by exclusively affirming specific approaches under a fixed set of ideals, one denies the validity of novel or alternative strategies. In contrast, by exploring a range of possibilities, factors, and stakeholders, attention to any specific entity decreases and hinders conventional progress.[96]

However, are conventional notions of *progress* appropriate considerations in the development of sustainable building methods? Beneficial solutions for one group may have significant consequences for another, necessitating a wide scope despite a slower, more laborious process. Perhaps with the redefinition of natural and technological realms, a parallel shift in the concept of progress is also imperative. Rather than a steady stream of typically "easy" solutions, where speed and efficiency are primary values, humans should aspire to more effective solutions that may result from a more cautious, calculated, and iterative approach with a wider range of choices, voices, and decision makers. People must seek balance in their investigations, studying on a variety of scales and seeking inclusiveness of factors, stakeholders, and solutions without ignoring details. Achieving such a balance is a challenging, subjective, and evolving task requiring constant vigilance and reassessment.

When practitioners achieve a proper balance of local details and wider considerations, they may reap the rewards of unique, hybrid methods as more integral solutions. A middle ground between arcadian and imperialist traditions would include the use of technology for environmental remediation or biomimicry. By applying lessons from nature or attempting to improve upon nature's processes, humans naturalize technology.[97] The creation of closed-loop, autopoietic machines, rather than open-loop, allopoietic machines, is likely to satisfy the goals of all sustainability advocates by cooperating with, rather than controlling or submitting to, nature.[98] While technology develops from a long diffusion of ideas, it has much to learn from the elegance and endurance of nonhuman nature's solutions.[99] However, Callon's method of free association discourages the application of any solution, including nature's processes, without skepticism.[100] Nonhuman nature evolved its processes over millennia to suit specific conditions, not a universal ideal; therefore, natural processes are not universal solutions.[101] When mimicking nature, consideration of both the contexts of natural processes' origins and applications is crucial for proper translation and function.

The Crystal Palace and local Dominican buildings provide cautions against using either nature or technology as a universal ideal. Joseph Paxton, Crystal Palace's designer, was a self-taught gardener who admired botanical structural capabilities.[102] In his design for

Crystal Palace, Paxton literally translated the structure of lily pads into longitudinal and transverse girders, expecting architectural materials to mimic the lightweight strength of their floral inspiration. According to Frederick Kiesler, these romantic ideas made the structure's collapse inevitable.[103] Fostering the belief that all things "natural" are ideal is a tenet of greenwashing,[104] deceptive product marketing based on misconceptions of environmental benefits.[105] Therefore, practitioners must not apply nature's lessons literally; one must consider materials, structure, function, and context to assure appropriateness. Yet technologically-labeled solutions cannot be generalized haphazardly either, as illustrated by the open-air vernacular in the Dominican Republic. The application of unneeded forms of high technology would consume excess monetary and natural resources that the region lacks; the geographic, social, political, and cultural context dictates alternative methods overlooked by a mindset of strict control.

Lastly, designers must not only consider *what* materials they use but also *how* they use materials to attain sustainability. Many consequences of materials arise from the actions they permit, rather than from materials' substantive properties. For example, "ultra light and super strong" materials allowed building on unprecedented scales, yielding immense skyscrapers and vast warehouses.[106] While some ancient structures attained great scale without industrial materials, large projects were limited due to their difficulty to construct. Increases in building size, consumer and national ecological footprints, and often social inequality are consequences of new material properties that facilitate large-scale construction. Many factors of application contribute to the sustainability (or unsustainability) of materials, and designers must not rely on assumptions of naturalness (or unnaturalness) to make material decisions with significant and/or lasting impacts.

Conclusion

By rethinking the assumptions of environmental dualisms, the defining qualities of nature and technology, and the applications of technology, designers can recognize that a single solution, or even a single ideology, is unlikely to meet the needs of all the world's diverse regions. Crystal Palace and Dominican structures, as iconic examples of high-tech and low-tech building practices, reveal the benefits of blurring distinctions between humans, nature, and technology in both physical applications and underlying ideologies. As examples of "technological nature" and "natural technology," Dominican structures and the Crystal Palace convey the appropriateness of both low-tech and high-tech materials according to the needs of their applications. Views of buildings as interacting aggregations of living and nonliving parts, similar to ecologists' perspectives, can inform future architectural practice that is better attuned to complex human-environment relationships.[107]

Aiden Davison recognizes that Western society has built a risky world that will continue to embrace environmentally degrading, open-loop technologies if practices remain unchecked. In order to enact change in the building industry, innovators must first provide alternatives that architectural and interior designers accept. Every human-made object emerges from the interaction of what is thinkable and possible, and innovators must know when to accept limits and when to press against them.[108] These decisions may implicate a wide range of stakeholders and expertise, in which collaborative technologies will be a benefit. However, Western society must also embrace ecological ethics and morals to make shifts in technical solutions effective. Sustaining technology necessitates identifying technology that sustains humans and the nonhuman entities that humans wish to sustain. By targeting its end goals, society can gradually define and enact a "commerce of sustenance" to nourish the things it values, leaving behind the unfocused and wasteful "commerce of consumption."[109]

Once people perceive the value of diverse solutions, suited to both individual contexts and global concerns, green building debates may no longer center on technological disputes but rather the best methods to balance a wider range of values with a precise focus on key details. In this way, openness to hybrid and alternative forms of knowledge assists both analysts, who seek to understand human-environment relations and the means for sustainability, and actors, who require a wider array of solutions that meet their specific needs. A new way of thinking, shaped by agnosticism, general symmetry, and free association, could impact fields far beyond the building industry to solve social, cultural, and political disputes that hinder social and environmental justice.[110] This shift to equal openness and skepticism is key to sustainable development, which seeks to balance all human and natural requirements.[111] The following chapter will analyze the less technological issues of sustainable development in more detail.

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Eco-medical vs. Eco-social

Introduction

Development is a significant topic for sustainability movements. The buildings, infrastructure, institutions, and programs that societies construct produce tangible benefits and costs for diverse stakeholders. Environmentalists often fear detriments to ecosystems, and human rights activists may suspect social exploitation with significant modifications. However, as humans must interact with their environments to survive, many analysts distinguish between scales of development to judge desirability. Developmental dualisms tend to separate large-scale, rapid, and externally funded development from small-scale, gradual, and internally initiated ventures, and the values of different groups dictate their favored strategies. However, dualistic preoccupations can mask and oversimplify important criteria to judge developmental actions, indicating a need to analyze and challenge assumptions in order to fully explore sustainable options.

Guy and Farmer's dualistic pair of eco-medical and eco-social logics details the values that drive different scales and types of development. The eco-medical logic grows from concerns for human health; interior environments must shelter humans from the possible hazards of nature and human-made artifacts. Eco-medical environments are characterized by scientific knowledge. As human bodies tend to respond similarly within a range of environmental conditions, eco-medical designers seek to maintain established conditions for health and comfort. At their core, eco-medical interiors strive for consistency, whether utilizing mechanized, high-performance systems to isolate the interior from external harms or carefully controlling visual, air, water, and other exchanges with the surrounding environment. To understand the needs of their users, designers rely on communication between academics and professionals worldwide. This educated network and the product of a standard set of healthy data ranges defines the values of eco-medical followers.[1]

In contrast, the eco-social perspective places less emphasis on individual comfort in favor of human community welfare. Rather than relying on an international network of knowledge, eco-socialists seek self-sufficiency and democracy within their communities. Buildings should convey a message of unity and empowerment through a regional identity. Design criteria arises more from socially communicated needs than scientific findings, allowing users to participate in building design and operation. Whereas an eco-medical approach may support standard equipment or strategies across locations on the basis of universal data, eco-social views emphasize the use of appropriate technologies, flexible and tailored to the unique environmental, social, and economic needs of the location. Due to divergent emphases on the individual and the community, global and local knowledge, standardization and customization, and collaboration and sufficiency, eco-medical and eco-social logics present seemingly oppositional paths for building and development.

Prior to Guy and Farmer's identification of logics, Banham (1969) defined two approaches to environmental control and development according to perceived human-environmental relationships. *Global* modes, like the eco-medical, seek to control nature, rather than understand it, which prevents environmental holism. *Local* approaches, like the eco-social, are responsive to their contexts through form, materials, and proportion, celebrating the interior and exterior through connections.[2] However, Banham and contemporary dualistic thinkers oversimplify the methods and effects of global and local initiatives, and as a result, ignore beneficial opportunities toward sustainable building. Economic and developmental incentives are often considered antithetical to ecology and sustainability, perpetuating the human vs. nature dualism that precludes symbiotic human-environment relations. In addition, associations of globalization with First World, capitalistic, human greed and nature with Third World, local subsistence limit understanding and cooperation between stakeholders. In order to identify a suitable path for development in Punta Cana, analysts should recognize the challenges, dualistic definitions, and ambiguities of development that implicate both nonhuman nature and human societies.

Challenges

Many barriers to sustainable development are linked to the concept of *progress*, which is central to Western culture. By continually seeking a more advanced state, societies do not remain content with workable solutions and may adopt changes without proper criticism. Settlers established America around the idea of progress, seeking a “new world” to remedy the “backward” and “unprogressive” cultures of Europe.[3] Philosophers of the Enlightenment, such as Descartes and Bacon, viewed traditional stability as a restriction on freedom and social betterment. In these views, rational knowledge overcomes the “inefficient meandering of evolution.” Conceptual connections between economic growth and progress did not arise until Victorian commercial enterprises; societies were simply moving from an imperfect past toward a more perfect future. Consequently, many ideas were, and continue to be, embraced without extensive reasoning.[4]

The most notable machine of the industrial age, the clock, marks the idea of progress within Western culture. Timepieces symbolize consistency and accuracy, allowing unprecedented coordination and demanding efficiency from all succeeding mechanical inventions. While accurate timekeeping has undeniable advantages from certain perspectives, the clock also dissociates time from space and human and natural events; humans rely on mathematically measurable units, rather than weather or bodily signals, to dictate many of their actions. The weakening of human reliance on natural cycles either passed unconsidered or was deemed less important than the industrial gains of progress.[5]

Only a few decades after Descartes and Bacon, Hobbes reignited concerns of scarcity and self-preservation. However, Mill's anti-progress stance and advocacy for a steady state were too extreme for widespread support.[6] Instead of resisting all development, many past and current analysts recognize the need to consider the application and contexts of specific developments. Cultures, institutions, and ecosystems have different resiliencies, defy simple cause-and-effect logics due to complexities and adaptations, and can suffer significant developmental side effects.[7] Technology that is high in productivity but does not nourish the livelihoods of communities is undeniably unsustainable and a key danger of development.

Particularly in Third World nations, social oppression, poverty, and environmental degradation are linked; these consequences can overshadow any gains of industrialization and become a deadly trap for the poor.[8] In Punta Cana, where locals rely on natural resources and environmental beauty for their livelihoods, all technical and political solutions must preserve environmental health. Many fear that industrial processes, without proper ethical measures, can cause erosion, waste, inequalities, desertification, resource exploitation, and other social and environmental damages.[9] However, new development can also provide employment and goods that have advantages over current opportunities and conditions. While economic goals can conflict with environmental and social needs, they are not inevitably destructive and should be included within comprehensive solutions.

Many analysts also fear the imposition of industrial influences onto more traditional customs and processes. In addition to growing concerns regarding environmental health, cultural heritage seems threatened in the 20th century.[10] Technocratic and cultural sustainability are often considered as two separate discourses and concerns, but significant links exist between them. The ecomodernist agenda is largely centered around eco-efficiency, and technocratic discourses can often render anxieties about culture unheard.[11] Cultural traditions in the past tended to build resiliency by restricting fast changes that favored short-term benefits over long-term costs. The "Great Acceleration" of the 1950s, a period of globalization and urbanization after the economic and population restraints of war and the Great Depression were removed, exemplifies the dissipation of traditions and holistic stability. These changes altered human-environment relationships, privileging indirect knowledge gained through science over direct, experiential knowledge. While global transfer has many benefits, it can also increase global inequalities and fail to resolve poverty, hunger, sanitation, health, and pollution in areas in need.[12] The costs and benefits of globalization suggest the need for judgment to meld the benefits of customs and change.

Contact between the ideals of First World development and Third World resources also raises concerns due to past unethical business practices. Racial minorities and impoverished groups have been consistently exposed to the costs of development, such as toxic hazards, waste disposal, and pollution. Countries lacking basic needs are particularly vulnerable to the pitfalls of environmental racism, in which wealthy, dominant groups bear a large share of the benefits and small share of the costs of development.[13] Regulating agencies have had difficulties incorporating social dimensions into sustainability, including human rights, education, health, gender, and diversity.[14] However, social interests are equally as important as the other facets of sustainability, and models are needed to clarify balances of development, tradition, assistance, and returns. Grupo PUNTACANA demonstrates the possible mutual success of First World support of developing countries' autonomy and wellbeing, rather than selfish exploitation.

Globalism was a major feature of environmentalism in the 1960s and 1970s, acknowledging the need to discern between interventions in varied nations.[15] The global North and South face very different problems; while the North is destructively consumptive, the South suffers from underdevelopment and struggles to meet basic needs. Due to their varied situations, each category, and the nations within them, requires differentiated solutions.[16] Many challenges arise in attempts to assist developing countries, such as the Dominican Republic, to support themselves with a combination of global and cultural practices. How should the global South improve their standard of living without adopting the unsustainable practices and standards of industrialized countries?[17] How can Third World countries gain the resources to break cycles of poverty without losing their traditions and autonomy? Does sustainability require reduced standards of living in First World countries, and what standards should measure quality of life?[18]

In order to guide resolutions to these questions, Integrated Global Models attempt to build quantitative understandings of human-environment relations. However, without the means to model qualitative cultural or social factors, models are very limited tools to predict or judge the viability of alternatives.[19] Likewise, environmental building rating systems and guidelines, such as BREEAM, CASBEE, and LEED, are designed for temperate climates and may not easily translate for more diverse areas, such as the tropical conditions of the Dominican Republic.[20] However, the systems do not publicize that their solutions are not universally effective; on the contrary, they encourage the use of their criteria globally. Michael Redclift states, the "usefulness of sustainability indicators is directly related to the policy context which they are used to address"; many designers do not oppose use of quantification in general but only the assumption that ideals are objective and universal.[21] Existing guides to sustainable action suggest that systems more suited to local conditions, such as the Taiwanese EEWH system for tropical climates, or hybrid models to factor both natural and human components would be helpful to determine appropriate paths of action.[22]

A final challenge entails not only the problems communities must solve but also the processes to develop a more sustainable path. Davison states, "Before we accept sustainable development as a new morality, as well as a new economic strategy, we need to know what ecological, social, political, and personal values it serves, and how it reconciles the moral claims of human freedom, equality, and community with our obligations to individual animals and plants, species, and ecosystems." Beyond defining values and goals, stakeholders must realize that local perspectives cannot be simply added to scientific knowledge because they often become meaningless when generalized and removed from context.[23] By encouraging critical contemplation, rather than hegemony and presumptions, communities are more likely to maximize social capital, maintain moral codes, and act rationally toward long-term sustainability.[24] Further investigation of developmental dualisms will reveal and question the assumptions that often prevent a beneficial mix of influences for change.

Dualisms and ambiguities

Literature on the Third World commonly details two distinct crises: the environmental and the developmental, separating natural ecology from society and economics. For example, Pearce pronounces that strong models of sustainability differentiate between natural capital and capital stock, whereas weak models do not.[25] The perceived need for categorization fuels dualistic thinking. As a consequence of attacking narrow, isolated problems, actors overlook the interdependencies and possible synergies between human and nonhuman entities.[26] Alternatively, other analysts recognize these links but view economic, social, and environmental categories of different scales as oppositional. Commonly, the affluence, abundance, and security of the technological world are viewed as key contributors to unsustainability. These views are equally problematic, as the separation of concepts into dualistic categories fuels oppression by establishing masters and subordinates. Ecofeminism identifies the oppression of women, developing countries, and nature as a consequence of their "otherness" to dominating males, developed countries, and technology. Likewise, ecomodernism "devours others" with technical mastery and its imposition of the ideal of global "progress"; neither theory supports holism or equality of beings.[27]

The most prominent dualisms surrounding development, which help explain the eco-medical and eco-social divide, include human vs. nature, global vs. local, science vs. social, First World vs. Third World, and economics vs. environment. With further investigation of these dualisms, the Brundtland Report's assertion that development and environmental issues cannot be separated will become more apparent.[28] Morals, understandings of relationships, and conceptions of self are embedded within ideologies and practices, which are necessary to study in order to effect change. By questioning the reasoning of prevailing dualisms, designers can better align morals with their actions for beneficial solutions on a variety of scales.[29]

A. Human vs. nature

At its core, communities perceive development to indicate control of nature and people. Development is seen as human endeavors with tangible results, creating imbalances in nature by transforming nonhuman resources to meet strictly anthropocentric needs. The assumption that humans are unnatural and destructive to nature has been discussed at length in previous chapters but remains relevant as a base for other developmental dualisms.[a] However, environmental modifications are natural and inevitable for all species; human development, when viewed from an evolutionary perspective, is simply change, rather than unnatural or destructive. In their choice of building materials, designers must challenge the assumption that all things "natural," or with less human manipulation, are beneficial and preferable to more processed alternatives. As human actions vary in desirability and can be considered natural, all "natural" materials cannot be assumed universally good and should be analyzed individually. Without the baggage attached to *natural* and *unnatural* terms, designers can focus more clearly on the physical impacts of materials and choose to promote the interests of both human and nonhuman societies.[30]

B. Global vs. local

Development is often divided along global and local scales to differentiate their impacts. While all buildings and infrastructure are based in a specific, local place, global development indicates initiatives that cross borders, either through physical construction or through the stakeholders involved. Globalization also has conceptual links to modernity, but separate perceptions of global and local are not unique to 20th century. The global vs. local

[a] See "Environmental Philosophy, Philosophy of Technology, and the Human vs. Nature Dualism" in this thesis.

dualism has a long history through nationalism and imperialism, which are characterized by increased cultural diffusion. Over time, global and universal, and local and particular, have become popularly synonymous with varying normative connotations.[31]

Opponents of globalization fear development fueled from external investors, characterized by prefabricated buildings, heavy industry, and commercialization, does not utilize local skills, knowledge, or conditions, creating negative connotations to global development in local communities. In these views, globalization disperses control among many people and places, but power often remains concentrated within groups with the most influence and wealth.[32] Consequently, wealthy groups often control development remotely with varying levels of consideration for local needs, contentment, and traditions. Even when opponents of global development acknowledge that developed nations often act beyond self-interests, they tend to claim that nations spoil local culture by failing to adequately integrate new developments into existing customs, structures, and practices.

In addition, citizens often perceive globalization as less environmentally sustainable and less natural due to its removal from local processes.[33] The air conditioner is a symbol of architecture dominated by global solutions untailored to a given place and its ecology.[34] Global material scientists often employ machine-like precision, consult many abstract variables, and rely on the expertise of others in collaboration. In comparison, societies widely consider decentralized craftsmen and artists as more creative, less machine-like, more self-sufficient, and more natural. Machines absorb the technical capacities of craftsmen to make materials homogeneous and standardized; the creative challenges of craftsmen become defects to machinery.[35]

However, not all machines are "air conditioners," or items of climatic ignorance, and not all manual labor is environmentally benign.[36] While it is easy to claim that industrialization and globalization brought resource depletion and land mismanagement due to their more recent and visible impacts, American environmental degradation began with European colonization, including deforestation and material extraction to build settlements.[37] Globalization can cause ecological damage, but local, decentralized processes can also be harmful and can concentrate damage more than global operations. Due to similar challenges of deforestation in the developing Dominican Republic, it is important to compare the specific impacts of tailored development to existing conditions, rather than assume industry will come and spoil its resources relative to more "natural" practices.

Despite the validity of many of these concerns based on past events, *global* and *local* concepts are often relative and socially constructed. Hannerz recognizes that "there can be no cosmopolitans without locals" because they are relative designations that define one another. In addition, "what was cosmopolitan in the early 1940s may be counted as a moderate form of localism now," according to Hannerz, revealing the unfixed nature of dualistic terms.[38] Likewise, regional and national borders are constructs with significant implications for human interactions. Borders, like dualisms, indicate difference, and varying values attached to divided entities can foster oppression. In addition, globalization is commonly marked as an attack on communities; however, the rise of conceptions of a "global community" questions the definition and limits of *community*. Is collaboration between material scientists an inferior community to assemblies of local builders? Is a global community desirable to aid and consult with local architects? Should material use be restricted by regional availability, or should materials be chosen primarily based on project and community needs?[39] How are the boundaries of the local community defined, and what are the benefits of communities that should be preserved?

Rather than threatening the physical community, opponents of development may claim that globalization endangers culture, one of the key values of community. Designers often reinforce the polarity of local assertions vs. global trends and good culture vs. bad civilization. These allegations assume that globalization overrides locality and development is culturally homogenizing. However, such claims are counterintuitive.[40] First, development of the new is not independent of past development; actors build upon all that has come before, learn from the past, and adapt prior techniques.[41] Next, culture and civilization are human products that rise in tandem and are not oppositional. Finally, the assertion of local traits conveys a generalized image of a locality. Local qualities tend to be constructed on a trans- or super-local basis; unique characteristics are identified by comparing cultures and recognizing patterns over time and space, often from an outside perspective. These observations dispute the assumed opposition between universalism and particularism; local traits resemble global assertions as both must make generalizations from a certain scale or perspective.[42]

Due to these ambiguities, it is possible to combine the dualistic categories of globality and locality, as well as homogeneity and heterogeneity. Global culture is not the exclusion of the local; global is inclusion, signifying the interconnectedness of local cultures of various ranges. Interaction cannot be equated with homogenization; on the contrary, interaction can increase diversity and societal resiliency. In addition, traditions need dynamics to survive, and encounters between civilizations can help perpetuate practices, proving possible cultural benefits of globalization.[43] Alternatively, ideas on a global level generally seem more distant and debatable than concrete details, and environmental problems may overlook individual contributions and unequal burdens. Consequently, global policies can benefit from global and local blends to inspire action.[44] Conventional notions of cultures as sharply bounded without hybrids should be reconsidered to realize the reality and benefits of polyethnicity.[45]

Roland Robertson introduces *glocal* as a desirable blend of commonly identified global and local factions. The term *glocal* grew popular in Japanese business in the 1980s to describe "a global outlook adapted to local conditions." Like micromarketing, glocal products adapt broad concepts to appeal to the differentiated customers of a given locale. Dominicans may view American influence as cultural imperialism, but Dominicans can choose to absorb new ideas in a variety of ways, and the United States also tailors its products and ideas to Dominican applications. By viewing specific actions, such as those of Grupo PUNTACANA, designers can realize that international design is more complex than homogeneous enforcement of practices and values. In addition, many First World members underestimate the flow of ideas from the Third World to First World communities; contact inevitably resonates to shift values and outlooks.[46] Within a given place, a glocal mindset overcomes other dualisms of development. City and country are no longer opposites but are varied patterns of human density and intensity. In addition, these developments are not antithetical to nature but are parts of their bioregions.[47] Consequently, glocalization may be a suitable path to guide material selection that fosters sustainable human-environment relationships.

C. Science vs. social

The associations of globalization with scientific precision and local culture with social relativity lead to further perceptions of divided interests. Bruno Latour recognizes the modern authority of "Science" as a source of absolute, objective truth, or "matters of fact." A serious consequence of scientific "experts" is the silencing of alternative, marginalized, and local producers of knowledge.[48] When scientific, or highly technological, methods of knowledge are considered ideal, indigenous values and enduring traditions are considered primitive and naïve. Westerners commonly judge indigenous people and their wisdom to be more natural, likely due to their low-tech and low-impact solutions, local materials, and slowly evolving practices, while technology is associated with developed, modernized populations. An absolute faith in technology can justify imperialism to Western cultures, which impose their ideals upon vastly different cultures without consideration of varied ways of life and regions. Therefore, human ideologies toward technology matter not only to pursue physical human and environmental needs but also to protect against social injustices.

However, the use of novel science and technology does not inevitably discriminate against less powerful groups. Science can also provide a means to represent racial minorities, low-income populations, and traditional cultures. Statistical data can recognize the relative needs of different zones and populations to distribute resources where political and social hegemony may otherwise discriminate unfairly.[49] Groups in need can benefit from scientific justification, but actors must always consider cultural, social, and political contexts to avoid imposing methods where they are neither appropriate nor desired. Where all groups are receptive, blurring distinctions between technology and nature may encourage a blending and sharing of knowledge across classes, races, countries, and neighbors. Indigenous cultures may actually initiate globalization by presenting their methods to globally influential cultures as a strategic means of preservation. With an open, rather than dualistic, frame of thinking, Western society can discover merit in multiple forms of knowledge, practice more inclusive thinking, and support the preservation of diversity. No knowledge or solution should be utilized in all cases, but a range of practices are appropriate to meet the world's diverse physical, social, and cultural contexts.

In the realm of material development and application, various forms of material science illustrate the possibility of partnering with alternative knowledges. Whereas popular conceptions of lab-based material science demand collaboration between elite, scientific, and design groups, chemurgy connects material development back to a more popular level, as agriculturalists become key suppliers and experts of material inputs. Utilization of less scientific inputs can be more democratic, both within developed and developing countries. The practices farmers implement affect the properties and implications of crop-based materials. All stakeholders must understand the intentions of sustainable production to reduce harms over the entire life cycle.

Not only are scientific and social hybrid materials possible, but also many modern material developments demonstrate the viability of chemurgic-inspired innovations for wide-scale use.[b] The success of linoleum proves crop-based materials can deliver high performance, gain acceptance in developed countries, and compete with industrial materials. Linoleum, produced from linseed oil, resins, cork flour, limestone, and jute, has been a utilitarian, durable, nontoxic, and inexpensive material since 1860. Today, linoleum is a greener alternative to polyvinyl chloride (PVC); no safe disposal exists for PVC, but linoleum can be composted or recycled with appropriate programs. Linoleum also avoids the toxins that PVC offgasses throughout its life,[50] and it performs superiorly in life-cycle analysis.[c] The enduring achievement and benefits of linoleum should inspire further exploration of

[b] See Stattmann (2003) for detailed product developments.
[c] See http://www.forbo-flooring.com/Home/Creating-better-environments/Linoleum-the-environment/ for a life-cycle analysis of linoleum.

processing techniques to reintroduce other sustainable, crop-based materials to modern, Western culture.[51]

While the threats of resource consumption tend to be most visible to the short-term values of Western sustainability movements,[d] the social consequences of material science can be equally severe. These costs extend beyond representation of knowledge to direct impacts on human health and wellbeing. Kenneth Geiser highlights the main design parameters of material science as functional criteria, including performance, processing efficiency, and costs of production. In its attempts to produce stronger, lighter, tougher, more durable, and more flexible materials, material scientists seldom give equal weight to issues of toxicity that damage human and nonhuman health and development. Toxicity has been accepted in the past because material solutions met functional needs; PVC is widely used due to its low cost, durability, and ease of use, despite the known harms of the dioxins it contains. Similarly, high-performance ceramics are celebrated for being harder, stronger, and stiffer than metal, despite their energy intensiveness and possible carcinogenic, nonrenewable inputs.[52] Social reformers urge manufacturers to employ the precautionary principle in production. Since producers cannot know the long-term effects of new materials, they should minimize possible hazards in their products. In support, Geiser states, "If we paid closer attention to the materials that we produce, we could pay less attention to the impacts of those materials once they are released to the environment and people are exposed to them."[53]

Science and social concerns are likely to blend in future material developments. Material scientists must innovate to make their past works safer for public and private use. Science is not antithetical to social objectives when materialism and profits are not the sole

[d] See "Sustainability Movements, Motives, and Metrics "in this thesis for further detail.

concerns; science can be a critical tool for social betterment. In order to fully consider social needs, sustainable material agendas and enforcement may need alternative methods. Currently, top-down policies rely on the knowledge of experts and scientists and do not empower individuals, conflicting with the multiple goals of sustainability.[54] A bottom-up approach may better reflect cultural and social contexts as local participants voice their needs and assist in material development.

D. First World vs. Third World

In addition to debates of overall social harms, material science is also targeted for generating social inequality between and within global nations. Ceramics began as clay and silica, abundant and inexpensive sources available globally. However, when combined with high technology, ceramics become prohibitively expensive and thereby less democratic.[55] Material science efforts are concentrated in and primarily benefit the First World, yet they consume resources that all humans must share.[56] In addition, the creation of materials with superior performance disadvantages Third World producers of raw materials who lack the resources to compete. If advanced materials replace a significant share of natural materials, Third World employment and livelihoods may be threatened.[57] Material science also creates competition within and between First World nations. The United States fears high-tech ceramics will replace more traditional metal production, leaving sectors of its economy vulnerable. In addition to rising internal tensions, the United States' material sectors feel threatened by Japanese ceramic research and struggle to increase their own studies.[58] International races, as exhibited in the Cold War era, often lead to excessive consumption and waste and divert resources from social, domestic issues.

These material examples illustrate the general divide between developed and developing countries in the environmental movement. Many environmentalists debate whether the First World or the Third World is more environmentally degrading because it is difficult to compare their disparate challenges. While the First World must reduce its consumption, developing countries must avoid depleting and polluting their resources in their attempts for survival and higher standards of living. In the Dominican Republic, a common threat to public health is the contamination of water sources with human excrement. First World recommendations and technologies to avoid such contaminations could greatly improve human and ecological health; however, much of the global South fears Northern control under an ecological guise. Apprehension may be particularly intense in the Dominican Republic, which has suffered a long history of domination and colonialism.[e] Sustainability and proclaimed goodwill can be means for hegemony, as pollution controls and conservation have allowed developed countries to manipulate the Third World's actions.[59] While many controls act in the interests of global welfare, should developed countries be able to dictate actions that may limit the poor's abilities to survive and prosper?

While other developed countries are responsible for severe environmental degradation, the United States is targeted as imperialistic and in need of change for three key reasons. First, the American lifestyle is an ideal that other countries aspire to and use to measure their own achievements. If developing countries seek to mimic overconsumptive lifestyles and demand higher standards of living, their desires would counter global sustainability goals. Secondly, the United States is the largest offender of consumption and pollution, epitomizing irresponsibility toward nature. Lastly, the United States' power and

[e] See "The Dominican Republic" in this thesis for further detail.

authority create a moral responsibility to join, if not lead, initiatives for more responsible environmental practices. America, as a historic symbol of progress and now a symbol of waste and greed, fuels assumptions that development is inherently harmful.[60] The United States' future actions are imperative to demonstrate the falsehood of this duality, proving that development can be regenerative and sustainable.

Necessary shifts in First World developmental policies include the utilization of communities' energies, knowledge, and imagination. Designers must consider residents as resources and rightful stakeholders in design dialogues. Engagement is not always easy as communities may not speak as a collective. Opinions may diverge, and stakeholders may require a variety of outlets to participate. Designers must also possess sustainable ethics to protect against NIMBYism, promote democracy and holistic sustainability, and choose proper solutions for communities.[61] Rather than expecting a quick and fluid transition from "unsustainable" to "sustainable" or "undeveloped" to "developed," designers must adopt a learning approach and long-term view to continuously represent stakeholders' priorities. An open dialogue that positions all stakeholders as partners, rather than experts and advisees, may break down barriers between First World and Third World parties and reveal common goals and values. Adams identifies four green principles: cultural definition, self reliance, social justice, and ecological balance. By seeking these goals, modernization is not imposed as an end in itself or for corporate greed but as a means for wellbeing.[62]

E. Economics vs. environment

Finally, many scholars assert the oppositional characters of environmental and economic interests. Adams claims neo-Malthusian ideals stifle economics and policies, and likewise, capitalism and consumerism damage ecosystems and resources.[63] Parr further explains that capitalism profits the rich, reduces accessibility for the lower classes, and produces waste as an environmental justice issue. By putting a price on nature or patenting traditional practices, resources and customs are removed from nonhuman ecosystems and indigenous populations.[64] The environmental Kuznets curve also links wealth to environmental degradation, in which moderate incomes correlate with maximum damages. However, correlation does not indicate causation, and income is not likely the direct cause for ecological harms. Rather, a combination of means and values is likely responsible. Low-income populations have less means for large-scale destruction, whereas the middle class has means but lacks the education and social pressures that lower environmental degradation among the wealthy. Therefore, it would likely be more effective to influence the values of the middle class than to restrict or increase their wealth through economic measures.[65]

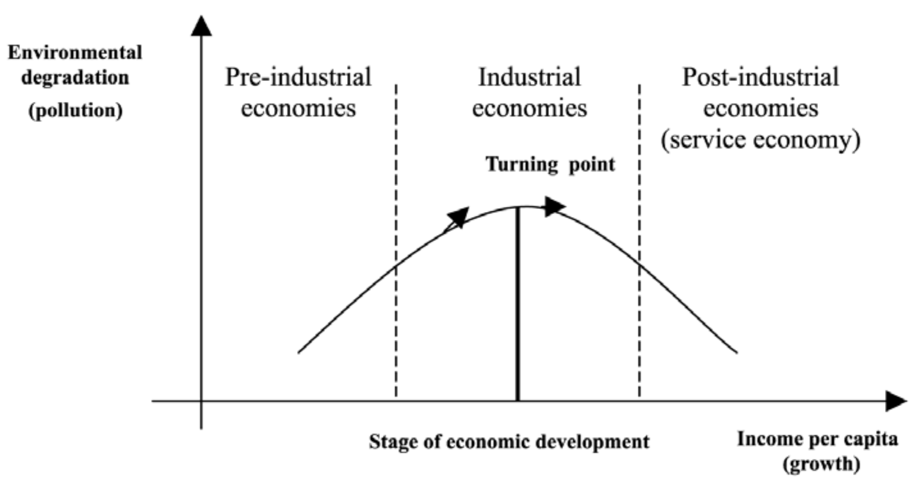

Figure 7: Environmental Kuznets curve[66]

The underlying values reflected in the environmental Kuznets curve reveal that ecological and economic priorities do not have to conflict. The relatively low impacts of the elite illustrate both economic and ecological success. Counter to conventional beliefs, sustainable development is an opportunity for economic growth, not a prohibition.[67] The environmental Kuznets curve also indicates that economics is not synonymous with materialism; a shift from preindustrial economies to service economies could greatly raise quality of life without extreme resource consumption and pollution. Economies can create sensory richness through experiences and green collar jobs to remediate human-environment interfaces. In building construction and operation, designers that utilize passive strategies, site-specific methods, and local materials will reduce client costs and increase the desirability of their services.[68] A common ground for environmental and economic goals invites a larger range of supporters for sustainability and seems more feasible and credible than missions that exclude the pursuit of income and comforts.[69]

Green development and ecotourism as resolutions in Punta Cana

Ecotourism and green development present opportunities to reap the benefits of glocal influences and balance environmental, social, and economic priorities in Punta Cana. Firstly, past struggles for Dominican autonomy necessitate control at the community level, including discussions between regional officials, resort managers, business owners, residents, etc. Ecodevelopment focuses on fulfilling human and ecological needs through community participation and appropriate technology.[70] Debates of the mechanisms and dynamics of general development often obscure its ethical basis, and green development focuses on individuals' rights to choose methods, rather than have them imposed. In other words, green development is not only about how environments are managed but about redirecting power to the poor and silenced; green development is a process, not an end. According to Western scientific mindsets, it can seem counterintuitive for methods to arise from the bottom-up, but top-down knowledge must only advise decision making, rather than control it, to take advantage of context-specific familiarity.[71] Without understanding the geographical, political, environmental, cultural, and socio-economic characteristics of a place, designers cannot adequately tailor their solutions to fit specific needs.[72] With an openness and understanding to different approaches and knowledge, international stakeholders can fulfill their collective responsibilities to improve equity and autonomy through sustainable solutions.[73]

Ecotourism, as a kind of sustainable development, has the potential to greatly increase international contacts to protect the ecosystems and provide for the residents of Punta Cana. Ecotourism combines conservation with economic development, overcoming the discussed economics vs. environment dualism.[74] In addition, ecotourism follows the "Global Code of Ethics for Tourism" established by the World Tourism Organization (WTO) to protect social interests as well.[75] Like other forms of development, many conventional ideologies assume that tourism always threatens the environment. However, ecotourism is marketed as a complete win-win, earning profits for investors, supporting countries in need, and providing environmental protections. In reality, ecotourism is neither entirely good nor bad; it can be a means to protect populations and environments, but its effectiveness depends upon its context, motivations, planning, strategies, and execution. Developers and other stakeholders choose their relationships of conflict, coexistence, or symbiosis with the environment. By balancing the anthropocentric and ecocentric priorities and voices of many participants, ecotourism can be an opportunity for Third World countries to meet their specialized needs.[76]

In Punta Cana, ecotourism may be a viable solution to showcase, enjoy, and preserve the health of its unique and treasured landscapes. As ecotourism relies on the beauty and authenticity of its natural experiences, developers must protect ecosystems to maintain their businesses. Ecotourism is most beneficial when tourists become aware of the special qualities of the featured location, and Grupo PUNTACANA has greatly contributed to raising awareness of ecological value and the need for protection. The shift from a preindustrial economy directly to a service economy is also likely to preserve ecological health while increasing quality of life, according to the environmental Kuznets curve. However, the developments at Punta Cana have been particularly successful because of their comprehensive and specific approach. Whereas many ecotourist ventures emphasize environmental interests above cultural priorities, Grupo PUNTACANA has fostered strong connections through aid and employment in their region.[77] The group's attention to detail and cohesion with its surroundings fosters the development of initiatives closely tailored to the needs and goals of the stakeholders.[f]

In 2003, tourism accounted for 35% of total export earnings in the Caribbean, acting as a major source of employment and economic revenue. However, the majority of Caribbean tourism is mass tourism and lacks many of the benefits ecotourism could provide. Specifically, much income from mass tourism leaks back to developed countries through airfare and suppliers. Nonetheless, this leakage can be reduced through ecotourism principles, such as careful planning, education programs, and agricultural incentives. Punta Cana acts a model for actions that reduce these leakages.[78] Grupo PUNTACANA considers both short-term and long-term effects on the community beyond their own profits, judging not only how much money flows into regions but how much stays and multiplies to build local economies.[79]

[f] See Grupo PUNTACANA at http://puntacana.org/community/index.html for details on current initiatives.

Another danger of current mass tourism in the Dominican Republic threatens the small businesses of resident entrepreneurs. Of the hotels in the Caribbean, 75% are mass tourism and/or all-inclusive resorts. Restaurants and cultural centers are prone to fail if tourists do not leave the resorts. Sustainable tourism, in contrast to mass tourism, is integrated into the socioeconomic environment to support local development. Often, a less homogeneous experience appeals to alternative tourists, who may seek authenticity. The PUNTACANA Resort and Club features shuttles to PUNTACANA village, providing symbiosis through attractions for visitors and revenue for local businesses.[80]

Despite the numerous possible and current benefits of ecotourism in Punta Cana, many of the challenges previously identified by dualistic thinking remain. A primary concern is the diversion of resources, which are often already strained in the Third World, to serve tourist needs. To meet the expectations of upper class, First World clientele, resource consumption can easily become unsustainable. Scarcity can lead to increased conflict between residents and resentment toward visitors.[81] Such challenges illuminate the complexity of ecotourism planning. In order to attract business but not compromise sustainability goals, ecotourism may need to challenge tourists' preconceptions of accommodation.[82] If mass tourism is unsustainable, ecotourism cannot provide the same amenities. While these changes may restrict Dominican tourism's target market, they will attract visitors more aligned with their values. A unique, educational experience will likely appeal to many alternative tourists to uphold profits.

As previously discussed, greenwashing remains a threat to ecotourism's credibility in Punta Cana. Many activities and ventures that label themselves as ecotourism do not uphold the ethical responsibilities of the title. National governments are often most effective at regulating the ecotourism industry; however, the Dominican government is too fragmented and vulnerable to corruption to provide adequate support. Even with regulation, it is difficult to establish a baseline for ecological damage and measure cultural and social impacts. With these barriers, the need for ethics and self-regulation arises. As Grupo PUNTACANA demonstrates, ecotourism is not simply a business but an expression of support for ethical values. Developers and tourists must conceive of their resource use as a privilege, spreading sustainable values beyond ecotourism in Punta Cana to all facets of daily life.[83]

Lastly, ecotourism in Punta Cana and beyond may struggle to define and represent the "community" in their actions. Who is the community? What are its boundaries? Should consultation of "locals" stop at city limits? How should developers represent implicated nonhuman entities? How should conflicting values be prioritized? Once again, the answers to these questions are likely context-specific and require careful consideration in the planning process. By attempting to consult and respect the needs of stakeholders as inclusively as possible, ethical ecotourism is likely to continue to benefit the glocal community of Punta Cana.[84]

Conclusion

Sustainable development, despite professed honorable intentions, has faced many barriers to its effective operation. In addition to the environmental damages of industry, vulnerability to unethical practices, and limited tools for action and measurement, sustainable development faces an arguably more formidable opponent in the dualistic ideologies that foster assumptions and preclude full consideration of locally appropriate solutions. By overcoming dualisms that separate humans from nature, globalism from locality, science from society, First World from Third World, and economics from the environment, stakeholders are more likely to recognize shared goals and possibilities. Within Punta Cana, tourism can act as both a vector and beneficiary of globalization.[85] Not only can ecotourism provide employment, protections, and other benefits for societies and their ecosystems, but it can also grow recognition for the need for ethics in tourism by embodying competence, integrity, justice, and utility. An ethic of stewardship spread throughout the mass tourism industry in Punta Cana could have far-reaching effects and advantages throughout the community.[86] The implementation of measures at the right level and context can provide unexpected benefits as well as intended solutions; these solution multipliers that extend sustainable values on global and local, or glocal, scales could be the most significant benefits of ecotourism and sustainable development.[87]

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Eco-aesthetic vs. Eco-cultural

Introduction

Metrics to compare the sustainability of materials often highlight embodied and operational energy, compiling data on performance, processing, and transportation distances, as well as health hazards and disposal criteria. While these considerations focus on the processes, users, workers, and resources implicated by the materials themselves, other relevant sustainability criteria directly consider human reception of materials, which dictates enjoyment, maintenance, and prolonged use. Analysts reason that, without suitable aesthetics, symbolic meaning, and attachment, human users will not utilize materials' performance and life spans to their fullest potential, resulting in waste, inefficiency, and/or further material demand. In addition, buildings and culture are co-productive; due to architecture's influence to shape and be shaped by culture, design intentions and symbolic communication deserve contemplation.[1] While architects generally acknowledge the importance of users' architectural interpretations, designers often hold divergent opinions of the appropriate meaning for current sustainability projects. Eco-aesthetic and eco-cultural perspectives reveal two popular stances, in which architecture symbolizes modernity or tradition. This dualism disregards cross-temporal linkages that can resolve many conflicts between architectural styles.

It is difficult to challenge stylistic dualisms because many factors influence the way societies and individuals perceive materials, and these factors are often more challenging to measure than material properties due to variability, intangibility, and subjectivity. Consequently, the heuristic categories that designers must rely on to identify and describe cognitive matters give rise to assumptions about materials and techniques. In particular, descriptors, such as vernacular, primitive, high style, modern, and industrial relate to the human vs. nature dualism, under which practices and materials with longer histories and less technological inputs are assumed more natural than other alternatives. By understanding the meaning of materials, the assumptions and ambiguities of material cultural dualisms, and viable hybrid stylistic solutions, designers will more fully consider human users as factors in material selection and select culturally appropriate materials to encourage sustainable use.

Meaning in materials

Designers consider materials, and technology in general, by both measured mechanics and metaphorical meaning. In other words, people care about the significance and experience of technology, as well as its performance. Lance LaVine claims, "The role of technology in architectural design is to present the natural world to people in a way that allows them to understand, and hence to belong within, that world." Vernacular, in particular, connects societies to workable solutions within their local landscape. Technology not only shapes relationships between human and nonhuman entities but also perceptions within human society, such as status, wisdom, and power. Jane Jacobs recognizes that buildings are not static artifacts but containers for complex, dynamic, and interdependent users and uses. Social quality matters when humans are considered valuable resources, and material meanings can validate or deny the importance of certain kinds of contributions.[2] Therefore, the manifest perceptions of individual buildings may impact user comfort and security, but the latent meaning of architecture's fit within the cultural landscape has equally important impacts for the community at large.

LaVine declares that architects contribute these metaphorical attributes and latent meanings, whereas engineers are more responsible for material mechanics and manifest meanings.[3] Consequently, materials are not only substantive but also procedural; materials are often categorized in isolation, but much of their significance arises through interaction within their contexts.[4] If architects shape, or even select, material meanings, they are capable of imbuing new connotations through their continued work. William McDonough claims design is the foremost statement of human intention; therefore, designers must be clear of their intentions before building occurs.[5] Currently, the positive attributes associated with vernacular, including truth, honesty, expressiveness, naturalness, and sustainability, are often overshadowed by negative social qualifiers that discourage their use in mainstream buildings.[6] In order to pursue sustainable material applications, designers should seek to diminish the cognitive barriers to the use of vernacular materials.

Rammed earth buildings require ten to twenty times less energy to build than concrete or brick and can greatly outlast timber construction with life spans of 500 years. Earth is available locally and/or onsite, requires low maintenance, offers good insulation, regulates humidity, and is completely biodegradable. These benefits have been proven over generations of use, and construction requires little training, tools, or expenses; the main barrier to wider use of earth as a building material is psychological.[7] Architect and planner J.C. Moughtin writes:

> Earth or mud architecture is often described as impermanent and therefore an inferior method of building. Yet unbaked earth has been used for many thousands of years, not only for housing, but for some of society's most prestigious developments: great ziggurats, pyramids, religious and public buildings have all been constructed from this material.

Moughtin conveys dramatic changes in material culture over time. Materials once honored and sacred can become discredited with new standards and preferences toward performance and innovation.[8] Due to social factors, the accessibility of mud building to people of all economic and skill levels can actually decrease its use in the Western world. While cob was popular for both peasants and the elite before brick was available, the wealthy tend to gravitate toward more exclusive and refined products.[9] Natural and unfinished materials, like mud, become associated with poverty if only people without means to afford alternatives continue to use them. The pursuit of prestige can cause additional problems when materials of status are ill-suited to their applications. The wealthy tend to prefer concrete as a substitute for mud despite its expense, failure to moderate temperature, and instability in natural disasters. As the wealthy tend to control much of public development, their material choices can have significant consequences for ecosystems and the public at large.[10]

According to eco-aesthetic views, traditional materials are also discarded due to their impermanence relative to industrial materials. Western culture values permanence, which many organic materials lack; however, permanence, as a standard, may need reconsideration in response to dynamic environmental and cultural environments.[11] The wish for permanence has spurred desires for imported, expensive, industrial, standardized, and individualized materials.[12] Earth is not the only building material facing resistance; straw bale, fiberboard, and bamboo have limited usage due to associations of "non-technological" green design with shoddy construction and poor aesthetics.[13] Building with earth or timber frame may seem regressive to some architects, but these methods have become more accepted with environmental concerns due to their low embodied energy. With the interplay of technological innovation and low-impact revivals, the 21st century promises to be diverse, combining traditional, industrial, and newly invented materials in unexpected ways.[14]

Relativity and subjectivity also play roles in judging the modernity of materials. Metal and glass are associated with modern aesthetics despite their ancient histories. While these materials have long histories of non-architectural use, their use in building construction is relatively new compared to stone, brick, and vegetative materials.[a] Therefore, the context and application of materials matters to shape their meaning. The absence of crop-based materials from most First World buildings may be advantageous to market them toward modern sustainability as unfamiliarity entails a degree of novelty. There is hope that, rather than meanings of regression, crop-based materials could convey new values of sustainability.

The perception of materials is also closely linked to their appearance and culture, proving the malleability of their meanings. Material processing is capable of changing material appearances without significant alterations to content; crop-based materials with rustic aesthetics can be "reinvented" for modern applications. For example, unfinished wood is highly reminiscent of their original trees, but by hiding the knots and grain with finishes, wood loses its "natural" feel. The popular associations of materials, such as stone's impenetrability, wool's intimacy, and steel's coldness, are products of culture, experience, and intuition.[15] Design can bridge culture and technology by generating shared symbolic meaning in public space.[16] Design can also connect people to the phenomenology of nature and daily events by representing ephemeral, natural qualities that uniquely define a given place.[17] By actively working to suit materials to united cultural meanings and preferences, designers can make sustainable alternatives more attractive for contemporary projects.

[a] See Appendix A for further detail.

The malleability of material perceptions can be both an advantage and a concern; designers are wary of material science's ability to change designers' and users' material interpretations and interactions. Louis Kahn and others stress the need for hands-on experimentation and understanding of properties to be expressive with a given material. Materials have not always been considered key to conceptual developments, but materials largely define the physicality of architecture and can generate inspiration to advance the discipline.[18] Material science can be a tool to illuminate material properties and also reverse age-old associations of materials. For example, sawing improvements in the 1900s allowed the use of stone as a finishing material. Stone, in this application, became known for its lack of tensile strength and vulnerability to shocks. In addition, stone could be precisely shaped and cut thin to achieve translucency; in these instances, users may interpret stone as glass-like.[19] Such alterations in perception may or may not be problematic to cultural symbolism and psychological wellbeing; further research is required to explore the possible effects.

Material meanings also drive divided support and opposition toward the industrial aesthetic. Ruskin argues that the moral and imaginative aspects of materials elude machine production and industrial materials.[20] Others were troubled that the very idea of regional materials, in terms of both sourcing and history, was antithetical to International Style. In opposition to "could-be-anywhere" enclosures, Jorn Utzon used local materials in his designs, recognizing materials' roles to create identity, belonging, texture, familiarity, and daily life in their contexts. Modernism considers these tectonic, or local and cultural, considerations as nostalgic and outmoded, denying material agency.[21] However, Semper agrees that the proliferation of new materials can cause uncritical abandonment of the old in favor of the new, causing detriments to the user experience.[22] Material meanings have place-based value that is established through origin, history, scarcity, and convention over time; Utzon, among others, valued continued and humanizing meaning above architectural fashion.[23]

Utzon, Semper, and others likely identified industrial materials as symbols of "throwaway culture" before the mindset fully developed in society. Semper pioneered the connection between materials and culture; he pronounced a "logic of reciprocity between the material quality of the component and its respective method of deployment within a larger system of construction and signification." Without significant personal, cultural, or aesthetic connections or value within places and their materials, buildings are liable to degradation, misuse, and replacement, using excess resources and preventing cultural richness. The value previously embodied by age declines as new products and buildings are built with shortened life spans. Industrial materials' emancipation from detail and tradition can support ecological sustainability through dematerialization and performance but rob structures of cultural meaning and aesthetics, as feared with the use of ubiquitous plastics and concrete that patinate poorly. These consequences of material meanings can set environmental, social, and cultural goals at odds.[24]

Alternatively, natural building movements, and eco-cultural perspectives, rely on human labor and creativity over capital, high technology, and specialization.[25] After World War II, the proliferation of cheap housing in the United States supported mechanization and mass production, abandoning traditional techniques and craftsmanship. Kennedy claims that buildings have become soulless, lacking distinct regional character and meaning.[26] Industrial materials allow buildings of unprecedented scale with little physical human exertion or customization. In contrast, natural materials installed with human labor dictate a different lifestyle. Humans are more likely to build modestly, and building becomes a social activity defined by community exchange. With user involvement, low-impact building is commonly adaptable, user-friendly, and economical.[27] Communities and individuals can feel empowered by their self-sufficiency and view the rewards of their labor with pride.[28] In addition, typical pre-scientific building practices studied and mimicked nonhuman nature.[29] Past critics, such as Semper, identify nature as a teacher, stating architecture should respond to the laws and processes of nature, rather than applying materials without ecological regard.[30] Geiser echoes these historic beliefs in biomimicry as he states, "By more consciously modeling our materials and their uses on processes of nature, we would be more likely to fit our materials needs into the ecological systems by which the planet already operates."[31]

Natural building is likely to remain alternative to conventional strategies, but it has already been influential in broader culture. More people recognize the importance of vernacular and possibilities of hybrid local and industrial methods.[32] Designers strive to respond to natural cycles through dynamic, regenerative, and passive design strategies. By realizing the possibilities beyond the habitual mindset of humans separated from nature, designers can accept less polluting, less consumptive, and less toxic materials for design.[33]

Defining vernacular, high style, and their dualistic relationship

Many terms exist to describe the style of architectural works. Formal studies of architecture tend to focus on high style, eco-aesthetic architecture, identifying changes in movements shaped by notable architects. The study of architectural movements is tied to concepts of progress and modernity; architects draw inspiration from past works to create new styles and practices. In the 700 years preceding the Industrial Revolution, designers slowly traded or adapted traditions as transportation allowed exposure to alien materials and practices.[34] As designers were no longer confined to the materials of their surroundings, they sought unfamiliar materials to fulfill the functional and aesthetic desires of their projects.[35] The eco-aesthetic logic supports the embodiment of the "New Age" and contemporary zeitgeist in architecture to encourage ongoing pursuits of ecological holism and complexity.[36] Designers should not cling to traditions that arose during prior eras and impede invention but incorporate the most current advances and interests. Eco-aesthetic results reflect social and cultural influences of their time, and architecture becomes symbolic of modern living.

The label of *eco-aesthetic* supports the perception of architecture as an art form. Buildings, however, are not synonymous with architecture. When analysts do not recognize aesthetic intention through form, materiality, or a notable designer, critics do not consider buildings to be artful.[37] The definitions of buildings, architecture, and the divide between them are unclear and debated, yet designers maintain the two separate categories. Vernacular building commonly refers to "buildings of the people… customarily owner- or community-built, utilizing traditional technologies… [and] accommodating the values, economies and ways of living of the cultures that produce them."[38] Rather than conveying the wonders of modernity through continual change, vernacular structures continue the practices that have endured over time and build distinct regional culture. Howard Marshall states, "Folk things tend to vary little over time but much over space- and the opposite is true for fashionable things and academic architecture."[39] The *eco-cultural* logic recognizes the value of local traditions and supports the materialization of linkages to the past through contemporary works. Eco-culturalists and Critical Regionalists mark the construction of industrial buildings, corporatism, and postmodernism as breakdowns of the local identities that they seek to preserve, perceiving technological change as the dualistic antagonist to vernacular practices.[40] In other words, by using the term *vernacular* to highlight the cultural and contingent nature of buildings, modern, or non-vernacular works, are cast as acultural.

Both industrialized countries, such as the United States, and developing countries, such as the Dominican Republic, have been at the fore of stylistic debates. American architecture generally follows eco-aesthetic ideals, characterized by acquisitiveness, plasticity, and productivity. Prefabrication began in the United States as early as 1578, and American designers have readily received and applied subsequent technologies to great efficiency. A patterned use of metals and glass arose because the materials were technically advanced, economically beneficial, and culturally desirable. Prefabrication and industry made units more affordable and accessible to the middle class due to economies of scale and standard conformity to building codes. Cultural stories, such as "The Three Little Pigs," reveal a desired progression from primitive, inarticulate structures to stable, permanent forms. Overall, new technologies removed hard labor, scarcities, vulnerabilities, and inconveniences of past building experiences and were thereby gladly accepted.[41]

Nonetheless, eco-culturalists critique rapid stylistic changes and technological adoption for several reasons. Primarily, they claim American architecture favors aesthetics over performance, valuing form over function. Without flexibility and proper planning, buildings can hinder user activities. Over a century ago, Semper claimed that goods are designed to maximize market sales, rather than to ideally suit specific needs. Today, universality is often a goal because it appeals to the broadest market.[42] Heidegger voices similar concerns that modern buildings provide structure and revenue but lack the essence of dwelling. Environments should enrich and nurture, rather than simply allow, human life.[43] Mumford also cautions against modern architecture, stating a "machine for living" idealizes characterless, air conditioned boxes. After designers have made their calculations, they must still consider the effects of space on the human soul, local landscape, and global health. According to Mumford, the "greatest problem of our time is to restore man's balance and wholeness," rediscovering the value of life to restore meaning to human actions.[44]

A lack of function pertains not only to human use but also buildings' integration into the ecological and cultural landscape. Mass production and technologically engineered building systems yielded designers, builders, and consumers ignorant of the need for buildings to accommodate site-specific qualities. Luxuries of comfort, control, modernism, and amenities became higher priorities than regional-appropriateness and ecological responsibility. Fitch claims, "Unimaginative and inefficient standardization is possible only because of the relative cheapness of fuel and power, as well as of heating and cooling equipment."[45] If buildings must rely on continual inputs lest they fall vacant, are modern changes really improvements upon "primitive" works? What is the boundary between comfort and excess?[46] As resources become increasingly scarce, eco-culturalists fear the pursuit of uniform interior conditions and exterior form is unsustainable in the long term.

The removal of certain limits of time and space has additional consequences for environmental and user health and quality. Particularly, engineering and industrialization greatly alter the design process. Designers' roles change from manipulating materials to supervising specialists and coordinating prefabricated systems. Specialization hinders feedback and inclusive, integrated solutions by fragmenting decision making and communication. As building professionals become less accountable and knowledgeable of the design process, interests in efficiency and trends replace former accumulated wisdom essential to symbiotic human-environment relationships.[47]

Mechanization can also distance humans from understanding building processes and caring about their effects. How can humans be stewards of the Earth if they do not understand or care about their relationship to it? Turning on a furnace or air conditioner requires so little forethought and effort that users may not realize the mechanisms and consequences of their actions.[48] Mumford states, "An environment or a structure that has been reduced to the level of the machine, correct, undeviating, repetitious, monotonous, is hostile to organic reality and to human purpose: even when it performs, with a certain efficiency, a positive function, such as providing shelter, it remains a negative symbol, or at best a neutral one." Instead, designers should empower users to design for themselves, which forges user connections to their environment and daily processes. To beneficially mediate stylistic dualisms, designers harness the energy and creativity of postmodernism without overlooking vernacular opportunities to celebrate the building site and region.[49]

However, the drawbacks of industrialization can cause complete reactionism in industrialized nations and resistance to industry in preindustrial regions. Frank Lloyd Wright cautioned against the dangers of ready-made forms, which can stifle creative expression. According to Wright, designers should choose materials by their nature, fitting their selections to desired function and aesthetics, rather than judging by cost or rarity.[50] Mies van der Rohe's Farnsworth House illustrates the pitfalls of blind pursuits of material prestige or iconography. The glass box lacks privacy, shading, and operable windows and suffers from glare and heat gain; the client claims Farnsworth House is entirely uninhabitable in the dramatic temperature fluctuations of Illinois weather.[51] Utopian, industrial pursuits in the Dominican Republic could meet similar undesirable ends; materials and their applications must respond to the unique aspects of the site's climate, topography, and functions. As these factors were the key drivers for traditional architecture, eco-culturalists tend to support vernacular practices to avoid the detriments of stylistic hubris as well as conserve monetary costs. Consequently, designers in many developing countries where traditional methods have largely endured support their continued use, rather than industrial adoption.

As a result of their exclusion from artful categories and as another contributor to dualistic thinking, vernacular structures have historically drawn less attention for formal study, despite their dominance in the building industry.[52] Marcel Vellinga, Paul Oliver, and Alexander Bridge estimate that 90-98% of all buildings globally are vernacular with higher concentrations in developing countries where traditional economies, social structures, and cultural values have been more persistent. Due to its links to developing areas, despite its prevalence in all regions of the globe, vernacular architecture is associated with tradition, primitivism, and folk building.[53] While these terms describe attributes of some vernacular works, they obscure the diversity, and particularly modern possibilities, of vernacular. By noting vernacular as primitive, architectural historians create perceptions of a dualistic relationship between vernacular and high style buildings.

A. Primitive

The term *primitive* has a notable tradition of use in architectural history. In previous generations, primitive indicated simplicity, a lack of self consciousness, attunement to the past, and an avoidance of excesses and vanity.[54] Until the 18th century, primitive meant "original" or "at the origins" without strong cultural associations. A notable primitive archetype is the primitive hut, recognized for its basic elements designed for function alone and as a model for Classical architecture.[55] However, the admiration of primitive works faded within many disciplines with the rise of postmodernism and post-colonialism. *Primitive* continues to signify simplicity in architecture, but its use is controversial, raising concerns of condescension, romanticization, and authenticity.[56]

Two distinct frames have arisen to describe primitive works, but they are often entangled within descriptions of traditional buildings. First, primitivism can be an attractive paradigm that represents noble truths that modern society has lost, threatens, and/or needs to preserve.[57] For example, some 20th century architectural writers, such as Le Corbusier, describe primitive works as exotic, aboriginal, anonymous, spontaneous, unconscious, and indigenous. Rather than denigrate low-income, non-Western cultures, Corbusier draws inspiration from the danger and excitement they elicit. Alternatively, other contemporary analysts, such as Adolf Loos, consider primitivism to be repulsive and use savage, barbarian, uncivilized, and instinctive as descriptors. By viewing buildings in evolutionary terms, Loos asserts the superiority of the West over the inferior, culturally degenerate East.[58] Architectural evolution is linked to Darwinism and progress, claiming that origins are less evolved and desirable than subsequent developments. Therefore, primitive works have come to be both praised and derided to create dualistic views of cultivation and primitivism, and stereotypical views have obscured the nature and impacts of vernacular structures.[59]

Regardless of sentiment, the labeling of primitive has always identified the more ancient past as the Other to conventional means. The Otherness of primitivism maintains the superiority of Western practices and an asymmetrical distribution of power. Even though designers may see value in the primitive, and the primitive can challenge the authority of conventional means, Otherness perpetuates problematic dualistic categories that cause designers to choose between modern or primitive methods, rather than recognizing both traits in their work.[60] Architecture, in particular, can change rapidly with contact with new materials and techniques, whereas myths, community organization, and language tend to be more resistant to change. As architecture can be a catalyst for wider cultural change, designers must understand vernacular not as an Other to replace or draw bits of inspiration but as ongoing processes that comingle with all subsequent building developments.[61]

Literature about vernacular architecture generally focuses primarily on ancient, or primitive, buildings. These accounts support stereotypes of vernacular building as uneducated and unsuitable for modern application. However, vernacular architecture spans far beyond primitive stereotypes with many connections to culture and society. Modern examples outweigh ancient models but remain underrepresented in academic study. According to vernacular criteria of locality, many contemporary projects within First World nations are considered vernacular, and many structures utilizing imported materials or techniques in the Third World may not be vernacular. Therefore, while vernacular is strongly linked to time and place, vernacular is not restricted to particular eras or regions; vernacular can exist wherever traditions endure over time. Vernacular must overcome its associations with primitivism to understand the value of local practices that have prevailed and have significant relevance to enrich professionally designed structures and advanced techniques.[62]

B. Human vs. nature

The link between vernacular buildings and primitivism contributes to the perceived divide between humans and nature. According to the concept of progress, human work transforms nature into civilization. Fox notes that a conflict arises because nature is driven by the past, but humans are inspired by the future.[63] As primitive works preceded modern developments, primitive vernacular— the structure, its builder, and users— is often described as "closer to nature."[64] These "natural" human works are associated with wilderness; primitive builders lack the means to radically transfigure large tracts of their surroundings.[65] Therefore, primitivism and closeness to nature may contain certain benefits, but they are perceived as less advanced and less fitting in the modern world. Time is a construct that plays a significant role in stylistic choices, and designers should reconsider its assumptions to contest the human vs. nature dualism. Why do analysts assume the roots of architecture to be pure, innocent, savage, or dignified? Why are origins significant and viewed differently from later developments?[66] Designers often fail to distinguish between contemporary, vernacular structures and their ancient, primitive roots, discounting the value of resiliency and sustainability. By viewing the past and future as connected parts within time, humans may recognize evolving forms and methods, rather than faintly related poles of practice.

Time not only defines the naturalness or artificiality of structures by their origins but also by the periods required to develop the rules for their creation. Many building professionals note that artificial materials and processes develop more quickly than their natural counterparts. For example, "unnatural" material science has greatly changed structural capabilities over decades, whereas "natural" forms for human huts developed slowly over millennia. However, these claims are based on the identification of modern developments, such as material science, as unprecedented and distinct from all former discoveries.[67] Instead, designers should acknowledge new outcomes as simply the latest steps in a full set of building innovations. While the rate and magnitude of innovation may be increasing, such steps are possible because they build upon millennia of accumulated knowledge. Therefore, modern developments should not be considered unnatural based on time because, when their connections to their origins are considered, the most recent inventions represent the longest periods of development in history.

Designers also associate vernacular structures with nature because they often imitate natural processes. Original human structures, without architectural precedents, implemented lessons from animal nests, hives, and burrows, drawing comparisons between primitive homes and nonhuman nature. These "natural" dwellings use function as their primary consideration, which has debatably changed in "unnatural" dwellings. In addition, without standard metrics, ancient buildings lacked the precision and standardization of current industrial materials. New technologies increased tensions between mechanical and climatic forces as structures defied gravity with increasing scale and grew impervious to weather patterns.[68] These opposing traits are generalizations that tend to romanticize low-tech building and disparage First World conventions; designers must realize their abilities to implement the benefits of vernacular-based practices in tandem with the modern conveniences that caused practice to change over time.

Lastly, the manual human labor associated with vernacular is widely considered more natural than the human-made machinery of industrial architecture. Techniques in which human producers directly interact with material sources are commonly considered primitive, closer to nature, and therefore more "natural." However, while industrial processes can mask their origins, they can also illuminate human relations to the environment. As industrialization's shortened time and lengthened geographic scales increased visibility of change, awareness of continual reliance on nature to source all means of production intensified. Specifically, humans acknowledged their dependence on a simplified, regulated "nature" and the bodies of animals and humans as power to fulfill human wants and needs.

These connections reveal the inseparability of human and nonhuman entities, challenging the dualism dividing humans and their technology from nature.[69]

C. Romanticization, anonymity, and globalization

Romanticization and anonymity of human labor and knowledge pose further challenges to establishing the identity of vernacular as a link between ancient traditions and modern applications. With increasing concerns of sustainability, eco-aesthetic tendencies to ignore indigenous knowledge have waned to seek and celebrate such wisdom.[70] However, much interest in native traditions tends to be anti-technological, calling for a return to simplicity, organic forms and materials, and manual craft.[71] Rather than seeking to integrate the value of vernacular with the benefits of international, scientific innovation, deep ecologists demand the abandonment of many comforts, which causes users to doubt the desirability and/or feasibility of such changes. While many vernacular practices that respect natural cycles, require less energy and materials, and foster human knowledge of nature may be more sustainable than their mechanized counterparts, designers must find a middle ground that is acceptable to users for adoption to succeed.

Manual labor has been received very differently over time. Since ancient times, the elite has enjoyed the use of material goods but looked down upon the manual laborers that extracted them.[72] Much of this disregard likely spurs from the lower class status of laborers, but analysts also have questioned the nature of manual work. Early exploration and primitive work have been equated with leisure due to similarities to wilderness adventures and lack of scientific precision.[73] Where modern society employs *techniques*, analysts view primitive cultures' work as *creativity*, suggesting scientific, white-collared employment is more useful work.[74] However, views of primitive work as creative play have also created perceptions of alternative value by excluding it from the category of work, which is often assumed harmful to the environment. Under such views, analysts romanticize manual labor as simple, holistic, environmentally benign methods and, in effect, vilify machinery that replaced many manual methods. These assumptions ignore the impacts of early building and agricultural practices, which must be considered when choosing proper strategies.[75] Instead of falling upon the general primitive and natural assumptions of vernacular, designers must analyze the strengths and weaknesses of each proposed idea within its specific applied context.[76]

By revealing the role of context that prevents universal definitions and assessments, members of society can recognize the need to reevaluate their actual and desired relations with nature. In this effort, Richard White challenges negative preconceptions of "unnatural" work by highlighting different types and effects of work.[77] Like technology, *work* is a broad category of actions, an assemblage that is obscured by a single term. When scholars claim that technology and work can both connect and distance people from nature, they reference both the possibility of dualistic effects within single entities *and* varied effects across different actions. For example, by removing the need for labor and participation through machinery and automation, First World building designs can mask natural processes to building users. Alternatively, construction workers manually work with the land and materials, forming understandings of nature unobtainable without participation.

Dominican buildings also convey varied effects of work and technology within themselves and in comparison to high style architecture. Dominican builders learn about the land through construction and by utilizing local materials. While shelters inevitably seek to remove humans from the dangers of natural processes, open-air buildings seek to foster human connections with nature by providing a safe forum of interaction. All work physically impacts nature and humans' relationship to it; the labor of building users is implicated as much as that of manual laborers. By recognizing separation as an illusion, society can actively choose its desired relationship to nature with mindfulness to their co-productive actions.[78]

Anonymity is another implication of primitivism that vernacular architecture must overcome. Many accounts detailing structures labeled primitive, such as Laugier's essay of the primitive hut, omit the builder from their descriptions. Buildings appear without agency, downplaying the importance of the builders' knowledge and process. These texts satisfy neither eco-aesthetic or eco-cultural perspectives, since the cultural and social aspects of buildings that eco-culturalists value are omitted from the accounts. Disregard for complex cultural exchange and focus on simplistic form lead to views of homogeneous vernacular works. Conceptions of primitive are often removed geographically, chronologically, and socially from their contexts to generally describe a diverse set of practices that are dissimilar to Western models.[79] Designers must recognize the cultural background of vernacular designs in order to understand their intended uses and possibilities for expanded use.

Like other aspects of local culture, globalization has been targeted as a threat to vernacular styles. High style architecture is linked with globalization because notable architects often work internationally and mimic ideas learned from various places. As international contact inevitably introduces new ideas that can alter traditions, designers often view high style as antithetical to vernacular. The Chinese building industry sees rapid destruction of vernacular buildings as a necessary aspect of modernization, following the turnover of American culture. However, professionals disregard the need to create a modern vernacular that utilizes local materials, cultural traditions, and climate-appropriate techniques in a contemporary aesthetic.[80] Global practices could yield benefits in China, but strategies must be adapted to maximize social and environmental fit.

In order to balance innovation and preservation, designers must question the delineation and value of traditions to understand this complex relationship. Since human actions are not absolutely replicable, what changes can traditions undergo without losing their continuity? Traditions must adapt and evolve over time to continue to meet changing local needs, but is there a limit of evolution before tradition folds? In addition, all traditions were new at some point in time; how should designers choose when to continue traditional practices or embrace new possible traditions? A desirable balance of change and constancy is not universal; designers must analyze the costs of benefits of innovations and precedents within given contexts.

Ambiguities

The process of evolving traditions reveals that eco-aesthetic and eco-cultural perspectives are not inherently dualistic. Many architectural theorists, such as Semper, believe the industrial arts are fatal to traditional art, but modern and traditional influences can be combined to create local, sustainable architecture that solidifies the identity of place-based, contemporary living.[81] Culture and aesthetics are not exclusive or restricted to particular time periods; modern culture and historical aesthetics exist. The present has been built on the past; events punctuate the passage of time, but no definitive divide separates time periods and their works into oppositional categories. Henry Glassie states:

> Architecture is like any realization of potential, like any projection of thought. The things of this world- this sentence, that palace- preceded themselves in the mind as plans. Plans blend memories with a reading of the immediate situation. They are realized in things. They can be reversed in analysis. Things become plans, plans disaggregate into sets of

> decisions, decisions become intentions. All creations bespeak their creators. They stand before us as images of will and wit. In this, architecture is like other things, and there are no differences among kinds of building. All are cultural creations, orderings of experience, like poems and rituals.

No building is entirely new; for example, the concepts of windows, doors, and walls have precedent in earlier times and are necessary to make buildings comprehensible. If buildings did not carry some consistent traits over time, how could one logically define a building?[82]

Distinctions of stylistic periods have had implications for material selection in the past. In future designs, brick, stone, and wood should not be automatically discarded in favor of futuristic concrete, glass, steel, and smart materials due to their associations with the past.[83] Instead, designers should seek to innovate with low-impact materials to seek sustainability within a modern framework. How could wood be used structurally with a postmodern aesthetic? How would a contemporary earthen interior celebrate its site and modern notions of prosperity? Innovative applications for historic materials present many opportunities to bridge the gap between conceptions of primitive and modern design.

Hassan Fathy and Simón Vélez are two notable architects exploring new forms and uses for crop-based, sustainable materials. In Egypt in the 1940s, Fathy recognized the suitability of traditional sun-dried bricks and methods, rather than the more expensive concrete that was in vogue, to provide housing for poor citizens. Through experiential material manipulation and interaction with cultural notions, Fathy developed impressive curvilinear forms to be applied in a wide variety of projects while preserving the climatic and cultural suitability of the designs.[84] While undeniably vernacular, Fathy's designs are also admired for their aesthetics decades later. Similarly, Vélez demonstrates the possibility of modern aesthetics and performance through the use of bamboo. In his pavilion design for the Universal Exhibition in Hanover, Germany in 2000, Vélez proved the superior structural capabilities of bamboo constructed by skilled workers relative to many industrialized materials assembled with the assistance of machinery.[85] Vélez's display of modern aesthetics and high standards of stability with a rapidly renewable and biodegradable material provides encouragement for future exploration of hybrid style, sustainable architecture.

Other architects have explored vernacular in high style projects through strategies beyond materiality. Henri Lacoste, in his design for the Belgian Congo Pavilion in 1931, incorporated vernacular lessons in order to present a more judicious representation of African culture. Lacoste utilized symbolic form and decoration and considered the site and program in his design, rather than succumbing to uncritical, romantic ideas. His challenge was to convey a message of modernization without disregarding tradition as insignificant. Juxtapositions of technology within a traditional shell present possibilities to combine cultural symbols with industrial developments in future Third World projects.[86]

Combinations of vernacular and international influences grew popular at the Bauhaus and continue in practice today. Walter Gropius professed the dangers of dividing theory and intellect from practice and craft and sought a multidisciplinary approach at the Bauhaus. Concurrently, Frank Lloyd Wright also valued hybrids of simple materials and techniques with high functioning power. The hopes of creating a modern industrial society with the organic unity of preindustrial societies continue to live in the ideologies of Ken Yeang.[87] Yeang contests assumptions that sustainable architecture must be small and low-tech as his "Bioclimatic Tower" embraces high-rise construction.[88] Rather than abandoning the benefits and norms of skyscrapers, Yeang employs biomimicry to provide passive strategies, avoid waste, and respect his skyscrapers' sites, which are goals of vernacular practice. Yeang compares buildings to prosthetics; technology can be rejected by natural systems, or it can work symbiotically to enhance wellbeing. A combination of significant study and experience increases the likelihood of advantageous solutions.[89] Scholarly experts should advise methods because of their depth of study, but they must also be open to the exchange of ideas and needs to adapt beyond professional norms.[90]

These creative architects have helped reveal that, due to the popularity and endurance of vernacular buildings over time, designers can learn many lessons through their study. Current fixations on formalism and pure geometries limit the appropriateness of buildings for human and nonhuman requirements; modern form and style should be means to a more functional and sustainable end. As Fitch states, "To be truly satisfactory, a building must meet the demands of all the senses, not just those of vision alone." Recent mechanical technologies have been incomplete, cursory remedies to replace broad concerns, failing to address the key ecological and social challenges at hand. In other words, technology extends limits, but without changing the logics of building processes, limits will remain.[91]

However, technology itself is not at fault because vernacular methods are also forms of technology. Both vernacular and industrial technologies seek to overcome certain factors of nature by providing shelter, comfort, control, and understanding. Key distinctions between kinds of technology entail the effects that technologies have on resources and social organizations.[92] As previously discussed, beliefs that mechanical precision, material abundance, and rationalization always provide both superior performance and harmful environmental effects are fallacies.[b] Many countries with "lower" standards and fewer resources produce superior workmanship and stimulating results.[93] The goals of First World

[b] See "Eco-technic vs. Eco-centric" in this thesis.

“progress” can have unintended consequences on creativity, and these consequences must be taken into account as they are encountered.

Not only can seemingly dualistic eco-aesthetic high style and eco-cultural vernacular be hybridized, but several of their common traits may also be reversed in certain instances to question their dualistic categorization. As shown by the malleability of perceptions according to appearance or culture, no material possesses an absolute truth or essence. The perspectives of Peter Zumthor and Jean Nouvel present additional evidence that stylistic assumptions can be reversed; vernacular can reflect modern ways of life, and contemporary styles can provide ample links to heritage and the landscape. Zumthor suggests that richness results from expressive “traces of human life” within buildings that speak to human visitors, evoking a sense of history associated with eco-cultural views. He states:

> Although wear and tear result in subtraction, they also allow for a significant sort of addition. Over time and through use, architectural settings accrue legibility as they chronicle the patterns of life they accommodate. Time does not pass in architecture, it accumulates. If it passed, it would leave no trace- but the reverse is true. Everything around us exhibits signs of its history, its development or deterioration.

According to the accumulation of time, the present is a representation of all prior happenings, and the more traces that buildings convey, the more complete picture users have of current ways of life. These traces persist regardless of style; therefore, a dwelling of history is also an eco-aesthetic portrait of modernism, and vice versa.[94]

Unlike Zumthor, Jean Novel supports contemporary architecture that is “light, not heavy; changeable, not permanent; dematerialized, not matter-bound.” According to eco-aesthetic “architectural Darwinism,” advanced knowledge allows the elimination of useless materials and superior performance. However, technical innovations can also pursue the nontechnical goal of reconnections with nature. To Nouvel, glass is an interface, not a barrier. With transparency and dematerialization, ambient qualities of the landscape become qualities of the building itself, which operate in unity. Contrary to critiques of static and permanent solutions, Nouvel finds modern methods to allow more dynamic and flexible solutions than ever before. Other designers, such as Frank Gehry, acknowledge that technology is also a tool to encourage creativity, allowing more complex and precise shapes and treatments. These tools allow both tangible and intangible means to communicate design intent; technology can facilitate collaboration and bridge the gap between building professionals and with the local community. Therefore, postmodern strategies can support cultural values by improving architecture's integration into the social and natural landscape, promoting connections beyond the confines of industrial living. Although their stylistic methods and beliefs vary, Zumthor and Nouvel both encourage architectural links to their surroundings, making important strides toward a sustainable, modern vernacular.[95]

Many architects have come to realize that any method of construction or material can be used creatively and that site conditions, such as material availability and climate, may indicate that traditional materials and methods are more efficient than novel ideas. Traditions in ornament are generally only sentimental, but traditions in use of material and compositional concepts may be valid, operative elements. According to regionalism, site conditions, such as topography and views, should be used as dominant elements in design and aesthetics.[96] In order to fully engage with a given place and community, architects can use innovations that are responsive and promote continuity. New methods can improve upon the old to provide more inclusive and integrated solutions;[97] as Davison says, sustainability "is not so much an invention of the future as a rediscovery of the past."[98] By recognizing the need for diversity to survive in a changing world, designers will be more open to materials associated with various stylistic characters and investigate suitable options for each specific project context.[99]

Lessons of a modern vernacular

After acknowledging the need for environmentally and culturally responsive buildings, designers are often skeptical of more sustainable paths to follow. However, vernacular traditions can provide a proven basis for sustainable design in specific regions. Schropfer and Carpenter believe that, despite the perpetual development of new materials, traditional materials will remain foundational due to their honed, extensive applications and knowledge.[100] Vernacular tends to represent collective wisdom about materials, methods, and techniques that have been tested and affirmed over centuries.[101] Vernacular knowledge is not unscientific, but rather, "the laboratory was in the field," investigating and copying the most effective solutions across time and space.[102] Vernacular inventions, such as the wind scoop, are apparent demonstrations of technology that yield desired functions without academic study. Where First World practice may be accused of pursuing knowledge and innovation for its own sake, vernacular seeks only appropriateness for adequate functioning in its physical and sociocultural context.[103]

Many scholars have also noted that no two climate control solutions are identical among anonymous builders, suggesting that design neither has one fixed solution nor can be applied universally without adaptation.[104] One danger of idealizing the "primitive" is that without adaptation, traditional structures would not accommodate modern lifestyles.[105] Likewise, modern strategies encountered through globalization are also prone to dissatisfaction and failure without tailoring them to local conditions. Palacios Guberti (1999) demonstrates these dangers in the Dominican Republic, as Dominican residents disliked the new housing provided without their input. Without an understanding of cultural norms of housing flexibility for expansion, security, privacy, sanitation, and cleanliness, the designers produced undesirable structures according to functional and symbolic criteria.[106] Consequently, designers must seek engagement with stakeholders. Ecological and social responsibilities dictate the formation of plans based on each specific site, rather than making a preconceived plan work on the land. The consideration of all tools at hand, including the most recent inventions and an inclusive history, provide the best odds to guide future actions in a sustainable direction.[107]

Consequently, many of the lessons of vernacular are sought to achieve the goals of sustainability. The passive strategies for building heating, cooling, and ventilation of vernacular architecture are widely admired among sustainable designers. Stone, mud, and brick efficiently insulate interiors from heat gain. Structures with open sides or fenestration allow cooling winds to circulate. Orientation and shading are also critical to shelter from heat; Third World builders who lack access to mechanical systems do not overlook these important steps, whereas architects who rely on air conditioning may increase their cooling loads without regard. Haitian and Dominican housing often employ these methods, as well as permeable screens, thatched roofs, and deep rooms, to regulate comfort levels without additional inputs.[108] In their design of resort accommodations, Grupo PUNTACANA has not abandoned these wise examples by using open pavilions for several of their dining facilities, showing their values for the local climate and culture and decreased resource consumption.

In terms of materials, notable architects have often resisted the use of vernacular materials due to the privileging of permanence, stability, and modern aesthetics.

Architectural historians note the efficiency of tensile structures for nomadic lifestyles; tents are lightweight, portable, and require little material. However, due to the arguably more stable lifestyles of today, dwellings constructed of vegetative materials are deemed incongruent and impoverished by modern standards. While citizens logically would resist relinquishing the comforts and safety of their long-lasting, sturdy homes, the dissimilarities between past sustainable practices and current unsustainable ways raise important questions. Are buildings meant to last?[109] Would it be possible to maintain comfort and safety but allow materials to return to ecological cycles at the end of their useful lives? Historic material usages may reveal fruitful paths for future sustainable material applications.

While vernacular offers useful insight for the current building industry, professionals must apply its lessons with care to avoid shallow inspiration. "Formalistic mimicry" or "pseudo vernacular" imitates form but lacks the original, intended, or appropriate function. For example, if designers utilize mud or adobe in a hot climate but fail to provide the proper orientation, organization, or shading that maximizes the intended cooling effects, designers disregard the full extent of vernacular knowledge and perpetuate views of its simplicity and primitiveness. Low technology is widely considered simpler and inferior to high technology because its complexities are not readily apparent; designers should seek to equalize low-impact strategies by implementing them holistically and elegantly.[110] Beyond functional concerns, designers must also be transparent regarding the source of their inspirations. Tourism, in particular, can manipulate culture for presentation, misleading tourists who presume authenticity. In order to avoid misinterpretations, designers should be explicit regarding the source and effects of their choices relative to past and current cultural norms.[111]

On the other hand, designers must also use caution when applying innovations to vernacular. Concrete has become a dominant material for housing in the Dominican Republic, displacing the use of wattle and daub with thatched roofing. By using concrete, a material adopted for its prestige and modern aesthetics, in tandem with traditional organization and orientation, Dominicans create culturally hybrid homes. However, the use of technology may be misguided, as concrete imposes additional risks in natural disasters, limits passive cooling, and restricts flexibility. Alterations to vernacular must not increase the demands of buildings beyond environmental, economic, or social means.

The United States faces unique stylistic challenges as an industrialized country without a long history. Throughout its history, "people chose to exchange the confidence of communal life for the excitement of the pursuit of wealth."[112] If vernacular signifies stable practices that characterize an area by their suitability and continued use over time, does the United States, or regions of the United States, have a vernacular? Some analysts may claim that Americans lack a vernacular because their lifestyles have been largely exploitative and volatile from their origins. Instead, American designers create popular and high style architecture that is symbolic of American lifestyles but is largely unsustainable. A return to preindustrial building would likely degrade supplies of renewable resources due to current levels of demand and would not fit aesthetically in the landscape, violating the goals of vernacular. The United States strongly demonstrates the need for a modern vernacular as neither past nor current examples are sustainable models for long-term use.

Henri Lefebvre presents a helpful model to consider a future path for stylistic choices in his writings about the everyday. *Everyday* is ordinary, bottom-up, and egalitarian; it does not privilege romantic nostalgia nor seek ultimate prestige and novelty. Lefebvre recognizes that much of the resistance to an everyday blending of past and future desires is not only functional but also due to the conceptual meanings attached to particular methods and materials. In order to utilize the most sustainable methods, many Western notions may need to be questioned to consider ideas in their own right.[113] In this study of materials, it is critical to identify widespread attitudes toward particular materials that prevent logical decision making when seeking sustainability.

Application in Punta Cana

Much of the architecture in developing tropical regions implemented by external parties consists of unmodified models from temperate countries, particularly the United States. Ease and low cost fuel the use of preexisting structural and material designs. Many international architects recognize the inappropriateness of untailored resolutions, especially due to the stark differences across climates and cultures. With the rapid growth of Punta Cana and other tropical regions, it is important to address these building challenges immediately. Punta Cana faces many unique obstacles as a Third World nation encountering First World development; special attention is necessary to mediate the conflicts between tradition and modernization, poverty and wealth, and other social and cultural strains.[114]

The applications of a sustainable modern vernacular in Punta Cana would permit many opportunities for ecological, economic, and social support. The current standard of concrete mass housing is already eliciting dissatisfaction, indicating unsustainability in the long term. Shelter must not be achieved "by any means necessary"; research and user participation is critical for all responsible designs. As previously suggested, architects and users should be partners in Punta Cana and beyond, integrating facilitators of change, not authoritarian experts, with local know-how. Grupo PUNTACANA has identified the need to blend Dominican meaning and traditions with newer practices to facilitate acceptance for both residents and visitors of divergent backgrounds.[115]

The sense of ownership elicited by user involvement has many positive effects, including pride to increase maintenance, empowerment to fulfill personal needs, and local employment.[116] On a national scale, vernacular is also a patriotic, unifying gesture that could have significant relevance for the Dominican Republic. After a long history of imperialism, fragmentation, and instability, the additional confidence given to local identities through regionalism could be very beneficial. Architectural interpretations that are accessible and meaningful to all users also foster democratic ideals, which are growing in Punta Cana. Alternatively, the integration of international stylistic elements and/or techniques could conceptually link Punta Cana to the rest of the world. A balance of stylistic intentions could help the Dominican Republic reap the benefits of both national and international cohesion.[117]

Grupo PUNTACANA has already explored several paths to integrate eco-cultural and eco-aesthetic intentions. By employing Dominican architect, Oscar Imbert, the developers gained insight into local materials, techniques, and culture. Notably, Imbert popularized thatch roofing in the Punta Cana region, a traditional practice of the indigenous Taino Indians. Thatch is climate-appropriate, efficient, beautiful, renewable, and economical. Its primary demands are time, requiring material knowledge, technical experience, and maintenance. The historic transition from thatch to tin roofing in Punta Cana relinquished local autonomy, pleasure, money, and beauty. By readopting thatch, Imbert recognized an opportunity to utilize Dominican expertise through skilled employment, regain cultural value and self-sufficiency, and reduce waste and material transport for ecological benefits.[118]

Grupo PUNTACANA has also incorporated other strategies suited to the tropical climate, such as shaded porches, balconies, and overhangs, large ratios of fenestration, and moisture-resistant materials. In the implementation of industrial pavements and building materials, designers selected light-colored items to reduce the heat island effect. Many dining pavilions are constructed from the local Cana trees, and their open-air designs reduce material consumption and energy usage for ventilation. However, even Punta Cana's exemplary designs retain instances that could benefit from further stylistic integration. Many hotel guest rooms are housed within cementitious structures and rely on air conditioning for cooling. Perhaps Dominican vernacular dwellings could provide examples of more sustainable material selections, organizational layouts, and passive cooling techniques to reduce the ecological impacts of tourism on the community. When confronted with a seemingly unlimited array of material and technical choices, the limits imposed by choosing vernacular strategies can guide decision making and elucidate elegant designs by necessity.[119]

First World designers seeking recognition for their sustainable efforts often refer to Building Environmental Assessment Methods (BEAMs), or green rating systems, to select and document their strategies. The quantitative and materialist nature of most of these criteria can conflict with the social and economic aspects of sustainable architecture. Users may be excluded from participation, and designers may apply methods without prior observation or adaptation. Listed actions may also exclude vernacular tenets that are more difficult to measure, such as proper orientation, which can increase comfort and reduce energy loads. Therefore, rating systems may be best used as references within a wider scope of sustainable design that keeps the users and community at the forefront of considerations.[120]

Conclusion

Eco-aesthetic and eco-cultural logics, despite their seemingly oppositional characters, are not inherently dualistic and incompatible. Like time, architecture is a process that is not easily categorized in isolation.[121] As history and current inventions are linked by precedent and inspiration, it is not only possible to combine the new and the old, but it is inevitable. The categories that users and designers place upon materials are important because they shape the perceived meaning of materials, which affect the choice of materials according to the intended building concept. As vernacular materials often entail lower environmental impacts, green designers often attempt to change views of vernacular as outdated to increase its acceptance within a modern aesthetic. However, new developments may provide additional benefits and can adapt to fit the local contexts of vernacular designs.

In Punta Cana, vernacular is an attraction within tourism as an authentic means to represent national culture. The social, economic, and environmental benefits of vernacular provide great incentive for vernacular practices to continue. However, to accommodate the expectations of First World clientele and increase the standard of living for residents, alterations to incorporate new innovations are likely more desirable than preserving tradition for its own sake. In Punta Cana and beyond, the development of a modern vernacular to bridge the conceptual gap between new and old, as well as the disregard of many First World designers to adequately accommodate the features of their contexts, is likely a viable path for future sustainable designs.

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RESULTS, PART 2: RESPONSES TO DUALISMS

Zero Waste

In response to the challenges and dangers that arise from dualistic thinking, zero waste may present a more desirable framework to guide sustainable material selection. A key strength of zero waste, besides its effective measures that can support sustainability, is its embodiment of a common, universally desirable goal to overcome divisions and inspire unified action. However, other ideals can also serve this objective. The elimination of wastes that serve no beneficial purpose is agreeable to all people, but carbon neutrality and zero toxicity also support the removal of collective harms. Therefore, zero waste is just one promising goal amongst others, and as a single idea may fail to specify all vital attributes for sustainable building, other frameworks may be critical complements to zero waste. Nonetheless, the scope of this thesis chooses zero waste alone for exploration due to its relevance for current times and the selected region of study.[a] This chapter will analyze zero waste, describing the threats of current waste production, stating the benefits of a zero waste paradigm, and justifying zero waste as a suitable strategy to implement in Punta Cana.

Consumption and waste

Consumption and waste have risen as consequences of modern material culture. Until the late 1800s, policies to conserve materials were not in place. Material usage was based on assumptions that people were scarce and natural resources were abundant. However, industrialization and continuous usage have reversed these assumptions, as humans are now abundant and resources are more scarce. Many federal policies now direct

[a] See “Research Design” in this thesis for detail.

the extraction, use, and disposal of industrial materials through subsidies, investments, regulations, and prohibitions, but few communicate a comprehensive and coordinated approach.[1] When facing these limits, societies must alter their policies and assumptions to match their actions to the problem conditions, rather than outdated assumptions.

Capitalism is often linked to increased waste due to its goals of increased production and consumption. The concept of *planned obsolescence*, coined by Bernard London in 1932 as a solution to the Great Depression, is highlighted as a cause of the contemporary "throwaway culture" that creates excess waste. While planned obsolescence was justifiable to boost revenues during the Depression era, it has continued to increase consumerism even when not needed for economic stability. Manufacturers enjoy the profits from increased purchases without adequate concern for wasted materials. In addition, unplanned obsolescence occurs due to technological development; innovations displace older products.

As a result of obsolescence, changes in consumer preference, innovations, and more, consumption increased dramatically over the 20th century. Positive feedback loops of lower prices through technology, material innovation, and substitution in times of scarcity have driven the exponential growth of material consumption.[2] From 1992 to 2002 alone, raw material consumption in the United States increased by more than one-third. When fuels are included in measures of consumption, the United States consumes over 6.5 billion tons per year, or 23.6 metric tons per person.[3] The building industry is a prominent contributor to these high levels, consuming the largest amount of raw materials after the food industry.[4] Waste has also reached an all-time high in recent years.[b] On average, each American

[b] Visit http://www.epa.gov/osw/nonhaz/municipal/pubs/msw2008rpt.pdf for additional statistics.

generates 4.5 pounds of garbage per day, yielding 250 million tons of trash nationally per year. These quantities are over five times higher than consumption and waste a century ago.[5]

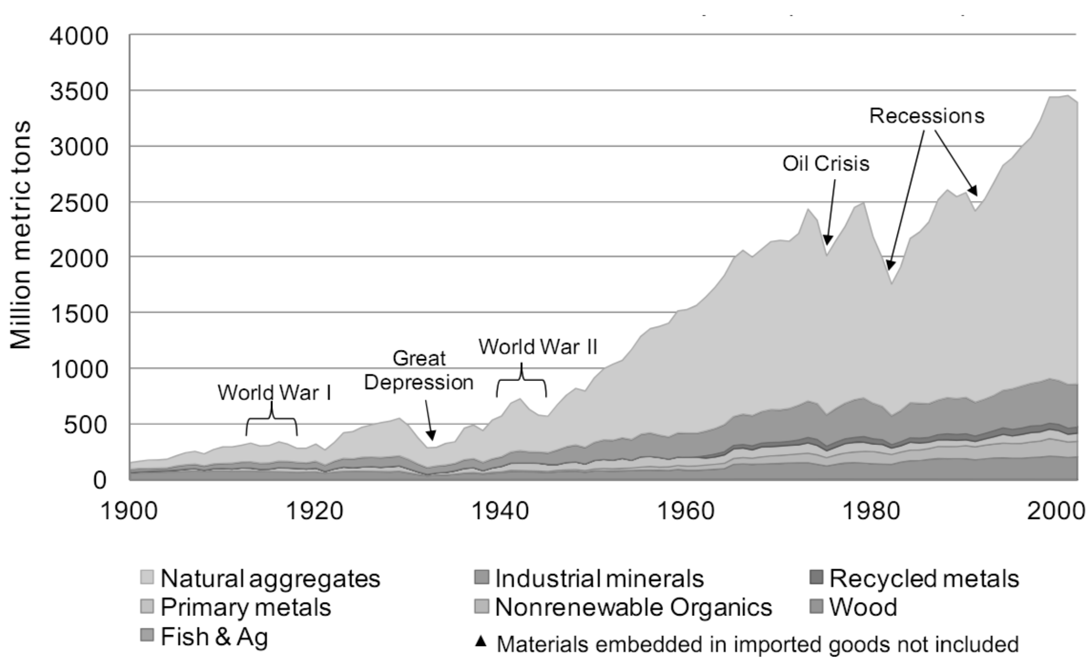

Figure 8: United States nonfuel materials consumption (1900-2002)[6]

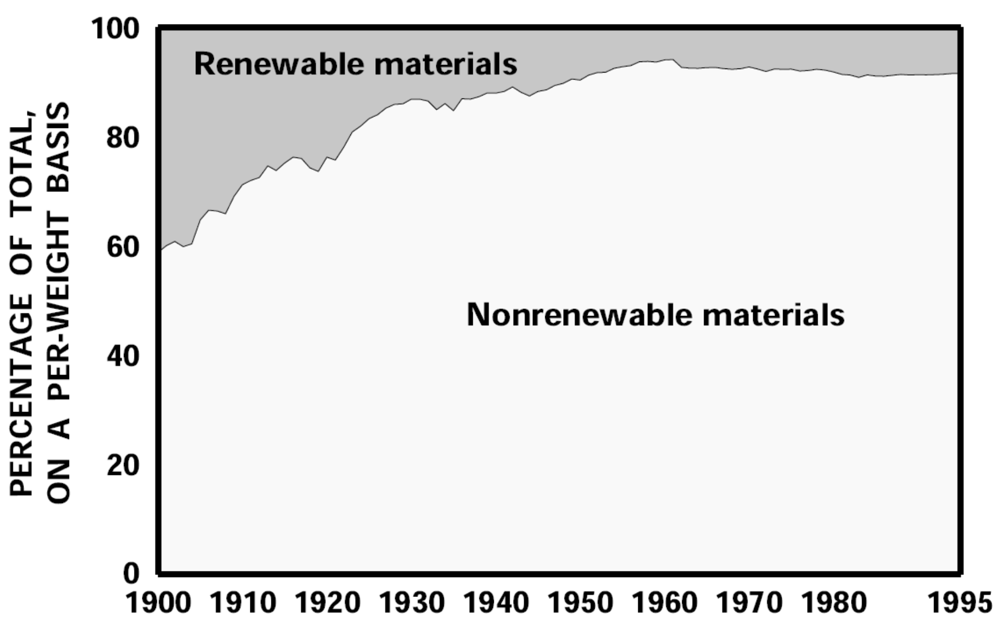

Figure 9: Distribution of material usage[7]

Not only has total consumption increased to alarming levels, but the composition of materials consumed has changed dramatically. Just prior to 1900, 75% of materials were derived from renewable resources with 25% nonrenewable resource use. Today, these percentages are flipped; the vast majority of material consumption is nonrenewable (Figure 9). This shift resulted from lower production and labor costs as well as the value of versatility, ease of processing, and lower density of industrial materials. Despite the benefits of lighter, stronger, higher performance, and less costly materials, environmentalists fear the consequences of environmental exploitation.[8]

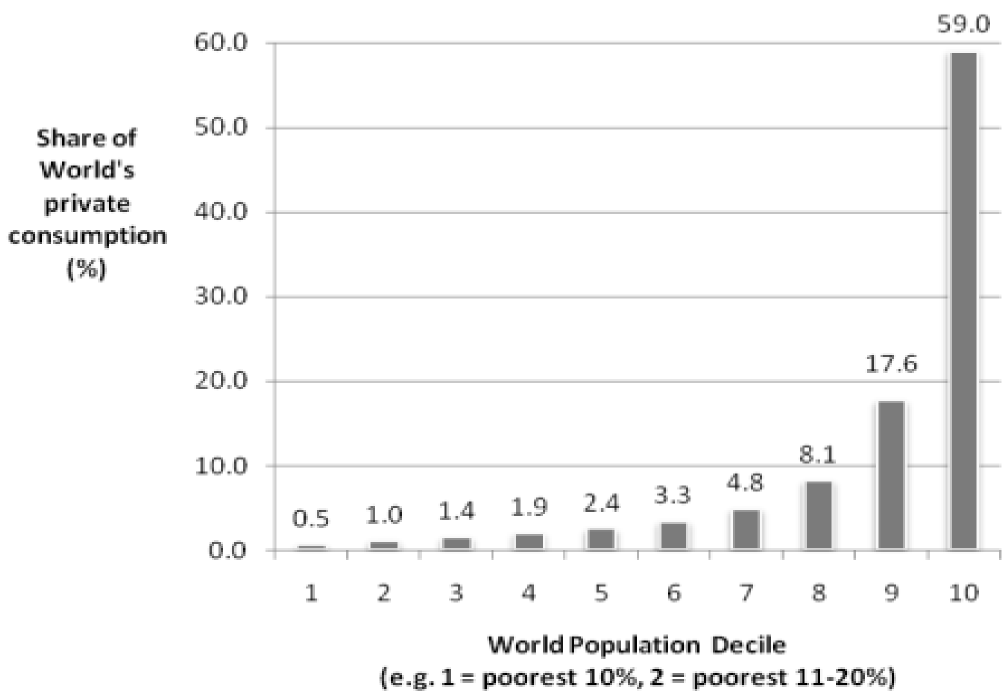

Figure 10: Share of world's private consumption, 2005[9]

Social equality activists also lament trends in material consumption. The richest quintile globally accounts for over 75% of total consumption, while the poorest quintile accounts for only 1.5% (Figure 10).[10] The United States consumes a particularly disproportionate share of resources at 51% more per capita than the European average.[11] The profligate use of finite, nonrenewable resources selfishly prevents other nations from reaping the benefits of use and creates burdens that all global citizens must bear. Activists challenge the wealthy's irresponsible disregard for the pollution, resource exhaustion, and waste that threaten the future health and stability of global populations and ecosystems.[c] The current materials management system is not sustainable because it only meets the short-term needs of some people and neglects long-term needs overall.[12]

Not only does waste threaten social and environmental security, but it is also uneconomical, making waste unsustainable in all categories. Users must pay twice for materials: once to purchase and once for disposal. At the end of life, the value of both the material and landfill area is lost. Disposal costs will increase as finite landfill space becomes filled, and the probable increase in illegal dumping would result in costly damages to ecosystems and human health. Therefore, actions to reduce waste are desirable to mitigate environmental, social, and economic hardships.[13]

Strategies to manage waste have varied greatly across time and place. Many European countries favor incineration, and the United States also considered this option during the 1980s in fear of landfill shortages. Incineration raises many concerns, including carbon emissions, toxic effluents, energy consumption, and reusable material loss, which have prevented its implementation as a dominant strategy in the United States. However, the United States' primary waste system of landfilling entails significant risks as well. Landfills can contain carcinogenic materials, such as heavy metals and poisons, that threaten human and nonhuman health and elicit environmental racism in their placement.[14] The most significant landfill damage occurs when bioaccumulative toxins seep into the water supply,

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[c] See page 5 in Geiser (2001) for data regarding the costs of American material production, use, and disposal.

concentrate within the nutrient cycle, and endanger all life in the ecosystem.[15] Landfills also emit large amounts of methane that contribute to global warming; landfills' effects reach far beyond their confines. The impacts of municipal waste policies that tackle waste as an isolated issue are limited; policy makers must address construction, agricultural, industrial, and commercial fields to tackle the production of waste, rather than simply its disposal.[16]

The United States' government, industries, and citizens have recognized the dangers of current material culture and have taken actions to combat the growing waste problem. Grassroots activists inspired the rise of recycling programs in the 1960s, and the first national Earth Day in 1970 initiated many recycling centers as a new industry apart from municipal waste. However, recycling is vulnerable to material output and disposal; many recycling centers were forced to close in 1974-1975 when material markets suffered in a recession. Governing bodies also demand that recycling pay for itself, whereas solid waste and sewage do not elicit the same expectation.[17] Consequently, the high costs of curbside pickup are prohibitive in some areas, particularly where volunteer support is unreliable and material resale value is low. In addition, some materials, such as glass, ceramics, metals, and polymers, cannot be recycled indefinitely and will become waste after several degrading cycles. The social and technical drawbacks of recycling provide incentives to solve waste problems at their source, avoiding ineffective efforts at consumer levels.[18]

Consumer waste programs also fail to tackle the bulk of waste generated in the United States. On the basis of weight, construction materials account for 75% of all material consumption and 40% of all solid waste.[19] Much of buildings' material inputs become waste at their end of life, typically yielding 3-5 pounds of waste per square foot. Of residential construction materials, which include asphalt, cardboard, wood, metals, gypsum, masonry, paper, and plastics, 80% can be recycled, but only 30% are recycled in practice.[20] The failure of full participation in building recycling programs indicates a need for recycling incentives, improvements to the current system, or alternatives to recycling programs.

Assumptions

Many assumptions fuel the material and waste culture that persists today and resist the development of alternatives to its challenges. Primarily, American culture has accepted waste and pollution as givens. Since products have limited useful or desired lives for consumers, the public generally believes that the production of some waste is unavoidable. Studies and measures are undertaken to reduce wastes through material reduction, reuse, substitution, or recycling and to handle waste in more ethical and appropriate manners, but waste elimination is rarely considered as a feasible goal. Political stakeholders play a role in perpetuating pessimistic viewpoints as the United States government allocates funds toward landfills, and the garbage industry seeks to position itself as a necessary and safe resolution.[21] Specifically, landfill advocates argue that landfills protect human and environmental health by providing a lined and sealed repository to prevent harmful leeching and off-gassing from contaminating the soil, air, and water. They also claim that anaerobic conditions drastically slow decomposition and thereby decrease the release of methane gas and carbon dioxide that contribute to global warming.[22] These arguments claim landfills are environmentally friendly resolutions to inevitable waste and encourage consumers not to think about the continued existence of their waste after removal.

Views of waste as inescapable are also firmly grounded in popular conceptions of waste itself. Definitions of waste, pollution, and other environmental undesirables have changed over time. As the use of *waste* shifted from unusable land, or *wasteland*, to later include refuse, by-products of human activity, and inefficiency, waste changed from a pre-existing condition to a phenomenon that required monitoring and management.[23] Likewise, *pollution* is "an undesirable change in the physical, chemical, or biological characteristics of the air, water, or land," associating unfortunate side effects with human interventions. Under mindsets that view "progress" as the rightful path for human betterment, waste is a necessary evil; it should be minimized, but production and consumption are assumed to entail some waste.[24] In addition, exploration can invent new wants that further increase consumption without sufficient regard for wastes and burdens placed on non-benefiting stakeholders. If society will not abandon the assets of work that produces wastes, it must reduce waste or ideally recognize the possibility of eliminating waste to pursue sustainable lifestyles.[25]

However, while society resists relinquishing its comforts, its assumptions about waste position development as oppositional to environmental health. Consequently, many citizens see reductions in production and consumption, rather than alterations to production, consumption, and disposal processes, as the most viable resolutions to reduce waste. The scientific law of entropy affirms their beliefs; energy and materials are conserved and circulated, but human applications of energy entail a loss of usability with each usage. Therefore, even though humans enjoy a "higher state of being" through their organizing works, their actions accelerate the entropy of the inputs they rely on, degrading the sources for future use. These views support many precautionary principles and provide proof that it is easier to protect an existing ecosystem than to restore it after damage. However, these assumptions can overlook opportunities to decrease entropy through the cultivation of photosynthetic matter. Unlike the closed material system, energy cycles are open as the Earth receives continual energy from the sun. Urban ecologies are notably degrading due to their deficiencies of natural producers relative to natural ecologies; by utilizing plant materials to change the way products are made, humans can rectify this balance to improve the sustainability of their material culture.[26]

Zero waste

By overcoming the current limiting assumptions surrounding waste, Western cultures can realize that zero waste is a proper goal. Increasing the efficiency of production processes designed to allow waste is not enough; every material has a loss factor due to storage, transportation, and installation, and these losses persist if they do not biodegrade.[27] Dan Imhoff asserts, "Pollution allowances are based on the premise that controlled releases will 'dilute and disperse' in the air or water and so be rendered harmless. But at the molecular level some chemicals do not simply vaporize– they can accumulate in organs and tissues, move across food webs, and come back to haunt us."[28] Sealed landfills, controlled emissions, and other cautious disposal methods seek to prevent waste from causing further harm, but they do not attack the issue of waste itself. In order to preclude the need for landfills to contain harmful wastes, the products themselves must be devoid of dangerous contents. Then, once there is no need to limit decomposition, products should be able to return easily to natural cycles to replenish resources for future production.

This closed-loop cycle is the definition of zero waste that Western designers should strive to achieve. Zero waste communicates three goals: *zero discharge*, which precludes toxic or persistent counterparts; *zero material waste*, indicating total reuse through biological and technical cycles; and *zero atmospheric damage*. Zero waste derives from

Japanese total quality management (TQM), a concept that focuses on full product life cycles.[29] As most consumer products have a limited useful or desired life, zero waste goals cannot preclude the discarding of goods. Instead, William McDonough coins the phrase "waste equals food" to indicate the reutilization of safe outputs as inputs by direct reuse, recycling, or biodegradation, which not only eliminates wastes but also reduces the need for further resource extraction.[30] Like water and energy, waste is not a sectoral matter; it involves all areas of society and industry. Therefore, zero waste, as a single framework to combine producer responsibility, ecodesign, dematerialization, design for disassembly, waste reduction, reuse, and recycling, is better fit to anticipate and coordinate the changes needed to resolve the dangers of waste.[31]

In order to achieve a closed loop, or *cyclical production*, designers must choose materials that act as "good wastes"; that is, all input materials must be able to be directly reused, recycled without loss, or biodegraded. Waste cannot be treated in isolation as it is embedded within the chain of production, consumption, and disposal. Many policy makers do not consider that 55-75% of total wastes are discarded during production; the waste of "hidden resources" reveals the need to revamp the way products are made, rather than simply target consumer disposal.[32] For all products, designers should assess: What is being discharged? What effects does it have and where? Do these effects matter to sustainability? Can damages be corrected and/or are corrective actions in place?[33] Life-cycle analysis (LCA) attempts to numerically represent the costs of materials over their entire life, but life-cycle analysis is limited by its static nature, complexity, and uncertain scope. The three affirmative criteria of zero waste may define a clearer set of responsible materials, from which designers can choose based on more apparent economic, cultural, and aesthetic criteria. When waste is used as an indicator of design failure, the zero waste framework guides all steps of the design process, acting as both a target and methodology for redesign and consumption.[34]

Beyond the benefits of waste reduction and reusable inputs, zero waste initiatives have additional advantages. By diverting waste from landfills or incineration, zero waste can reduce emissions that contribute to global warming. Biodegradable waste also sequesters carbon by enriching the soil, regenerating the land and atmosphere. Zero waste strategies, through the materials and processes they use, have further emission reduction potential; Appendix D quantifies carbon savings up to 1300 $MtCO_2e$. In order to support zero waste operations, many green-collar job positions would be created, supporting local employment and environmental and equitable action. Economically, zero waste is an opportunity to save costs and increase efficiency. Therefore, zero waste supports the environmental, social, and economic tenets of sustainability when implemented with contextual appropriateness. Groups have begun to seek the benefits of zero waste programs; the European Union Landfill Directive aims to divert 65% of 1995 levels of biodegradable wastes from landfills by 2020.[35]

Alternatives to conventional material culture

Zero waste is not the only method suggested to replace the dominance of landfills. One rising alternative and/or supplement to recycling programs is "reverse channels of distribution," or take-back programs. In these scenarios, manufacturers reclaim their products at the end of their useful life; formerly disposable products are rented and returned. Manufacturers can then reuse or recycle the products to make new products, fulfilling all three Es of sustainability, or bear the full costs of disposal.[36] Like reverse channels of distribution, "polluter pays" strategies also place responsibility on both producers and consumers for their wastes. Individuals who accumulate waste must proportionally pay for disposal, which encourages households and businesses to reduce their wastefulness.

Reverse channels of distribution and polluter pays schemes both provide economic incentives for producers to resolve waste at its source, but they also provide outlets for the wealthy to maintain their current levels of consumption and disposal.[37] These models are also supportive of "business-as-usual" practices because they strive for eco-efficiency, rather than eco-effectiveness. Eco-efficiency entails incremental improvements, devising strategies to reap greater outputs from less inputs. Consequently, eco-efficiency does not guarantee sustainability if inputs and processes cause some harm at any level. Zero waste provides a model of eco-effectiveness; the objectives of a product are achieved in a manner that can be sustained in the long term.[38] When production, consumption, and disposal cause no harm, the quantities of inputs and outputs become less significant. Industries must shift to an eco-effective mindset to halt and reverse their damages to their surroundings, conceiving of *economy* as not minimum provision, but as minimum waste.[39]

A shift to an eco-effective mindset will require industry to alter material culture. The primary rationale against industrial materials is that "the sustainable rate of use can be no greater than the rate of regeneration." Therefore, only well-managed, renewable materials can sustain long-term, continual use by humans, unless nonrenewables can be used and completely recycled without loss. In addition, there is no absolute limit to renewable material usage; sustainability is simply based on the comparison of rates of production, use, and recycling to resource regeneration.[40] The exploration of rapidly renewable and biodegradable materials is a viable solution to pursue a zero waste goal.

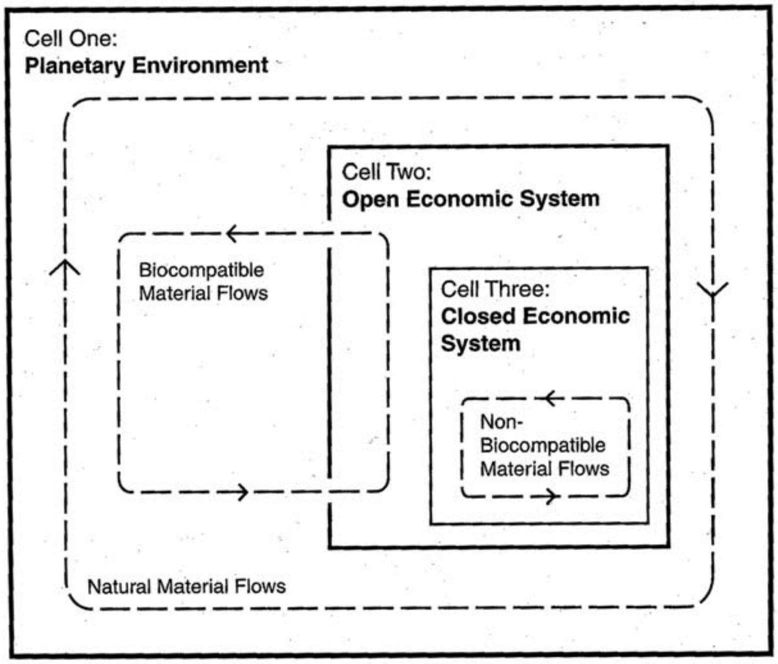

Figure 11: Materials flow model[41]

Geiser provides a materials flow model to comprehend the shift in material selection, as shown in Figure 11. When tackling waste elimination, designers cannot consider strategies in isolation; the flows of energy and matter through interactions are as important as the physical inputs and outcomes.[42] Industrial materials, or non-biocompatible material flows, are only sustainable when fully contained and reused in a closed economic system. Biocompatible flows, such as largely unprocessed, rapidly renewable crops, can be exchanged between human society and the nonhuman environment without harm or waste. Open exchange with the natural environment is desirable for many reasons. Producers and consumers do not need to worry about harmful substances leaking out of the economic system, causing pollution or waste. In addition, as previously stated, recycling is vulnerable, more expensive, and more energy-intensive than biodegradation.[43] Alternatives to industrial materials should not abandon the benefits that improve humans' quality of life, but it is likely that crop-based materials can support a higher level of both human and nonhuman life.[44]

Despite the general benefits possible with biocompatible flows, debates continue to arise between "full recyclers" and "full composters" within the zero waste movement. The development of biodegradable plastic illuminates their key arguments. Full recyclers claim that biodegradation of plastic is economically wasteful because plastic is expensive to produce and could be more efficiently recycled. Alternatively, full composters assert that the majority of plastic that is currently recyclable is still landfilled, and it is better for plastic to biodegrade than persist indefinitely. Currently, 30% of consumer waste is organic and can be composted, and another 30% is recyclable.[45] Manufacturers must tackle the end of life considerations of the remaining 40% to achieve sustainability, and this thesis will contribute further insight to guide industry in its important decision making.

Justifications

A. Crop-based materials

As discussed throughout this thesis, many factors contribute to perceptions of materials as natural or unnatural. Materials labeled natural should not be automatically preferred for green buildings because they may not be best suited for the context and application, they may require great costs in transportation, and/or their processing techniques may raise harmful impacts on human and environmental health without compromising their "natural" appearance. In addition, nature produces many nonrenewable resources that cannot endure sustained human use and can be polluting when disturbed. All these shortcomings produce waste, indicating that naturalness and human manipulation are insufficient criteria to judge sustainable materials from a zero waste perspective. In order to choose sustainable materials, how can designers determine what characteristics separate materials from natural cycles and produce waste?

All crop-based, renewable resources have photosynthesis in common. As the most efficient means to transform solar income into usable materials and energy, photosynthesis is key to provide resources and sustain life. Currently, humans only use an estimated 40% of the Earth's photosynthetic activity, indicating great potential for growth. However, even renewable resources must be used with caution because crops lose their abilities to regenerate themselves and the land around them when the right conditions for production are not maintained.[46] With proper care, crops can provide adequate quantities of materials for their surrounding communities without environmental degradation.

Materials labeled nonrenewable, synthetic, and high-impact often employ toxic chemicals, nonrenewable energy in processing, and/or end products that do not biodegrade on a human timescale. These attributes, while not exclusively caused by humans, are associated with human intervention and cause products to persist as waste, making their use undesirable. According to zero waste, designers should strive to remove these negative attributes. If humans could fully integrate their materials into ecological cycles, on what grounds could materials be deemed unnatural or harmful? Human manufactured materials could be differentiated by active intentionality and a shortened time scale, but the ecological dangers of human intervention would be removed. Therefore, human actions would no longer be undesirable; rather, human actions would help tailor materials to meet specific needs in a sustainable manner.[47]

Crop-based materials provide a viable basis for humans to create ecologically integrated products. Current building materials are almost entirely inorganic (Figure 9), whereas ecosystems balance both inorganic and organic components. In order to mimic nature, buildings should increase their organic components.[48] Urban ecologies can become more self-sustaining by increasing the number of producers, or plants, to harness the energy of the sun.[49] Crops are already part of natural cycles of growth and decomposition, so humans need only not disturb the natural advantages of the materials in their manipulations to achieve sustainability.

Using crop-based materials, cycles of nourishment for buildings can parallel that of agriculture. Traditional societies, such as the Ifugao of the Philippines, compost the stalks of their crops to increase the fertility of the soil. The soil then yields new crops to build, feed the people, and replenish the soil. Like architecture, agriculture has become unsustainable in modern societies because many synthetic inputs are unhealthy for the long-term health of humans and the wider environment, and the products of the soil no longer return to the land. When the cycle is broken, processes are no longer sustainable for long-term use. Crop-based materials present opportunities for architecture to return to a cradle to cradle cycle, promoting healthy environments for sustained human life without impending waste.

One concern regarding the use of crop-based materials is durability; many designers fear that organic matter will not withstand continual climatic conditions and structural demands. While these concerns are not completely unfounded, they are vast generalizations; natural materials have been proven to perform throughout buildings' life cycles with proper human care. For example, wooden Norwegian stave churches have lasted a millennium when maintained. However, without care, these churches decay within a generation. The flexibility of organic matter's persistence based on human manipulation is advantageous; buildings can last as long as they are cared for, and those lacking purpose will fade away without waste. In contrast, synthetic materials can survive or deteriorate independent of human care. While the life spans of non-organic materials can be shortened or extended with care, in general, their range is less flexible than that of organics, and often synthetics persist long after their intended application has ended. Materials should live, die, and decompose like all other life to close the loop of material production.[50] Designers should consider crop-based materials to take advantage of their biodegradability, to ease the pressure to reuse or recycle all materials, and to increase connections between businesses, buildings, and the landscape.[51]

Crop-based materials also afford other advantages beyond their adaptable life spans. Compared by weight, most wood is 50% stronger than steel and supports less microbial growth than steel or plastic. Wood provides tactile warmth, sound insulation, comfort, and shock resistance. Whereas timber keeps in absence of fire, insects, or mold, plastics are vulnerable to many external factors, including ultraviolet light, heat, cold, stress, wind, snow, hail, acids, ozone, water, and microorganisms. Finally, organic materials have enzymes that allow them to break down and biodegrade, which mineral-based materials lack.[52] These aspects of function and performance are important to consider to fulfill design intentions.

B. Rapidly renewable materials

As a subset of crop-based materials, rapidly renewable materials can offer additional benefits for modern, Western culture. Renewable sources regenerate themselves relatively quickly, whereas nonrenewables form over long periods of geologic time.[53] The separation between these categories is vague and relative; how quickly must materials regenerate to be considered renewable? Generally, products obtained directly from plants and animals are considered renewable resources. The designation *rapidly renewable* presents a clearer time frame with a regeneration period within ten years, according to the United States Green Building Council (USGBC). Rapidly renewables include linseed, straw, cotton, sunflowers, wheat, natural rubber, bamboo, and cork and can be used as flooring, insulation, millwork, casework, furniture, fabric, and coatings to reduce impacts throughout buildings.[54] Appendix C contains a partial list of crop-based materials and their current uses in construction.

Many advocates of crop-based construction favor wood as a primary material, but rapidly renewable materials may offer needed alternatives to overcome the shortcomings of wood. Wood has endured as a crop-based building material throughout human history and exhibits the listed environmental benefits when well managed. Its success is also connected to its durability and suitability to both traditional and modern aesthetics. However, the popularity of wood as a sustainable material has paradoxically caused environmental concerns. Only 4% of old-growth forests within the United States remain, raising alarm of deforestation. Proponents claim clearcutting mimics natural destruction by fires or hurricanes, but industry does not generate the heat and ash that help forests regenerate after disasters.[55] The use of wood demonstrates that renewable resources do not ensure sustainable action; all resources must be properly managed and applied appropriately with consideration for entire ecosystems. The Forest Stewardship Council (FSC) monitors and communicates principles of sustainable forestry to protect environmental, social, and economic interests.[56] However, it appears that wood does not regenerate quickly enough to meet its current demand. To harvest timber responsibly and fulfill global resource needs, it is likely that sustainable alternatives must supplement the current demand for wood.

The current conditions of global societies highlight the attractiveness of rapidly renewable crops for building construction. Globally, growing populations correlate to increasing demand and consumption. In response, rapidly renewable materials can be produced quickly, and with proper methods, often with less expense and environmental impacts than other material choices. A primary goal of rapidly renewable material use is to reduce the number and quantity of products derived from fossil fuels. Many fast growing crops, such as hemp, are flexible and hardy enough to be grown locally in diverse climates without synthetic chemical inputs.[57] These features reduce nonrenewable resource usage and foster the self-sufficiency of communities.

The value of decomposition over recycling and reuse is also apparent in cultural norms. Western society places high value on new, or virgin, materials, lower value on used materials, and nominally no value on wastes. High rates of turnover due to innovation and changing preferences fuel continuous demand for new products with unique material requirements. These perceptions and changes have fueled "throwaway culture," in which consumers upgrade their products, accumulate wastes, and resist cultural continuity. Most environmentalists resist throwaway culture by building durable products and encouraging repair and conservation among their consumers. Environmentalist urges for decreased consumerism and dematerialization cause conflicts with industry and economists, who feel threatened by decreased demands and revenues. The conflicts between stakeholders are counterproductive to a sustainable material culture.

However, the application of crop-based materials in a zero waste paradigm supports the desires of society, environmentalists, and industry. To society, crop-based materials may be attractive because each use installs virgin materials; whereas recycling and reuse have a secondhand stigma, biodegradation produces new materials from outputs.[58] Economists and industry enjoy employment and continuous demand to compost and reform new goods, and environmentalists achieve the low-impact production they seek. Zero waste and throwaway culture initially seem oppositional: the former generates no waste while the latter creates abundant and incessant waste. However, rather than fighting the tendencies of throwaway culture, zero waste can sustainably work with throwaway culture by adjusting materials with "good wastes" to suit product life spans and functions. Instead of viewing sustainability as an inhibitor, industry can use zero waste as an opportunity for innovation, a re-industrialization to achieve closed-loop systems.[59] A surprising symbiosis arises because zero waste does not fear disposal due to full reuse, recycling, or biodegradability. If the products of throwaway culture are part of a closed loop fueled by renewable energy, designers should not lament consumption. Instead of focusing on eliminating human actions, which is impossible for survival, designers can seek to make actions benign with rapidly renewable and biodegradable materials to protect biotic functioning.

One similarity between throwaway culture and zero waste strategies is the tailoring of material durability and longevity to product functions and life spans. Many designers resist the use of crop-based materials that have short life spans; however, how long are buildings and products meant to last?[60] In the United States, 50-75% of all materials produced become waste within one year of purchase. Consequently, most materials do not need to last for a particularly long term.[61] Nonetheless, many materials sent to landfill persist for hundreds or thousands of years, causing waste to accumulate. While building materials tend to outlive the average consumer product, the majority of American buildings are financed and designed to last 30 years, after which they are considered valueless. Due to the durability of its materials, a building's physical life tends to outlast its economic life, leading to demolition and waste.[62]

Therefore, there can be merit in strategically decreasing the longevity of products to assist material transformations at the end of life.

Francis Duffy states, "To assume that everything should last for the same length of time is absurd; to attempt to use only short-term elements to solve long-term problems is inherently wasteful; to have to dismantle long-term structures to solve short-term problems is ridiculously expensive." Duffy, like zero waste advocates, encourages designers to rethink the concept of wastefulness.[63] Throwaway culture creates a bad stereotype for replacement, valuing static stability over dynamic alterations. Disposal is not inherently bad; *waste* is the true harm. Renewable and biodegradable materials, such as thatched roofs, may need to be replaced twice as often as ultra-performing products that must be landfilled; however, these materials, when well chosen and maintained, are still likely to fulfill building requirements without waste. Materials may have sustainable, short lives in a closed loop as all outputs become useful inputs.

However, as a caveat, designers should not apply zero waste materials without regard simply because they produce no waste. Duffy acknowledges the value of conserving time and effort; constant replacement of short-term solutions, even without material waste, is not optimal to achieve human objectives. In sum, Duffy recognizes the importance of tailoring material selection to each application. Stewart Brand echoes Duffy's discernment in his diagrammatic separation of the six layers of buildings, each with different rates of change (see Appendix E).[64] Therefore, building materials should vary with the needs of their application, and designers must implement thoughtful, flexible designs to avoid disfunctionality or premature obsolescence.[65]

The speed and biodegradability of rapidly renewable, crop-based materials also allow long-term, societal benefits. Current populations cannot know the needs of future generations, yet the high-performance, durability approach to sustainability seeks to impose today's structures on later users. Building reuse may have limits if future needs require significant change. It is arguably better if materials can return safely to the Earth to generate raw materials to build new structures suited to updated requirements. Advances in renewable energy could reduce the ecological costs of producing new materials for building applications. Low-impact building methods give future generations the opportunity to build for themselves, free from inheriting material scarcities and static structures of the past.[66]

C. Tourism in Punta Cana, Dominican Republic

Zero waste initiatives, particularly the use of rapidly renewable, biodegradable materials, could greatly benefit the developing ecotourist ventures and the surrounding community in Punta Cana. Like the fast pace of Western culture, Punta Cana is undergoing significant development by both tourism and local inhabitants, generating material demand. Rapidly renewable, crop-based materials can sustainably and swiftly meet these needs. Besides tourism, agriculture plays a significant role in the Dominican economy, and crop-based architecture could provide further employment for farmers. The locality of material production has additional ecological and economic benefits of decreased transportation costs and possible lower purchasing costs to increase accessibility for low-income populations.[67] Since tourism relies on international cooperation and demand for its revenues, increases in Punta Cana's agricultural sector to support both hospitality and domestic structures could help foster self-sufficiency and pride in Dominican abilities.

One key concern of tourism in Punta Cana is the waste produced by lavish hospitality consumption. Mass tourism may produce wastes that remote locations lack the capacity to process and cause communities to bear the dangerous burdens of insufficient disposal methods. Likewise, if a tourist venture decides to renovate, rebuild, or abandon its facility, the buildings' waste becomes an additional problem for local communities. According to the tenets of ecotourism, the hospitality industry should maximize its support and benefits for local communities and avoid degrading their land and resources. Zero waste goals for buildings would mandate the use of materials that would not accumulate upon removal or demolition. Instead, when properly composted, recycled, or reused, buildings would become fuel to nourish the soil, create new products, or fulfill new uses respectively, aiding the area rather than harming it.

The strategy of biodegradable, crop-based materials would be particularly appropriate for the Dominican Republic for social and agricultural reasons. Biodegradability allows for independent disposal, whereas recycling and reuse programs require buyers and coordination. As many Dominicans lack access to rapid communication devices, the alternative zero waste methods could hinder the flow of disposal. Agriculturally, much of Punta Cana's soil lacks fertility to grow crops easily and could greatly benefit from the rich compost that crop-based architecture could provide. Punta Cana's impoverished soil could be an obstacle to local crop production for buildings, but the closed-loop cycle should help enrich and sustain growth. Several varieties of rapidly renewable crops are robust, viable candidates for implementation in Punta Cana.

Zero waste strategies already have precedents in the region to ease implementation on cultural and technical levels. In Haiti, vernacular housing built of organic materials has been burned in rituals at the end of its useful life. Haitians appear to share the belief in closed-loop material cycles as they return used materials to the Earth in order to harvest new ones.[68] Due to their contact and architectural similarities to Haiti, Dominicans may have encountered or hold comparable beliefs and practices to their Haitian neighbors. In addition, the feasibility of composting programs has been tested through the Punta Cana Ecological Foundation vermiculture project. Food scraps and other organic materials from the PUNTACANA Resort and Club are composted at the Foundation, where worms convert the discarded matter into rich soil. The soil outputs have produced significant agricultural gains, supporting a variety of organically grown produce available to the resort kitchens and local residents.[69] The presence of these preexisting impetuses to zero waste initiatives support both the acceptance and feasibility of closed-loop systems in Punta Cana.

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Investigation of Material Application in Punta Cana

Introduction

The previous section established the suitability of a zero waste goal for the tourist industry in Punta Cana. There are many combinations of materials and strategies that designers could implement in the Dominican Republic to achieve zero waste. This thesis will compare bamboo, a rapidly renewable crop with zero waste potential, to concrete, the current prevailing material for new, structural construction in the Dominican Republic. While many other vegetative species may be used to create interior and exterior cladding, finishes, surfaces, and products, *Guadua angustifolia* bamboo is one of the few crops noted for its structural capabilities. By demonstrating the possibility and benefits of a crop-based structure, the building layer provoking the most skepticism in natural building propositions, designers will likely have more confidence and support for zero waste architecture.

As stated in previous chapters, dualistic thinking is problematic for material selection because socially constructed terms can mask traits and effects in need of primary consideration. Material dualisms also prevail in the Dominican Republic and have shaped its contemporary material culture. While Dominican vernacular utilized indigenous resources from the immediate surroundings in the past, designers and builders have striven to incorporate more “modern,” “technical,” and “aesthetic” materials with increased exposure to Western culture. The perception of unfamiliar, processed, and imported materials as superior, conceptual opposites to their traditional earth- and plant-based materials helps explain the risky transition from reliable, successful methods to the unknown.

Table 2 applies the dualistic concepts of this thesis to clarify views of the materials at hand. Traditional wattle and daub construction is widely seen as simplistic and primitive due to its few steps to produce, widespread availability, and lengthy history. Concrete became an attractive selection, particularly for Western tourism, due to its aesthetic uniformity, interior environmental control, novelty, and prestige. However, concrete has many consequences when seeking environmental and developmental sustainability, prompting green designers to resist its acceptance in the Dominican Republic. Alternatively, zero waste alternatives, such as bamboo, are commonly linked to the stigmas of primitivism and poverty due to their crop-based appearance. Since bamboo seems well suited to the climate, style, economic needs, and institutions of Punta Cana, the conceptual resistance of designers, residents, and tourists likely plays a primary role in the limited adoption of more sustainable, crop-based options.

	Wattle and Daub	*Concrete*	*Bamboo*
Ecological Connectivity	Natural	Unnatural	Natural
Technique and Philosophy	Eco-centric Low-tech	Eco-technic High-tech	Eco-centric Low-tech
Developmental Scale and Goals	Eco-social Local	Eco-medical Global	Eco-social Local
Style and Symbolism	Eco-cultural Vernacular	Eco-aesthetic High Style	Eco-cultural Vernacular

Table 2: Dualistic assumptions of building materials

In order for materials to be judged based on their suitability for functional and other sustainability criteria, designers must realize that the dualistic terms they assign are relative, generalized, constructed, and often conflicting. Concrete is not unsustainable because it is "unnatural"; concrete is unsustainable because it creates waste, necessitates environmental damage in its production, and fails to meet the specific needs of its contextual application.

Likewise, bamboo is not sustainable because it is "natural." Rather, bamboo can be sustainable because of the specific attributes of its renewability, biodegradability, and accessibility in proper growing conditions and contexts. By analyzing the specific traits that influence the long-term sustainability of particular material selections, designers will likely support bamboo as a favorable material to create zero waste architecture in Punta Cana.

The limitations of this study include somewhat generalized information, which was deemed necessary to fit the research scope. The data and assertions presented are gathered from observations and written sources, rather than collecting extensive, formal data directly in Punta Cana. As this thesis recognizes throughout, detailed research and understanding of the specific time and place of application is critically important. Consequently, this case study serves as an introductory stage of assessment for a zero waste approach in Punta Cana. Quotes and data regarding pricing, sourcing, and production conditions that vary with suppliers, as well as community surveys and participation, would be necessary to support the success of this proposal.

Summary of findings

	Bamboo	Concrete
Environmental		
Material composition		
Origins	Crop-based	Cementitious
Methods of extraction	Harvest	Mining
Inputs and accessories		
Energy (mJ/m^3 per N/mm^2)	30	240
Water (gallons/ft^3)	Rainfall only	1.3
Foundation	Reused concrete or stone	Reused concrete or stone
Means of connection	Biodegradable fibers/joinery	Mortar
Treatments	Nontoxic available	Toxic
Cladding and infill	Biodegradable crops	None
Suitability for climate and conditions		
Cooling strategy	Natural ventilation	Air conditioning
Potential for environmental renewal	High	Low
Life cycle and renewability		
Life expectancy (years)	25	Over 25
Life cycle	Closed loop	Open loop
Renewable	Yes	No
Emissions and climate change		
Carbon dioxide	2 lb/yd^2 sequestered	400 lb/yd^3 emitted
Indoor pollutant absorption	Yes	No
Waste		
Disposal method	Biodegrade	Recycle or landfill
Meets zero waste criteria	Yes	No
Economic		
Availability		
Quantity of inputs in region	Abundant	Abundant
Economic opportunity		
Demand and revenues	High	High
Prohibitive for low-income buyers	No	Yes
Entry and input costs	Low	High

Employment and empowerment		
Employment created	Moderate	Moderate
Need for regulation	Moderate	High
Creative pride	High	Limited
Possible on individual scale	Yes	No
Social		
Health and Safety		
Dangers during installation	Low	High
Dangers during building use	Low	Low
Strength and performance in disasters		
Compressive strength[a]	Extremely high	High
Tensile strength[a]	High	Low
Weight (lb/ft^3)	37.5	150
Danger in material failure	Moderately low	Fatal
Versatility and changeability		
Versatility	High	High
Changeability	High	Low
Aesthetics		
History of inspiring examples	Moderate	High
Structural manipulation	Low	Moderately high
Nonstructural manipulation	High	Moderately high
Attractiveness to tourists	Moderately high	Moderate
Cultural receptiveness		
Prestige	Low	High
Novelty	Low	High
Alignment with green movement	High	Low
Barriers		
Regulation	Low	Moderate
Standardization	Low	High
Invasiveness	High	Not applicable

Table 3: Summary of findings

[a] Numerical data for strength is omitted due to variations across species, thicknesses, inputs, and installation practices.

Environmental

Material composition

Concrete is a composite composed of cementitious materials, such as Portland cement and fly ash; aggregate, including sand, gravel, and clay; and water.[1] Each component is found intact in nonhuman nature, questioning the unnatural label of concrete. Despite the benign impacts of each undisturbed element, the mining, gathering, and combination undertaken by humans have significant environmental impacts. The mining of limestone, shale, and aggregate destroys aesthetic and ecological functions of landscapes, threatening many forms of life through pollution and disturbance. Mining sources the majority of concrete production, utilizing virgin, nonrenewable resources. The concrete industry remains the highest consumer of limestone, which is one of the most common construction materials.[2] The use of fly ash, a byproduct of coal combustion, is a common strategy to increase the recycled content of concrete; this contribution is helpful to diminish the need for limestone quarrying, but fly ash cannot fully displace the need for virgin resources in concrete production.

The quality of concrete's inputs is as important as the quantity. Aggregate and water must be free of impurities for production.[3] Water quality can greatly affect concrete's strength, workability, and durability. However, potable water quality is not essential for concrete production. Recycled greywater that is monitored for levels of impurities can be used without significant declines in quality.[4] Seawater may be suitable for use in concrete, but it decreases the life of the product. Seawater does not compromise the initial strength of concrete, but seawater concrete deteriorates more rapidly than freshwater alternatives. Seawater can also increase corrosion of the steel in reinforced concrete, causing concerns for structural applications.[5] As Punta Cana requires resilient building materials to resist climatic forces, the unsuitability of its abundant salt water to produce strong reinforced concrete conveys a misalignment between resources and practice. The need for freshwater and cleaning or extraction of pure resources can place great strain on ecosystems.

In concrete production, the inputs are mixed to form a suspension, which is poured into a cast to cure over days. Concrete can be pre-cast or cast in place on the building site, affording flexibility for use and transportation. When combined, the properties of the whole become very different from those of its components, and each element cannot be separated from the rest. Concrete also combines well with various metals, such as steel, to provide additional strength and stability. Unfortunately, plant-based materials, such as bamboo, do not bond well with concrete, preventing an organic and mineral composite.[6] Finished concrete is characterized by uniformity and strength, but mistakes and impurities in the production process can easily violate these traits. The transformation of naturally occurring elements into an unrecognizable, distinctly human-made mixture that cannot return to nonhuman ecological cycles is likely the impetus for concrete's unnatural label.

Unlike concrete, bamboo is a single plant material. Over 1,000 species of bamboo grow worldwide, and each is a directly usable material.[7] Bamboo is the largest of the grasses, growing into long, hollow, intact stalks, or culms. *Guadua*, a tropical timber bamboo, can grow to over 6 inches in diameter and 100 feet high.[8] Its texture is similar to wood but is less homogeneous. Like tree knots, bamboo's nodes create a surface that lacks uniformity and smoothness before manipulation. However, bamboo's nodes partition the culm and add strength,[9] creating a more evenly stressed material than wood.[10] When the culm is intact, it offers a hard, clean surface without any bark.[11] A thick skin of silica and wax protects bamboo against deterioration from chemicals and insects.[12] When the culm is smashed, its dense, cellulose fibers can be separated into coarse hairs. The fibers are elastic perpendicular to the grain, allowing the hairs to both bend and retain their shape.[13] Manipulations of bamboo can greatly alter its functional properties; both culms and their component fibers can be used for a variety of tasks, and without the addition of synthetic treatments, all bamboo retains its ability to safely return to ecological cycles at its end of life.

The original form of the bamboo plant is also favorable for building construction. Bamboo is an evergreen, showing little variation with seasonal changes.[14] The shape of each stalk in cross-section is circular, which provides maximum strength. While wood has a hard core and softer exterior, bamboo has a hard exterior and softer inside, which increases bamboo's structural stability above wood.[15] Bamboo is recognized for its surprising resistance through its nickname, "the steel of vegetables," and through NASA's commission of bamboo furniture for its space station. However, bamboo's mechanical properties vary with its species, age when cut, moisture content, part of the culm used, and position of the nodes.[16] The combination of strength with a hollow, air-filled interior also makes bamboo well suited as a noise barrier and wind break.[17] Lastly, the young bamboo shoot begins to grow at its final diameter; it does not need to grow to gain strength, only to increase its span.[18] Bamboo then tapers as it grows, and its slight bottom-heaviness is ideal for multi-story construction.[19]

In composition, bamboo conveys an advantage by being directly usable, durable, renewable, organic, and biodegradable. While concrete's ingredients are in plentiful supply, its virgin inputs and persistence at its end of life are less than ideal. Particularly in an area, such as Punta Cana, that values its beautiful, productive landscapes for its livelihood, mining and construction wastes cannot accumulate and possibly alter the chemical functioning of the surrounding land and water. If architecture seeks to mimic ecosystems, buildings must increase the use of plant materials where mineral use is currently abundant.[20]

Inputs and accessories

As recognized in discussions of waste, green designers must consider not only the materials that compose final products but also the inputs consumed in their production and the accessories that must accompany them in application. One primary input is energy, which often entails the burning of fossil fuels. Concrete is an energy intensive material compared to bamboo. According to J.A. Janssen, concrete consumes eight times more energy than bamboo and three times more energy than wood to produce equal volumes of each material. On the other hand, concrete consumes less than 1/6 of the energy to produce an equal volume of steel.[21] While concrete may seem advantageous in comparison to metals, designers must also realize that steel rebar is included in structural concrete to provide needed stability and safety. When considered with all its components, the embodied energy of reinforced concrete greatly surpasses its organic alternatives. However, builders working with bamboo or concrete can take advantage of many energy-saving techniques, such as utilizing local materials to reduce transportation, labor-intensive processes, natural drying methods, and strategies to support reuse and recycling.[22]

Water is another input that raises concerns due to regional scarcities. General purpose concrete requires 6.5 gallons of water per sack of cement, which, with 4 cubic feet of dry sand and gravel, produces 5 cubic feet of concrete.[23] In addition to the water entering the mix, water is used to wash the aggregate; concrete is a water intensive material.[24] Bamboo's water consumption is far more variable since its production follows climatic demands, rather than a standardized recipe. While bamboo uses less water than most plants as the world's second most efficient photosynthesizing plant, bamboo still needs regular inputs of water, particularly when establishing a nursery.[25] The European Union asserts that *Guadua* bamboo's water requirements are low,[26] and bamboo typically requires between 500 to 2,000 mm of rainfall each year.[27] The average rainfall in Punta Cana is 1,025 mm per year, which falls well within the range of bamboo's water requirements.[28] Consequently, little, if any, additional water input is necessary to sustain the crop in the region of study.

While concrete can be used for all necessary parts of buildings, bamboo is not optimal for foundation construction. Bamboo decays readily when buried underground, compromising foundational stability. Bamboos in contact with soil should have dense nodes, which increase culms' durability.[29] Bamboo and concrete both have similar options for foundation materials, including stone, earth, concrete, and brick.[b] While rammed earth may not provide the stability in earthquakes and hurricanes that Punta Cana requires, the use of stone, brick, and concrete from abandoned and demolished buildings for new foundations could establish a pattern of building reuse and recycling.[30] Residents should make use of the energy embodied in their existing materials by extending their lives in new construction.

Adhesives, fasteners, and other means of attachment are included as material accessories. When poured into casts, concrete cures into a monolithic slab, requiring no fasteners. In applications of concrete block or multiple components, mortar is applied, which has similar content and characteristics to concrete. Bamboo, however, needs methods to secure its culms. Nails are avoided because they cause bamboo to split.[31] Other connecting methods vary according to the builder and application. Traditionally, ropes of bamboo, raffia,

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[b] See page 21 in Janssen (1995) for vertical cross-section to anchor bamboo housing to a masonry foundation.

coconut, sisal, or sago palms lashed culms together. Today, synthetic materials and wire ties are more common connectors. Other alternatives include bolts and pins, adhesives, and interlocking pieces.[32] The goals of zero waste favor the use of traditional, biodegradable fibers and/or joinery to secure components without health and ecological hazards.[33] In this instance, vernacular wisdom can be reintroduced to achieve modern sustainability.[c]

Chemical treatments may be added to both concrete and bamboo to improve attributes of their performance, but they are not required or intended for all applications. Liquid hardeners may be added to concrete, which are fluosilicates of magnesium and zinc, as well as chemical stains for aesthetic finishes and epoxy bonding for nonslip finishes.[34] Concrete curing compounds may include resin, sodium silicates, chlorinated rubber, or acrylic, and sealants and epoxy mortars may also be applied to extend concrete's life through encasement or repair.[35] Specifiers for concrete treatments face many tradeoffs between performance, life expectancy, and toxicity.

Likewise, builders may choose to treat bamboo with heavy metals and caustic chemicals for extra protection. A combination of lime, tar, creosote, and acid chrome copper is used to resist insects, fungi, and termites.[36] Another treatment includes copper sulfate, potassium dichromate, and either acetic acid or arsenic penta oxide. Steeping, dipping, and *Boucherie* are methods to distribute water and/or preservatives throughout the bamboo. These concoctions can be easily made in the field, but they cause burns with human contact and can contaminate water supplies when bamboo decomposes.[37] However, less toxic alternatives are available to increase bamboo safety and durability. Soaking bamboo in water for the three months directly after felling reduces the starch in bamboo veins and thereby

[c] See page 99 in Kaley for traditional joinery diagrams.

reduces the draw of borers. In addition, heat treatments, smoking, borax, and vegetable dyes can preserve bamboo from environmental threats without endangering health or compostability.[38] Untreated bamboo is also highly flammable; chemical treatments and plaster coatings are common to reduce fire risks. However, other precautions may be more effective to prevent fire and protect human and nonhuman health: cooking outside or in non-combustible cooking areas, constructing single-story buildings for egress, and spacing buildings attack the problem of combustion at its source.[39]

Concrete's monolithic structure also precludes the need for infill or cladding to provide privacy and separation from the exterior environment. However, when bamboo culms are implemented as linear, structural members, additional material is required for full visual isolation. Bamboo can serve this purpose by weaving its fibers into screens or mats, splitting culms into tile-like cladding, or infilling strips in a wattle and daub fashion with layers of earth. Complementary materials to bamboo also fulfill zero waste goals. Biodegradable textiles could provide opaque coverings that breathe, filter the air, insulate, and protect the interiors. The looseness of textiles also distributes forces well, absorbing impacts instead of resisting them at concentrated points.[40] For roofing, thatch presents an alternative to bamboo coverings. Thatched roofs can last over 60 years when built well and maintained. Like the other solutions, thatch provides rustic beauty, breathability, insulation, and local sourcing. In Punta Cana, the abundant seaweed and organic ocean debris could be reutilized in thatch roofing.[41] Each of these solutions is attractive for application in Punta Cana due to adaptability, familiarity, and compliance with the zero waste mission.[42]

Based on energy, water, and additional inputs, bamboo fares more favorably for sustainability than concrete. When fueled by renewable and human energies, bamboo and its accessories provide optimism for zero waste solutions. However, attempts to consider all the inputs necessary for any material highlight the limits of life-cycle analysis. What are the reasonable boundaries for a material's inputs? For example, the fuel used to transport materials and operate processing machinery is included in calculations, but should analyses also include the materials used to make the transportation vehicles and machinery themselves? At this level of analysis, bamboo gains an even more significant advantage over concrete by maximizing human labor and minimizing transportation, but it may fall short of zero waste goals. These contradictions reveal the need to think about solutions comprehensively; even the most suitable resolutions for a given context must be viewed critically to identify and eliminate material waste in all aspects of their life cycles.

Suitability for climate and conditions

In addition to the ecological considerations of materials and their inputs, designers must ensure that resolutions will perform well under the conditions of their application. If materials fail to provide their intended function, they cannot be deemed suitable options and will likely fall into disuse and waste. Concrete conveys several compatibilities with the climate in Punta Cana. Dramatic changes in temperature and moisture, particularly during freezing and thawing, can cause concrete to crack.[43] The Dominican Republic's warm and stable climate avoids damage to concrete from expansion and contraction. However, the heat, moderate humidity, and wind in Punta Cana may pose challenges during the initial curing of concrete. When concrete dries too rapidly, its strength and resistance to cracking is reduced. Preventative measures, such as installing on cool, humid days, constructing sunshades and windbreaks from tarpaulins and lumber, and curing during low-heat periods of the day, can allow proper application.[44] However, builders must know that precautions are necessary to avoid shoddy construction.

In operation, Punta Cana's climate poses obstacles to concrete's functionality. Many hot, arid climates use concrete for its thermal mass capabilities to absorb incoming heat during peak daytime hours and release the heat during the cooler nighttime hours. However, the use of thermal mass in Punta Cana is complicated because its night temperatures remain elevated. Structures may benefit from the heat sink during the day, but buildings should be placed in the shade and have copious ventilation to avoid overheating at night. Concrete's thickness and opacity can provide cool, shaded, and waterproof interior spaces, but these benefits simultaneously prevent breezes from cooling and naturally ventilating building interiors. These tradeoffs must be weighed to determine if concrete will meet the needs of each building. Due to the complexities of concrete's passive cooling strategies for tropical climates, air conditioning remains a primary strategy to attain user comfort in concrete buildings in Punta Cana.

Alternatively, bamboo presents potential congruities with the climate of Punta Cana. Bamboo grows in tropical, subtropical, and some temperate zones, including the Caribbean.[45] It is adapted to survive various levels of temperature and humidity; bamboo plants use transpiration to establish their own microclimate, cooling groves up to 10-15°F.[46] Like concrete, bamboo does not respond well to freezing and prefers stable, warm climates,[47] and it also needs careful attention during its early stages. Bamboo can crack if it dries too quickly, but the culms can be protected while drying by providing a clean, ventilated, covered storage area. Furthermore, to extend the life of bamboo, roofs should provide an overhang to protect bamboo walls from precipitation.[48]

As a plant, bamboo entails interaction with the soil. This relationship is characterized by mutual exchange, rather than consumption. Bamboo is a hardy crop; it can survive on non-arable slopes, degraded forests, and other wastelands unsuitable for food output.[49] It suffers in very heavy soil, soggy earth, and pure sand but is resilient in most other plots.[50] Bamboo's robustness is advantageous to thrive in the thin soils at Punta Cana. Bamboo benefits from the addition of compost to its plots, which is readily available through the vermiculture project at PCEF. In turn, bamboo can enrich Punta Cana's weak soil and reduce erosion and runoff due to its wide spreading roots.[51] As previously mentioned, rainfall in Punta Cana provides for the majority, if not all, of bamboo's water needs. It is also likely that PCEF could reuse greywater from its facilities and/or the resort for additional irrigation.[52]

Concrete, a material of monolithic mass, and bamboo, a material of lightweight fibers, employ seemingly opposite strategies for climate control. While concrete acts as a barrier to absorb and block heat, bamboo is a more permeable interface to allow natural ventilation as a cooling mechanism. With proper shading, bamboo's air circulation prevents heat buildup and fosters comfort. Designers often view concrete's strategies of interior environmental control, either through thermal mass or air conditioning, as more technologically advanced, but the details of bamboo's mechanisms, including its benefits of soil regeneration, reveal a more complex and elegant resolution. Therefore, bamboo provides technical solutions better suited to work symbiotically within Punta Cana's environmental conditions.

Life cycle and renewability

Material life cycles and renewability play significant roles in sustainability because the provision of new buildings requires energy, materials, and labor. The expected life span of concrete varies widely with the quality of its materials, methods of construction, treatments applied, and contact with its context over time. Concrete technically has an unlimited life under ideal conditions;[53] however, inevitable contact with air, water, soil, and chemicals cause degradation. Freezing and thawing cycles, abrasion, saturation, general wear from weather, and chemical reactions from organic acids and inorganic salts all cause concrete to deteriorate. Concrete also creeps and deforms under sustained loads, which weakens the structure and necessitates replacement after a given period.[54] Nonetheless, low-rise concrete construction in Punta Cana is likely to last several decades before demolition.

Under equal conditions, concrete generally outlives bamboo construction. In Punta Cana's climate, with a rooftop overhang, and on a suitable foundation, bamboo typically lasts 10-15 years untreated.[55] However, the bamboo rafters of Japanese farmhouses, which are completely protected from the elements, have lasted hundreds of years; like concrete, bamboo has a great longevity under ideal conditions.[56] Various types of treatments are available and needed to repel insects, reduce fire risks, and generally extend bamboo's life expectancy. Traditional treatment methods include clump-curing, smoking, soaking, and seasoning; the effectiveness of these strategies varies with species and location. Various chemical treatments are also known to increase bamboo's life expectancy to 25 years.[57] However, the chemical treatments are hazardous to humans and compromise the safety of bamboo composting. As bamboo decreases in strength over time regardless of treatments, it is important to ensure bamboo can remain within a closed loop at the end of its useful life.[58]

Although bamboo lags behind concrete in its life expectancy, bamboo's key strength is its renewability. Each of concrete's mineral components is nonrenewable, and, therefore, concrete production cannot be sustained indefinitely. Bamboo, however, is self-regenerating;

new shoots return each year after harvest. After 30 days of growth, bamboo spouts can be eaten as food,[59] and at 6 weeks, bamboo culms have reached full girth and height.[60] This rapid growth is achieved at a rate of one foot per day in an established nursery.[61] Bamboo reaches maturity within 3-8 years,[62] compared to 10-20 years for most softwoods.[63] At maturity, harvesting encourages growth without harming the plant.[64] As a result of its speed of growth and hardiness, bamboo yields 20 million tons, or 8 million kilometers, of cane each year at harvest. Eight million kilometers is approximately equivalent to 200 times the Earth's circumference, indicating a plentiful, ongoing supply for construction.[65]

While concrete trumps bamboo as a durable material, bamboo's renewability is more critical to achieve zero waste goals. The privileging of concrete over bamboo due to its life span is based on an assumption that durability, and its resulting resource conservation, are appropriate goals. Designers must rethink the cradle to grave sequence, as well as the dualistic notions that assume technological and globalized perspectives apply superior knowledge to prior methods. An ethic that recognizes the limits of conservation in favor of renewability will increase the acceptance of bamboo in the First and Third Worlds.

Emissions and climate change

Both concrete and bamboo interact with their surrounding environments throughout their life cycles. One of the key exchanges within ecosystems is through the air, in the form of emissions and sequestrations. Carbon emissions have become particularly relevant in the green building movement due to concerns regarding the greenhouse effect, which contributes to global warming. Concrete is responsible for 1.5 – 2% of the human emissions of carbon dioxide in the United States. Concrete's emissions are divided into two source categories: calcination, which releases carbon dioxide from limestone and clay when heated, accounts for 60% of emissions, and combustion, which primarily originates from fuel use, comprises the remaining 40%. In total, the manufacture of each pound of cement yields about 0.9 pounds of carbon dioxide, and the manufacture of a cubic yard, or 3,900 pounds, of concrete emits about 400 pounds of carbon dioxide. Luckily, as concrete ages, it carbonates and reabsorbs most of the emissions of calcination over its useful life. However, half of concrete's emissions remain after its demolition, significantly contributing to the rising challenges of climate change.[66]

Bamboo, however, is consistently recognized for its ability to sequester more carbon than it emits in its production. Some bamboo is able to sequester up to 12 tons of carbon dioxide per hectare.[67] Planted bamboo sequesters carbon dioxide from the atmosphere, but harvested and constructed bamboo also continue to act as carbon sinks. Bamboo stores carbon in all its applications, including poles, boards, siding, flooring, and other products. Bamboo Living, a design-build company specializing in bamboo construction, estimates that one of their houses, measuring 44 feet in length, is capable of storing 15 tons of carbon dioxide. All plant matter absorbs carbon throughout its life in this manner, but bamboo is particularly advantageous because of its speed of growth.[68]

Bamboo also affords additional advantages in its atmospheric exchanges. According to NASA studies, bamboo, like other household plants, absorbs many toxins that are common and harmful to indoor environmental quality, including benzene, formaldehyde, and trichloroethylene.[69] Bamboo also releases 35% more oxygen than equivalent areas of trees. Its rapid growth can readily repopulate degraded lands with usable crops, and through its leafy canopy, bamboo can protect lower life from intense light and ultraviolet rays.[70]

These benefits outweigh the environmental costs of bamboo, which primarily entail the fuel consumed in overseas transportation. Bamboo is already sourced in the Caribbean, and if Dominicans can establish their own bamboo supply for local construction, the emissions of bamboo can be even further reduced.[71]

The moderate levels of emissions resulting from concrete production cannot compete with the restorative sequestration that bamboo provides. Based on the criteria of emissions and climate change, bamboo should be utilized wherever it is functionally and contextually suitable to reap its atmospheric benefits.

Waste

Finally, concrete and bamboo greatly differ in their end of life strategies. In the past, concrete was landfilled, but concrete recycling is growing in popularity. Concrete recycling entails breaking and crushing existing concrete, which can then be reused as aggregate for new cement or concrete. No restrictions exist for the types of concrete that can be recycled. Concrete recycling helps close the loop of production by reducing the need for virgin inputs and the amount of unusable waste produced. Economically, concrete recycling can also reduce disposal costs, which have been as high as $100 per ton to landfill.[72] However, concrete recycling has significant drawbacks. Concrete can be difficult to recycle,[73] and only a portion of new concrete can derive from recycled inputs to avoid too much degradation from impurities.[d] New concrete always requires some virgin materials, and as recycling does not eliminate demand for further extraction of nonrenewable resources, concrete remains unsustainable.[74]

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[d] See http://www.wbcsd.org/DocRoot/hsj6ZVfbNRJu3684lbjk/CSI-RecyclingConcrete-FullReport.pdf for further information on concrete recycling.

In contrast, bamboo safely biodegrades in absence of toxic treatments and under proper composting conditions. Members or entire buildings that become broken, worn, or disused can be easily dismantled, replaced, and composted without waste.[75] In addition to providing nourishment for the soil at the end of their lives, bamboo leaves and excess culms can provide animal feed. Every part of the plant has a use during and after its life, eliminating the concept of waste.[76] Consequently, bamboo embodies the goals of zero waste better than concrete and is a viable solution to reduce the hindrances of ecotourism in Punta Cana.

Economic

Availability

Availability is one cause of the widespread use of both concrete and bamboo. Sand, limestone, and water are generally abundant in most parts of the globe to make concrete. The combination of high demand and supply results in concrete production surpassing all other human-made materials.[77] Punta Cana has great deposits of limestone beneath its thin soil, and its oceanside location provides seemingly unlimited sand and water.[78] To capitalize on these resources, the Dominican Republic has established domestic concrete production, which better supports its communities' economies than importation.

While concrete is the most common human-made material, bamboo is one of the most used plant-based materials worldwide.[79] Bamboo is native to every continent except Europe and Antarctica, indicating its adaptability to diverse environments.[80] It is most plentiful in South Asia, Latin America, Africa, and South America, where it is used to build houses, bridges, and other structures. In total, bamboo serves as livelihood for over 1 billion people, most of which live in rural areas of poor, developing countries.[81] A comprehensive system for growing, processing, and understanding bamboo does not yet exist in the United States or the Dominican Republic.[82] However, as Punta Cana retains the necessary resources to support bamboo production, it is likely that bamboo would thrive and become an abundant material for construction once introduced and tended.

Neither concrete nor bamboo is restricted by the availability of resources for their production. However, concrete's nonrenewable inputs limit its indefinite production, and the extraction methods to acquire its components may have severe consequences. While both materials may be able to thrive in Punta Cana for many generations, bamboo is a more sustainable choice for continuous use.

Economic opportunity

Concrete offers opportunities for monetary income in the Dominican Republic. Argos, a major cement producer in Latin America, has made investments in the Dominican Republic to ease its entrance into concrete production. With their startup costs met, Dominicans can utilize their natural resources to produce a product with high domestic and international demand. Cement has already become a key industry in the Dominican Republic.[83] Concrete is a low-cost material in comparison to many industrial materials, but an average price of $75 per cubic yard provides good profits for Dominican business.[84] The cost of concrete may be prohibitive for some residents around Punta Cana, but local production and labor can reduce overall costs. By producing its building materials within city regions or its national borders, the Dominican Republic can retain its money within its communities to improve its economic strength. However, the Dominican concrete industry must also be cautious of its operations. With corporate support, Dominicans must avoid corruption and assure they are receiving a fair share of their profits. Workers and communities must also monitor the effects of concrete production, balancing the profits they receive against changes to their environment and social structure.

Alternatively, bamboo overcomes many of the risks that concrete production entails. While concrete production requires specialized machinery and intensive inputs, bamboo can be produced on various scales without machinery or high startup costs. After the purchase of initial seeds or shoots, bamboo nurseries regenerate themselves, eliminating the need for continual purchases of raw materials that concrete necessitates. The inputs that bamboo requires for growth are water and compost, which can be obtained at little to no cost in Punta Cana.[e] The human labor that bamboo utilizes also tends to be less expensive than the fuel required to power machinery.[85] Consequently, bamboo can be harvested and sold at nominally pure profit, whereas concrete producers must closely balance their assets and liabilities. In addition, bamboo can improve the health of the landscape, whereas concrete can endanger the wellbeing of residents and the profits of tourism.

Costa Rica has become a popular supplier of bamboo, and its industry can serve as a helpful model for operations at Punta Cana and throughout the Dominican Republic. As in Costa Rica, shipping costs can be saved by growing bamboo within close proximity of building sites.[86] The Dominican Republic could provide bamboo as a low-cost option to low-income residents without losing profits and also take advantage of growing international demand for bamboo to gain immense returns. For example, builders can purchase *Guadua angustifolia* at Costa Rican farms for $0.87 - $1.34 per linear meter, depending on its diameter.[87] In contrast, Kool Bamboo, an American supplier of bamboo, sells the same crop

[e] See “Farming” in Kaley for bamboo farming details and cost analysis.

for $12.49 - $13.32 per linear meter.[88] Therefore, bamboo can allow Dominican businesses to provide for its residents' needs while maintaining great economic viability.

Bamboo appears to be more promising for economic ventures in Punta Cana because of its low environmental risks, low entry and maintenance costs, and ability to produce a premium, profitable resource that First World nations cannot provide for themselves. While Dominicans may have difficulty obtaining the resources to compete in the concrete market, bamboo provides opportunities to respond to demand with little initial capital. A production scheme that supplies domestically and internationally can both build communities and help money flow into the Third World, rectifying some economic imbalances of the past.

Employment and empowerment

Human labor is needed to produce, market, sell, and distribute all materials. Concrete production facilities require employment to mine, test, inspect, and handle their product. Workers must check for foreign substances in the aggregate, cracks, and surface checking, and an inspector must supervise and certify concrete production and installation.[89] In addition, knowledgeable workers are required to correctly combine inputs in specific ratios, mix and pour the concrete manually or with machinery, and plan for adequate curing and assembly.[90] Each step of concrete production is critical to ensure the safety and quality of the final product. In the Dominican Republic, a history of corruption and a lack of regulation, if continued, could endanger user and environmental wellbeing. Special precautions must be taken to increase the regulation and accountability for concrete construction in Punta Cana.

Likewise, bamboo also requires skilled labor for its production and construction. Agricultural workers are necessary to monitor plants, tend to their needs, and subsequently harvest, sell, and apply the bamboo.[91] The weaving, lashing, and combination of bamboo with other materials are intricate crafts; while concrete workers of similar experience may be interchangeable, bamboo contractors may be sought for their unique stylistic or technical sensibilities.[92] Since bamboo culms are not standard components, builders must balance the challenges of construction with opportunities for aesthetic improvisation. As respect and reputation build with experience and recognition, bamboo is likely to build pride within individual workers, the buildings they create, and the community as a whole. However, the basic techniques of bamboo construction are easy for most residents to master. Bamboo can be easily cut or split into the right size and shaped with simple tools, and residents can construct structures very quickly.[93] Therefore, bamboo can empower populations without advanced building experience and also build pride and craft within the culture.

It is this sense of pride and empowerment that is a key advantage of bamboo above concrete. While concrete can also be applied by either professionals or amateurs with sufficient knowledge, bamboo is able to circumvent “industry” altogether. Bamboo can be planted and grown on individual, family, or community scales, adapting easily to producer means and needs.[94] Therefore, bamboo caters to both bottom-up and top-down production, making it attractive to all kinds of economies.[95] The speed and density of bamboo growth greatly contributes to self-sufficiency, as a large amount of material can be grown quickly on a small plot,[96] and bamboo earns a faster economic return than wood.[97] When workers and users, rather than craftsmen, engineers, and managers, have more control, production tends to yield a better product, use resources more responsibly, produce less pollution, create less bureaucracy, and provide more flexibility, safety, and meaning for workers.[98]

Bamboo not only empowers individuals but also national economies and societies. Poverty is widespread in the Dominican Republic, and builders can construct structures with low environmental impacts and monetary costs using bamboo.[99] In light of the Dominican Republic's vulnerability to hurricanes and earthquakes, bamboo allows refugee housing to be built in record time.[100] In addition, by localizing bamboo production with accountability, most of the mistakes associated with bamboo building can be overcome, including a lack of quality control, communication problems overseas and across languages, and the costliness of transportation.[101] Lastly, bamboo can empower the Third World in equal international exchanges. By gaining expertise in the production and application of bamboo, Third World designers' knowledge will not be idealized as primitive wisdom; it will be valued as advanced, technological, sustainable knowledge. Therefore, bamboo is not only an economically stabilizing force but also an impetus for social equality, understanding, and exchange.[102]

Social

Health and Safety

Most of concrete's safety hazards are associated with its production and installation, rather than daily interior exposures. Most dangers arise when workers directly contact or inhale concrete or cement dust. Alkaline compounds, such as lime, are corrosive to human tissue, crystalline silica is abrasive to skin and lungs, and chromium can cause allergic reactions or cancer with prolonged contact.[103] Physical contact with wet concrete generally results in skin irritation and burns.[104] Concrete surfaces that have properly cured and been treated against dust are generally chemically stable and problem free during use, but improper curing can cause these health defects and indoor climate problems to persist.[105]

However, other unanticipated health effects unrelated to chemical exposures can result from concrete. The hardness of concrete floors can cause feet to ache and damage to muscles and joints over time. The temperature of concrete can also be problematic. Cold floors can suck heat from the body, upsetting its equilibrium. In addition, “Baker’s illness” was a problem in the past for bakeries with concrete and tiled floors. The ovens heated the tiles or concrete, and the high floor temperatures caused headaches and tiredness. While many of these nonchemical complications can be resolved with simple solutions, such as shoes or area rugs, users must be aware of the problems to recognize the cause of their indistinct symptoms and take corrective measures.[106]

Although bamboo can be produced and implemented without the addition of synthetic chemicals, builders must take precautions against bamboo’s natural toxins. The existence of natural toxins helps clarify the dangers of assuming all things natural are safe; all materials must be considered carefully to avoid unintended consequences. Bamboo is generally considered a hypoallergenic plant that does not trigger reactions in individuals sensitive to other plants and fibers. However, raw bamboo shoots contain hydrocyanic acid, which can cause cyanide poisoning. People with severe rhinitis, asthma, or atopic dermatitis may experience allergic reactions with exposure to the acid.[107] Therefore, it is critical to undertake the proper drying and storage procedures recommended by bamboo manufacturers to avoid these harmful exposures.

Concrete and bamboo both entail some possible dangers to human health in their applications and must be treated with caution. However, since bamboo only triggers reactions in hypersensitive individuals when improperly installed, bamboo currently appears to entail fewer hazards to human health than concrete.

Strength and performance in disasters

Due to the Dominican Republic's history of natural and unnatural disasters, including hurricanes, floods, earthquakes, and conflicts, its building materials must be able to provide safety in severe, unfavorable conditions. Concrete conveys several advantages in severe weather. Concrete is fairly watertight, can resist heat and fire due to nonflammable components, and has high compressive strength.[108] However, at a typical weight of 150 pounds per cubic foot, the collapse of concrete structures tends kill occupants when disasters cause the material to fail.[109] Concrete experts claim that the immense death toll in the 2010 earthquake in Haiti can be largely attributed to shoddy concrete construction, as Haitians approximated the ingredient ratios by eye. Test samples revealed a 1,300 pound per square inch compressive strength for Haitian concrete, whereas concrete in the United States has a minimum strength of 3,000 pounds per square inch.[110] In addition, traditional concrete lacks tensile strength; steel reinforcement and ductile joints must be added to concrete to survive significant tremors.[111] While concrete framing systems have proven their ability to survive major earthquakes and other inclement weather, they are not infallible and have undeniably deadly results in failure. If concrete use continues in the Dominican Republic, builders must understand that the precision of their mixing and installation directly correlates to the strength of the concrete and strive to build the safest structures possible.

Bamboo also conveys advantages in disasters, although its assets are very dissimilar to those of concrete. While concrete gains its strength from its massive density and weight, bamboo is lightweight, hard, and flexible. Concrete is four times denser and weightier than bamboo, and when compared by equal area, bamboo is definitively stronger than concrete.[112] With a compressive resistance roughly twice that of concrete and a similar tensile strength to steel, bamboo's strength-to-weight ratio surpasses that of steel, which is far stronger than concrete.[113] Bamboo is well suited to tensegrity structures, in which loads are transferred to the entire structure for stability.[114] Traditional lashed joinery allows some movement in the joints to avoid stress and cracking. Natural fibers, such as jute, hemp, rattan, or split bamboo, tighten around the joint if they are green when installed, and they expand and contract with the bamboo to maintain a secure fit.[115] Due to bamboo's flexibility, strength, and transfer abilities, bamboo structures often sustain little damage in earthquakes and other intense loads.[116] Bamboo may deform under pressure but tends to return to its original shape when the load is removed; it is rare for bamboo to fail in compression or tension.[117]

Traditional wisdom and experience confirm the numerical data regarding bamboo's stability. In Japan, children are taught that the bamboo grove is the safest place to seek protection during an earthquake. The growing bamboo absorbs shockwaves and serves as a windbreak.[118] Bamboo's underground rhizomes and roots form a tightly packed turf, which gives the ground good stability. From a business standpoint, bamboo crops are often not decimated in disaster. The plants can recover from severe damage to their stems and leaves, and their fast growth generates new supplies quickly.[119] The Columbian earthquake of 1999 also provides a comparative example of concrete and bamboo safety in disasters. The disaster destroyed 75% of the buildings in the region, but the bamboo structures survived relatively intact.[120] The easy workability of bamboo allowed workers to repair most damaged bamboo structures in a day.[121] However, almost all of the casualties were caused by falling concrete.[122]

According to both numerical data and past experience, bamboo is a safer alternative than concrete in natural disasters. Not only is bamboo more resistant to damage and failure, but bamboo is also lightweight enough to allow occupants to survive building collapses. As

Punta Cana is prone to dangerous weather, it is critical to select materials best suited to disaster situations and relief to fulfill the intended function of safety for users.

Versatility and changeability

Versatility and changeability are important characteristics for materials to secure market viability and to support functionality for the end user. Concrete is a very versatile material. Freshly mixed concrete can take virtually any shape, and it can be molded at ambient temperatures on site or prior to transport.[123] Due to its ability to fit any mold and retain its shape with durability, concrete is used for numerous building applications, such as foundations, walls, floors, and roofs. Concrete blocks, roof tiles, corrugated sheets, and other precast components provide a variety of products to meet diverse needs.[124] However, while concrete is highly versatile, concrete lacks changeability. It is very difficult to effectively alter concrete once it has cured. Concrete is not elastic; it strictly maintains the shape of its mold and weakens or crumbles when reshaped.[125] Concrete's heavy weight also resists movable or repositionable parts. Palacios Guberti (1999) noted Dominican residents' dissatisfaction in concrete's inability to meet their changing needs.[126] Since designers cannot fully anticipate future needs, flexible materials may be more beneficial than those lacking changeability.

Alternatively, bamboo maintains high versatility and changeability. Bamboo boasts 1,500 daily uses, including food, clothing, musical instruments, and household objects.[127] For building, bamboo may be used for walls, roofs, floors, doors, window frames, mats, boards, screens, trusses, scaffolding, drains, and channels.[128] Like concrete, bamboo takes a variety of forms for different functions.[f] Bamboo can be lashed together to form columns, embedded in

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[f] See Martinez (2000) for a study of bamboo manipulation.

wattle and daub construction, woven into ornamental lattices, halved lengthwise to form shingles or gutters, flattened into boards, crushed into fibers, and much more.[129] The nonconformity of bamboo culms is beneficial for its diverse applications, as different thicknesses are appropriate for different structural and nonstructural parts. Designers should also consider nodes during culm selection because increased node density indicates superior strength.[130] With seemingly unlimited uses for building, food, products, and exports, Dominicans should not fear developing an unusable surplus of bamboo.

Bamboo's changeability is apparent in its light weight and flexibility. Bamboo's traditional lashed bindings can be easily removed and adjusted, and the light bamboo parts can be easily repositioned. These features allow buildings to grow, contract, and rearrange according to the changing preferences of their users. The form of bamboo components is also able to change after initial installation. Although it is easier to bend bamboo when it is young and green, dried bamboo can be soaked and bent into smooth curves. Once the bamboo is dry, it will maintain its curved form. In addition, bamboo can often bear more load in curved states; perhaps designers should explore curved forms to provide additional stability in Punta Cana.[131]

Neither concrete nor bamboo poses significant challenges in versatility, but concrete's limited changeability favors bamboo for implementation in Punta Cana. As Dominican residents may face significant lifestyle changes with increased Western contact and sustainable development in the future and concrete's inflexibility has elicited dissatisfaction in the past, materials should be chosen that can adapt to unanticipated needs.

Aesthetics

Concrete and bamboo both provide interesting opportunities for aesthetic expression. Concrete has a great array of treatment options, including paints, stains, polishes, and other coatings. Many of these treatments are toxic, but other alternatives, including milk paints and clay paints, do not pose significant environmental dangers. In the Dominican Republic, many residents paint their concrete housing as a form of expression and decoration.[132] Other aesthetic interventions can be worked into the concrete material itself. While many finishes can be scratched and reveal the dissimilar material beneath, pigments can be added to concrete mixes to color the material throughout, effectively hiding wear. Concrete is generally pictured as a smooth, undifferentiated material, but textures and patterns can be added to the surfaces of concrete casts to create visual interest and meaning. Forms can also be built in any shape to convey concepts from stark linearity to organic decoration. Concrete is generally perceived as very industrial and cold as an isolated material, but in combination with fabrics, color, and other details, concrete can play a role in a variety of styles. Designers should not feel limited by concrete's aesthetic possibilities.

Bamboo also provides adequate variation in appearance. Bamboo varies in color and pattern across its life and species, displaying yellows, browns, reds, spots, and/or stripes.[133] Different anatomies also provide different shapes and curvatures.[134] As previously discussed, bamboo is not limited to its natural linear and tubular form; bamboo can be transformed by bending, burning, carving, cutting, crushing, flattening, splitting, weaving, and more. Through manipulation, bamboo can become unrecognizable, changing from a hard, stiff, wood-like material into soft, pliable fabrics. In some altered states, bamboo accepts dyes and finishes readily. However, the waxy exterior of bamboo culms limits finishes' abilities to bind well with their surface and to move with the building without cracking or flaking.[135] If designers want to use bamboo without much manipulation, such as in structural design in Punta Cana, designers may be limited to their chosen species' natural color and pattern.

While some designers may feel limited by the "natural" and "primitive" appearance of structural bamboo, notable architects have created widely admired designs with bamboo. Concrete celebrates a long succession of modern architecture demonstrating its capabilities, such as the work of Le Corbusier, and bamboo also benefits from its exemplars. Buckminster Fuller, Frei Otto, Renzo Piano, and Arata Isozaki all experimented with bamboo during their careers, conveying a more diverse history for bamboo beyond vernacular and the do-it-yourself movements of the 1960s and 1970s. However, Simón Vélez is the most well known for his use of bamboo. Nicknamed the "Calatrava of Bamboo," Vélez has linked bamboo to impressive structural feats and aesthetics. At the 2000 Universal Exhibition in Hanover, Vélez chose to embody the concept of zero waste for the Zero Emissions Research Initiative. His design consisted of 3,500 stems of *Guadua* bamboo, which were constructed by skilled builders without the use of cranes. In comparison to the excesses of other pavilions, such as the Millennium Dome, Vélez's bamboo pavilion was financially modest and ecologically responsible without sacrificing visual impact.[136] Vélez and others have inspired much interest to explore bamboo's possibilities. Designers have discovered that bamboo is well suited to create curves and vaulted ceilings, elements that tend to be expensive using other materials. Although these features may create different effects with bamboo than more industrial materials, bamboo makes many design features more accessible to a wider population.

Aesthetically, concrete and bamboo convey greatly different perceptions, but each has potential to fit within a wide array of contexts. In Punta Cana, some tourists may be attracted to the natural appearance of bamboo, which can blend into the ecological, island setting, whereas other visitors may prefer the familiarity of a concrete resort. Material aesthetics must be considered according to the preferences of a variety of stakeholders, as well as in conjunction with the other environmental, economic, and social factors dictating selection.

Cultural receptiveness

Concrete and bamboo elicit divergent reactions in both the First and Third World. In the Dominican Republic, concrete conveys a certain level of prestige due to its price and associations with Western culture. Steel, concrete, and glass have replaced bamboo in many areas of the world, instating bamboo's reputation as "the poor man's wood."[137] Bamboo has been used for millennia globally, and crop-based materials have been affordable for use in the Dominican Republic for many generations; bamboo lacks the novelty and technical perceptions of concrete.[138] However, familiarity can be both a drawback and attraction. In past and current vernacular, builders used Cana trees in construction, which are similar in appearance to thick *Guadua* bamboo. Bamboo can act as a tie to tradition, building pride in the valuable techniques of Dominican culture.

Ecological concerns may be likely pathways to improve the reputation of bamboo in Punta Cana, an area that relies on the health and beauty of its ecosystems for revenue and basic survival. Bamboo mimics the widely proven application of Cana trees but also prevents the deforestation that results from excessive use of Cana trees. Due to bamboo's rapid and dense growth, it can support more building demand than Cana trees. In addition, the Western green building movement is increasing the attractiveness of bamboo in the United

States, and this desirability will likely permeate to the Third World like other Western influences. Sustainability as a Western value removes the primitive stigma of regional, renewable, and crop-based technologies.[139]

Bamboo has also acquired a negative image because many bamboo houses are characterized by mediocre design and construction. However, by providing quality examples of bamboo's possibilities, bamboo can gain the prestige that Dominicans associate with concrete. Bamboo is currently used in the construction of expensive and beautiful houses in Japan,[140] and Vélez provides stunning examples of commercial building types. With continued exposure to good bamboo design, it is possible to break stereotypes and reinvent bamboo as a high-tech, economical, and attractive building material.[141] While bamboo may face some cultural resistance due to preferences for Western innovations, bamboo's stigmas are likely to fade as the demand for bamboo continues to grow in the United States and abroad. Developing countries currently pay a high price to use the concrete that embodies Western values, but builders in Punta Cana can realize the attractiveness of bamboo to meet their needs and value their traditional culture.[142]

Conclusion

Based on the criteria described, this thesis recommends bamboo for future building construction in Punta Cana. While bamboo may meet the environmental, economic, and social needs of Punta Cana, several barriers to its implementation exist. First, no codes for bamboo construction exist in the majority of the world. Without standards for safe building practices, bamboo meets resistance and skepticism as a valid structural material.[143] In addition, past associations of strength with rigidity create a disadvantage for bamboo, which possesses both exceptional flexibility and strength.[144] Displays, such as Vélez's 66-foot spans and 30-foot cantilevers, are critical to prove bamboo's stability and provide examples to help officials devise acceptable protocols.[145] By gaining approval, regulation, and recognition for bamboo, designers may more widely acknowledge that flexibility does not correlate with weakness and grow more receptive to a wider array of low-impact, crop-based materials.

Another barrier to bamboo use on a large scale is each culm's unique character. When mechanical properties differ with species, age, moisture, diameter, wall thickness, and more, bamboo is difficult to standardize and regulate.[146] Differences in thickness, color, and pliability may be beneficial to suit different needs, but variation slows and complicates mass production. However, one of the key strengths of bamboo is its ability to be used without high-input machinery. Bamboo's limitations may necessitate human labor and ingenuity, inputs that conform to the zero waste goal. In other words, bamboo's nonconformity to conventional, intensive means of production may help protect the sustainability of the material and the communities who produce it.

Lastly, as bamboo is a hardy, fast-spreading plant that does not currently grow plentifully in Punta Cana, bamboo may be identified as an invasive species. Bamboo can spread rapidly below the ground, dominate over regional species, and upset the balance of important ecosystems. However, bamboo can be deterred with precautions. Concrete, plastic, or other durable barriers that extend three feet into the ground can restrict bamboo to a limited area.[147] If PCEF wishes to establish a nursery and confine bamboo to its boundaries, it will be important to implement these barriers at its outset. If confronted with concerns of invasive species, PCEF may need to educate the community on the benefits, risks, and preventative measures regarding bamboo to justify its decisions and actions.

Instructive programs through PCEF would also be vitally important to educate and possibly provide adequate barrier methods for families interested in growing bamboo themselves in order to avoid unintentional ecological disturbances.

This study highlights the importance of detailed, qualitative life-cycle analyses to make informed decisions regarding material selection. By investigating specific traits that affect the suitability of material solutions for a given landscape, designers are less likely to rely on dualistic assumptions to limit and focus their possibilities. Through this process, bamboo is no longer discarded as a primitive, local, and low-tech solution, but rather, it emerges as an alternative preferable to the concrete practices currently in place. Ultimately, designers must establish the validity of crop-based materials by demonstrating their superior characteristics, shifting perceptions of bamboo and other crops in communities, and instilling sustainable values in order for the building industry to recognize the need for change and embrace zero waste as a feasible goal.

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CONCLUSIONS

Implications

The significance of this study for sustainable design is that dualistic, conceptual assumptions can mask important material attributes that have physical consequences for environmental, economic, and social health. As a result of discounting material options without proper investigation, designers may implement solutions that are less beneficial for a given context than other available alternatives. In the field of sustainable design, many professionals ideologically favor either “high-performance” or “low-impact” approaches. As high-performance designers gravitate toward materials deemed highly technological, globally renowned, and symbolically modern, they may overlook selections that do not meet their common criteria. Likewise, low-impact designers favor materials they consider to be lower technology, locally cultivated, and historically embedded, and they can alienate innovations that arise beyond their area of focus. While designers’ patterns of thinking are based on experience, which is applied to ease decision making, sustainability is a complex challenge that requires decision makers to rethink their conventions through more thorough inquiries.

Tourism in Punta Cana is at the crossroads of several common dualisms that affect the building industry. First World influence is seen as more advanced than Third World practices due to its novelty, more technological because of its prominent machinery, science, and precision, more global due to its widespread power, and more aesthetic because of its trendiness. The dualisms of eco-technic vs. eco-centric, eco-medical vs. eco-social, and eco-aesthetic vs. eco-cultural guide residents, visitors, and other shareholders’ interpretations of changes in their communities; from these viewpoints, incoming technology threatens existing traditions, local culture hinders globalization, and historical and modern styles struggle to coexist. These mindsets cause people to perceive opposition, and their perceptions shape their actions toward conflict and exclusion.

One of the most tangible effects of dualistic thinking in Punta Cana is the materials that have been and are implemented; namely, the Dominican Republic has experienced a shift from crop-based materials to concrete construction due to Western influences. Crops, such as bamboo, can be precluded by designers who associate them with primitive huts, ancient culture, and low-tech rusticity. However, bamboo and concrete do not conform to dualistic assumptions, revealing an incongruity between perception and physicality. When analyzed, bamboo and concrete cross dualistic boundaries, as they can be considered both global and local, natural and technological, and historical and modern (Table 4). Consequently, these descriptors tell little about the sustainability of a given material, and specific environmental, economic, and social criteria must be detailed to determine materials' contextual suitability.

When powerful, wealthy nations present materials with unprecedented capabilities, Third World countries are likely to accept new methods as superior to their own. However, the analysis of bamboo and concrete in Punta Cana reveals that Dominicans' abandonment of crop-based materials in favor of concrete is not desirable to meet the needs of the community. While concrete can provide adequate function, safety, and comfort on an individual, daily basis, concrete can endanger environmental and human health in the long term. Sustainable design brings these long-term concerns to the fore without sacrificing the short-term benefits of design. In order to ensure continued health and happiness, designers, especially in vulnerable and treasured areas like Punta Cana, must be cognizant of the issues of zero waste, disaster prevention, environmental toxins, economic empowerment, and cultural unity that largely shape the qualities of the future world.

	Bamboo	Concrete
Eco-technic	Requires skill and knowledge of crop and climate to maintain sustainable production. Product exhibits exceptional capabilities.	Requires precision and machinery. Mixed product is not found in nonhuman environment.
Eco-centric	Requires less precision and machinery. Allows passive cooling and exterior contact. Closed loop nourishes ecological cycles.	Inputs are extracted directly from the Earth. Can utilize some passive strategies.
Eco-medical	Knowledge can be built and exchanged over vast distances. Healthy for individual user.	International standards for production and application. Provides barrier to maximize interior environmental control.
Eco-social	Materials and labor can be sourced in community. Growth on various scales can be source of empowerment.	Materials and labor can be sourced in community. Can transform resources into income.
Eco-aesthetic	Malleable to various shapes and forms. Vélez's works and product appearance are natural, modern, and signify green future.	Treatments and techniques change color, texture, and pattern. Appearance and works signify modern and industrial future.
Eco-cultural	Techniques acquired through experience and passed down through generations. Long history of use.	Treatments and forms can express cultural symbolism. Long history of use.

Table 4: Non-dualistic traits of bamboo and concrete

This study and other analyses that examine materials based on the criteria of sustainability provide much support for rapidly renewable, biodegradable, crop-based materials. These materials are commonly identified as natural, but their naturalness does not justify their sustainability. Designers should not seek “natural” materials simply because they are supposedly natural; all things are natural, or originating from elements of the Earth, and all things have been changed by human actions. Instead, designers need more defined sustainability criteria. Zero waste outlines several important criteria, but any single idea is likely to overlook some of the diverse considerations of sustainability. In fact, William McDonough and Michael Braungart advocate the mantras of “use current solar income” and “respect diversity” in addition to “waste equals food” to cover possible gaps in a zero waste paradigm.[1] However, zero waste can also fit within a more comprehensive framework, such as The Natural Step. The Natural Step is one set of criteria that arose from statements agreeable across the dualistic and varied viewpoints of professionals. According to The Natural Step, material products must meet four criteria to be included in a sustainable, closed-loop system:

1. Nature is not subject to systematically increasing concentrations of substances extracted from the Earth’s crust.
2. Nature is not subject to systematically increasing concentrations of substances produced by society.
3. Nature is not subject to systematically increasing degradation by physical means.
4. Human needs are met worldwide.[2]

These criteria are not as simple as they may seem; each requires in-depth research to confirm or deny compliance. However, each tenet provides definitive mandates for material sustainability, where *sustainable* does not mean “natural,” “less harmful,” or “green” but the ability to sustain life indefinitely.

The Natural Step provides a means for organizing and evaluating the environmental, economic, and social data gathered about materials within a zero waste focus. In the Punta Cana case study, concrete clearly does not meet the first three criteria since it requires extractions from the Earth's crust that cannot safely return to their origins after humans combine them. In contrast, bamboo usage does not require humans to remove resources from ecosystems that cannot safely biodegrade after use; bamboo's closed-loop cycle can remain regardless of human use. When bamboo is well suited for its functional requirements, uses renewable energies, and avoids toxic treatments, it may fulfill the first three conditions of the Natural Step. One the Natural Step's strengths is its inclusion of social and economic criteria in the fourth condition, which many green building indices neglect. The ability to integrate user involvement, flexibility, and diverse economies into bamboo production and design make sustainable bamboo architecture possible. The fourth condition recognizes the important point that bamboo itself is not sustainable; the contexts and processes in which bamboo is applied are as equally critical as chemical composition for long-term success.

The Natural Step and other zero waste frameworks help define the roles of technology, globalization, and style in material culture. Technology, as a whole, is not an absolute source of harm, but it is vilified due to machinery's tendencies to violate the conditions listed in the Natural Step. Strict eco-centric perspectives that seek to minimize all mechanical technology in buildings fail to recognize that technologies can be beneficial to enhance performance and meet human needs without compromising safe biodegradation. Similarly, global exchanges can introduce new ideas that are not well suited to subsequent contexts, but the communication of concepts is not inherently problematic. Rather, new methods require criticism and testing to ensure their suitability for new climates, economies, and societies. Lastly, stylistic changes are highlighted as a cause of rampant consumerism, which increases waste in an open-loop system. However, change is inevitable, is often desirable, and can avoid wasteful pitfalls when employed within a closed-loop system.

The key to beneficial use of technology, globalization, and style in the building industry is not to seek originality for its own sake but to implement changes to meet the goals of human and nonhuman wellbeing, such as those described in the Natural Step. A primary challenge of "progress" is the diversion of resources away from meeting the needs of the human poor and nonhuman stakeholders. Humans need products to meet their needs and live with safety and satisfaction; innovation and production that meets the Natural Step criteria should be encouraged. Sustainable practices will provide the means for current livelihood and continued abundance, rather than scarcity that arises in open-loop systems.

The lessened impacts of dualistic thinking, increased criticism in material selection, and support for crop-based materials that this thesis advocates could significantly impact the building industries of both First World and Third World countries. First, the way that materials are categorized, discussed, and marketed may require alteration. Manufacturers and catalogs tend to organize materials by composition, resulting in categories such as wood, glass, metals, plastics, and more. Crop-based materials are often grouped with animal products and biocomposites in a "naturals" category, which raises the problematic concepts of natural and unnatural materials. Instead, designers may gain greater exposure to suitable materials if materials are described by what they do, rather than what they are.[3] Several material databases, such as Material Connexion and Materia, offer functions to search products based on sustainable, functional, and physical properties, allowing designers to explore a full set of options that meet their specific criteria without preconceptions. The use of computerized databases offers many possibilities to identify unexpected alternatives more quickly and objectively and allow data to be accessed and rearranged in an unlimited number of patterns. Flexibility and accessibility of data are critical to break stereotypes and spread the importance of using data to make selections.

The considerations of criticism and crop-based materials in this thesis are also highly relevant to current projects in global development. China is currently experiencing rapid turnover of buildings, and developed countries widely consider the practices of Chinese development to be wasteful and unsustainable. The idea of cultural turnover is embedded within Chinese heritage, as "old works must perish so that new ones can take their place."[4] Due to the Chinese proclivity for change, rapidly renewable and biodegradable materials may be ideal for Chinese culture. Rapidly renewable, crop-based materials can provide a great, continuous supply of building materials and lessen concerns of demolition due to the elimination of waste. If sustainable materials can yield sustainable development, developing countries can raise their standards of living without falling into the harmful patterns of past development. Developed countries, such as the United States, also experience high building turnover, and rapidly renewable crops should be explored for these applications as well. Material life spans should align with the desired life of their built structures, making crops a prime possibility to protect the long-term health of human and nonhuman inhabitants.

Lastly, the dangers of dualistic assumptions highlight the need to proceed cautiously with any design decision or intervention. The concept of regimes of (im)perceptibility makes apparent the impossibility of considering all essential factors equally and/or to an extent necessary to make decisions with certainty.[5] Therefore, with any solution, humans must move forward with care, as unintended consequences are not only possible but likely. Bruno Latour, in a keynote lecture to the Design History Society, claims that, while innovations are necessary to adequately tackle the modern challenges humans face, designers must proceed with “modesty, care, precautions, skills, crafts, meanings, [and] attention to details” as prerequisites to design. Guided by a new set of ideals, designers will seek new solutions for global sustainability by remaining “radically careful, or carefully radical.”[6]

Directions for Future Research

This thesis is a preliminary study outlining considerations of material selection for designers to investigate, and material selection is only a single stage in the full design process. Sustainable design is an extensive process, and many details require further research to better understand the benefits and consequences of particular material choices. The majority of this thesis’s research centers around the cognitive barriers to full material consideration. It is critical to recognize that abstract principles have physical consequences, but designers must be able to anticipate these consequences more adequately than this thesis allows. The Punta Cana case study begins to consider more tangible factors of how materials will be shipped, implemented, used, and disposed of at the building site, but these details are limited and lack specific data. As stated in the limitations of this study, further research would be required to ensure the effectiveness of bamboo and a zero waste approach in Punta Cana, including the compilation of data regarding pricing, sourcing, transportation distances and means, wages, production conditions, worker availability, community receptivity, user needs, and more.

Further research is also required to generalize these findings beyond Punta Cana. As previously stated, materials may not inherently violate sustainable principles, but they must fit within the contexts of their application for ecological, social, and economic success. Many crops grow readily and are suited for open-air construction in semi-tropical climates, but what rapidly renewable crops are appropriate to grow and provide shelter in the United

States? What zero waste solutions can be applied in the First World, and what interventions are necessary to make Western lifestyles sustainable? The implementation of crop-based building solutions may be more challenging in the United States due to its temperate climate limiting certain kinds of crop production and creating winter building needs, the complexity of piping, ductwork, wiring, and mechanisms within building systems, and more insistent ideological resistance. In the short term, American builders may need to rely on reuse and recycling of nonrenewables to adequately protect their users and building systems, but builders and material producers should continue to explore crop-based building materials to reduce exterior and interior material waste where needs can be met.

Many crop-based solutions are favorable for zero waste goals due to their minimal use of machinery and fossil fuels in their production. However, nonrenewable fuels consumed in transportation and building use pose complications to sustainable use. Consequently, renewable energy production is a prerequisite to widespread elimination of waste and pollution. Further research is required to develop energy sources that harvest renewable energy, are affordable to the general public, and can be fully biodegraded or recycled using renewable energy at the end of their usable lives.

Additional research is imperative to understand the strengths and limitations of a wider array of materials, particularly those that are rapidly renewable. Geiser claims that current material research is inadequate, lacking monitoring of material stocks, flows, environmental and health effects, and more. Manufacturers and/or governments must track wastes, inventories, and distribution to avoid waste accumulation, material depletion, and quality of life violations.[7] Despite their longest history of use, plant-based materials have the most prominent gaps in data due to their current low utilization in developed countries.

Experiments are required to measure their precise environmental effects, such as quantities of carbon sequestration, structural capabilities, chemical effects on human health, life expectancy and protective measures under various climatic conditions, and more. Appendix F lists numerous biodegradable materials that merit increased investigation to safely pursue their sustainable potential. Only further study can reveal unknown consequences and develop benign resolutions to overcome the shortcomings in production, use, and perception that have prevented more prevalent use of these sustainable alternatives in the past.

Crop-based building materials also necessitate a new field of research to explore and facilitate links between the architectural and agricultural industries. Each sector tends to operate independently, but cross studies of architecture and agriculture could reveal opportunities for environmental, social, and economic benefits. According to Paul Vidal de la Blache, food and architecture are symbolic of society's "genre de vie," or mode of life, joining culture and geography to reveal social character, resource use, economic structure, and global and local meaning.[8] Environmentally, manufacturers must not assume that crops that yield no waste have no negative impacts; it is important to consider the origin of the products in agriculture. Agriculturalists rely on the health of their resources for continued production, but the pressures of cost and competition have caused much of today's agriculture to degrade the land, air, and water to unsustainable levels. Continual crop production, polluting inputs, and overharvesting can cause soil depletion if not properly managed; these pitfalls must be avoided for sustainable production. Therefore, crop-based material production must be considered as an agricultural process, and designers must consult scientific knowledge and local wisdom to ensure ecological stability. Whereas designers previously consulted suppliers primarily for price, transportation, and quality concerns, sustainable designers and agriculturalists become partners in design and must investigate the effects and operations of production to promote environmental symbiosis.

Many questions inspire further agricultural research. Crop production and decomposition can be sustainable operations, but what conditions do crops require to properly sustain and enrich soils? Many organic farmers support growth in polycultures, in which a mix of different crops release and extract various elements to maintain a healthy environmental balance.[9] What crops grow best together? How much should humans tend their crops and with what methods? How do rapidly renewable and biodegradable materials affect larger environmental systems? Designers must recognize the importance of organic farming knowledge for crop-based production, and research must be ongoing to optimize the mix, density, inputs, and yield for new climates and desired materials.

Students must understand the connections of building production to agriculture and ecology as fundamental to their comprehension of design. To further sustainable design, how should educators alter architectural and design education to reflect ecological ways of thinking about building and the extension of designer responsibilities throughout the whole building life cycle? Should students participate in ecology classes to understand ecosystems' mechanisms? Should bionics, the design of systems based on biological systems, become a part of design core curriculum or become a more prominent field of study?[10] Design educators must explore new techniques and topics for education, and their decisions will play a pivotal role to inspire and disseminate further sustainable design research.

Zero waste architecture could also benefit from a reevaluation of spatial needs. Claims that the world's arable land cannot indefinitely support food, fuel, packaging, and architectural production according to current lifestyles are likely to be accurate. According to calculations of ecological footprints, the majority of First World nations demand more resources than the Earth can support in the long term.[11] While the substitution of energy-intensive and nonrenewable resources with crops would support needed reductions, declines in demand should take place in all sectors to ensure continued supply and replenishment of resources. Opponents of biofuels and bioplastics have raised concerns regarding the diversion of crops and land away from food consumption, and the promotion of crop-based architecture would likely raise similar apprehension of increasing hunger and soil depletion.[12] Therefore, it is likely best to use non-food crops for construction, but investigations to reduce resource demands are also desirable.

Designers should research and experiment with space-saving designs to reduce materials demanded from agricultural and industrial production. In *The Not So Big House*, Sarah Susanka describes the reduction of material use as one benefit of smaller buildings.[13] By demanding less crop-based materials, risks of soil depletion from overproduction would be reduced accordingly. By directly seeking to lessen material consumption through building compactly, rapidly renewable and biodegradable materials can avoid the dangers of the rebound, or take-back, effect. According the rebound effect, or Jevon's paradox, behavioral responses to new, and often more efficient, technology often negate the solution's intended benefits.[14] In zero waste architecture, consumers and practitioners may be inclined to use more of the green materials due to their lower environmental impacts; however, their abundant use may negate their sustainability if overproduction reduces soil fertility.

Consequently, material selection alone cannot ensure building sustainability; a variety of factors, including form, scale, organization, and amenities, must be integrated to mitigate impacts of construction, operation, and demolition. In form, zero waste architecture should further reduce its environmental impacts by responding to site and climatic conditions. Structures should take advantage of natural services to lessen the need for ongoing inputs. In addition to material input reduction, compact buildings also reduce operational energy loads and increase personal meaning within spaces.[15] Similarly, spatial adjacencies and layout can minimize energy consumption and improve the interior experience. Therefore, material selection must continue to consider content, quantity, and execution for ecological health, and further research can foster functional and dematerialization efforts.

Many critics claim that zero waste, as presented by McDonough and Braungart's cradle to cradle framework, fails to address this full range of environmental, social, and economic conditions. Environmentally, a primary criticism identifies cradle to cradle design as a means to justify consumerism.[16] McDonough and Braungart recognize the concept of ecological footprint but "see a world of abundance, not limits," claiming to overcome ecological restraints with "good" production.[17] However, even with shifts to zero waste materials and production, it is likely that current, excessive levels of consumption will need to decline to avoid exhausting available land and resources. As cradle to cradle design cannot allow sustainable rates of consumption to exceed rates of regeneration, certain limits remain.

Other challenges have arisen in attempts to implement zero waste, inspiring doubts and further critiques. McDonough Braungart Design Chemistry (MBDC) administers the Cradle to Cradle Certified[CM] program, which rates products' sustainability. However, the program's standards fall short of the full cradle to cradle concept. Products that contain toxic chemicals, produce waste, and are 67% recyclable or biodegradable may achieve Silver ratings. Counter to the inclusive demands described in *Cradle to Cradle*, certification may study only products' ingredients and claims, ignoring byproducts of production, energy of extraction, emissions of recycling, and actual performance. This thesis demands the study of materials within their applications to judge their actual effects; however, Cradle to Cradle Certified^{CM} examines products in isolation, ignoring critical social, economic, and environmental effects. Further concerns appear because, even with relatively loose standards, no products have achieved the highest Platinum level.[18] Some critics take this failure as a sign of zero waste's infeasibility, but bamboo reveals barriers to the certification process, rather than its concepts. MBDC charges $5,000 to $20,000 per product certification; local, small-scale, and affordable production contributes to bamboo's sustainability but also prohibits its abilities to seek certification. MBDC also holds its findings as intellectual property, hindering the sharing and validation of its data and solutions. Due to the current conflicts between profits, control, and widespread implementation, further research is required to bring zero waste to fruition.[19]

As a movement, zero waste will require institutions to support its missions. One of the primary roles of these institutions would include scientific research.[20] Many Third World countries lack environmental data, ecologists, and other scientists necessary to adequately inform their architectural, agricultural, and developmental decisions.[21] Even in the United States, no comprehensive data exists to track material cycles. The United States gathers some national data on material production, almost nothing on the use of materials, and a wide array of disorganized information on wastes and pollutants. As much data is gathered by independent organizations, reliable comparisons are rare.[22] When institutions lack sufficient data to define and monitor their challenges, it is difficult to devise and evaluate appropriate remedies. Therefore, organized research regarding ecology and material flows on a national level should be a priority for zero waste implementation.

Other tasks for institutions include regulation, financing, education, and promotion. Through policy, governments must seek to internalize the costs of materials to provide incentives to create materials with less environmental, economic, and social harms. However, even if adequate data on materials existed, causal connections between policies and results are difficult to establish due to confounding variables. Due to these challenges, extensive research must seek to determine what policies, incentives, take-back programs, and educational initiatives would be most effective in a given area to direct the market toward more sustainable material choices.[23]

While policymaking to manipulate business actions may be difficult, consumer behavior is often far more difficult to influence due to irrationality. This thesis has explored the cognitive barriers that resist the use of more rationally functional and environmental alternatives, but further research is required on the precise methods of changing perceptions and values. What media would be most effective to reach modern audiences and alter their preconceptions of crop-based materials and technologies? The viewpoints in this thesis and subsequent academic research may reach academic audiences, but methods of communication that appeal to the general public might be more effective to enact wider social change in support of sustainability. What language or imagery would be most influential for specific target audiences? Due to these complexities, it can be more challenging to disseminate knowledge than to produce it.[24]

During the rise of social activism and environmentalism, books were popular means of communication. Literary works by Charles Dickens and Upton Sinclair publicized living and working conditions, and Rachel Carson's *Silent Spring* caused widespread concern over chemical toxicities.[25] While books may not be the primary form of entertainment or even intellectual pursuits today, these past successes highlight the promise of engaging the public through popular culture and mass media to spur social activism. The 2006 documentary film *An Inconvenient Truth*, featuring former United States Vice President Al Gore, is a recent example of effective environmental recruitment and discussion through video. The combination of art and science can create intriguing and informative messages; the current fascination with information graphics, or infographics, supports the inclusion of visual and/or interactive features, particularly to communicate complex or numerical data. To demonstrate material capabilities, built examples, such as Vélez's bamboo works, have inspired further interest and use. However, all these marketing efforts must clearly convey the unique added value of the subject presented; for crop-based material, further research should explore ways to emphasize the regenerative aspects that industrial alternatives lack, such as carbon sequestration and biodegradability.[26]

Lastly, all stakeholders, including designers, policy makers, producers, and consumers, must continually explore and evaluate their ethical obligations and rights. Ethics are key to solidify human responsibilities to protect global health and organize complex considerations to create sustainable built environments. Moral codes must be clear in order to guide actions but also be flexible to allow participants to question ethical traditions. The ethics of sustainable building are complicated, requiring further study to regulate tradeoffs between individual comfort and human and nonhuman wellbeing. When should humans challenge their obligations, and when should they change behavior? How should society balance rigid, static order and unchallengeable, relativistic chaos? As values play a significant role in ethics formation, further research should seek to develop a system to identify values in building, examine the formation and diffusion of values among building stakeholders, and document resulting building choices and attitudes over time.[27] With stronger ethics of the built environment, building community stakeholders will be more cognizant of their economic, environmental, and social responsibilities, approach their choices with increased inquiry, and likely embrace the material means that help human society achieve their sustainable goals.

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[15] Susanka and Obolensky, *The Not So Big House : A Blueprint for the Way We Really Live*. 185.
[16] Jeff McIntire-Strasburg, "Robbing the Cradle to Cradle? William McDonough a Saint... And a Sinner," http://blog.sustainablog.org/2008/11/robbing-the-cradle-to-cradle-william-mcdonough-a-saint-and-a-sinner/.
[17] McDonough and Braungart, *Cradle to Cradle : Remaking the Way We Make Things*. 15-16.
[18] Atlee and Roberts, "Cradle to Cradle Certification: A Peek inside MBDC's Black Box."
[19] Danielle Sacks, "Green Guru Gone Wrong: William McDonough," *Fast Company*(November 1, 2008), http://www.fastcompany.com/magazine/130/the-mortal-messiah.html?page=0%2C8.
[20] Murray and Greenpeace, *Zero Waste*. 98.
[21] Adams, *Green Development : Environment and Sustainability in the Third World*. 151.
[22] Geiser, *Materials Matter : Toward a Sustainable Materials Policy*. 164.
[23] Ibid. 185, 376.
[24] Fox, *Ethics and the Built Environment*. 96.
[25] Guha, *Environmentalism : A Global History*. 5.
[26] Imhoff, *Paper or Plastic : Searching for Solutions to an Overpackaged World*. 73.
[27] Fox, *Ethics and the Built Environment*. 168, 212-213.

A P P E N D I C E S

Appendix A

History of material usage and development

Scholars, such as Vitruvius, Laugier, and modern historians, believe the earliest human-made structures utilized organic materials in their construction, claiming the "primitive hut" as the first shelter archetype.[1] Organic materials indicate those deriving directly from living organisms. Erected by Neanderthal nomads around 120,000 B.C., wood, reed, bamboo, wool, and skins served as protection from the elements. These lightweight materials allowed nomadic tribes to carry their houses, and simplistic construction of a sturdy frame eased reassembly. In different locations, each culture developed their own combination of natural materials, including ice in Arctic climates.[2] Building materials were closely tied to local availability and natural cycles, as materials biodegraded after their useful life and were replaced with new crops or game. The appropriateness of early shelters for nomadic lifestyles and local ecology permitted organic frames and coverings to dominate building construction through 5,000 B.C.[3]

While organic materials presented workable solutions in many parts of the world, inhabitants of areas lacking abundant fertile soil likely had few resources to build with beyond mud. The earliest mud structures were built without formwork, or cob style. With experience, builders learned to mix straw or grass with their mud to distribute cracking and drying through walls, floors, and roofing. Formwork later allowed the use of drier soils with greater stability. Subsequent advances included hand-formed blocks and standardized mud bricks. Evidence for sun-dried mud brick dates back to 6,000 B.C. in the Middle East, Egypt, and India;[4] burnt brick, or bricks fired in kilns for greater quality, durability, and water resistance, did not appear in Greece until 400 B.C.[5] Mud houses were particularly suitable for the specific environmental and economic needs of certain regions, such as Nigeria. The use of local knowledge of climate, vegetation, earth, structures, and tools allowed builders to sufficiently combat rain, high humidity, diverse temperatures, and strong winds with mud structures. Climatic attributes defined vernacular architecture; clay and mud slow heating and cooling, which is advantageous in hot climates. In response to limited economic means, mud houses do not require advanced technology or wealth, using only basic pottery techniques and free, community resources.[6]

Where available, thatch dominated as an early roofing method. Thatch roofs used brushwood, grass, bracken, heather, and other vegetable materials, which were held in place with stones, ropes, or poles and interspersed with mud. Only more contemporary applications associate thatch strictly with straw and reed. Styles, finishes, and methods of thatch varied with period and location; simple, original techniques developed into more skilled craft around 750 B.C. The craft explored in roofing applications was co-produced with the weaving of reeds and grasses to make mats and screens. In addition, reeds were bundled for further structural uses as columns, posts, lintels, and arches before stone elements prevailed. Iconic structures, now associated with strength, power, and presence and defined by their use of stone, originally utilized a material that would invert the meaning of columns today.[7]

In addition to the success of organic and mud structures in ancient Egypt, the earliest stone buildings arose in its region around 4,000 B.C. Due to need for copper and bronze tools, such as picks, bars, and wedges, to quarry suitable stone, as well as the massive labor of armies, slaves, and craftsmen, stonework was reserved for palaces, tombs, temples, and monuments of prestige.[8] The symbolic meaning of stone as timeless, rugged, powerful, and impenetrable persisted across time and place, encouraging the use of stonework in Gothic cathedrals and medieval castles. In contrast, the short life cycles of organic and soil-based materials rationalized their lower status for personal dwellings.[9]

Despite the growth of stone in Rome around 0 A.D., the use of wood persisted due to its light weight, speed of construction, and abundant supply. The growth of towns around 1200 A.D., which required quick growth, high density, and narrow, deep, and tall buildings, reinforced the dominance of wood. Even after tragic fires caused stricter buildings regulations, wood still remained prominent in comparison to stone construction. Heavy use caused many of the best wood species to disappear in populated regions. Like stone, wood contributed to the "primitive" connotation of wattle and daub construction; wood veneers, inlays, carvings, and decorations on half-timbered frontage indicated status. In contrast to its origins as primitive hut frames, wood benefited from technological innovations to expand its use. Developments in wind and water power enabled the sawing of trunks lengthwise to manufacture planks and beams. Before metal, wood was the sole source of structural framework, and innovations allowed a standardized wood framework to remain in use through industrialization. While stone cladding and construction required less maintenance than wood due to wood's sensitivity to moisture, wood was often selected as a more economical building solution.[10] Further comparisons of organic, wood, stone, and mud as construction materials are available in Appendix B.

In opposition to its symbolic meaning of strength, stone's tendencies to crack and crumble led to the development of cementitious materials, which were less expensive and less risky.[11] Gypsum plaster was the earliest deliberately manufactured cement, and it was used in the pyramids in Giza. The Romans used concrete around 100 B.C. to construct vaults and domes of superior strength and stability. [12] However, by 1200 A.D., the quality of materials used in cement deteriorated, and the knowledge of burned lime and pozzolana was lost.[13] In comparison to original mud mortars, cements have always been expensive and commonly diluted with cheaper fillers of sand, stone, tile dust, and ashes. Stucco was recognized as a "cheap substitute for dressing and tooling" masonry, with use dating back to the writings of Pliny. Nevertheless, forms of cement and plaster continued to spread to Europe in the Middle Ages. Aesthetic innovations, such as scagliola and sgraffito, created new color and ornamentation.[14] In the 1800s, inventors patented new types of cement, such as Keenes' cement and Portland cement, and formwork for modern applications. Concrete, made from a mixture of cement, sand, aggregate, and water, became a staple of modern architecture, despite its deeply historical roots.[15] However, modern use of concrete did not become widespread until iron mesh was added for stability and was rigorously tested to eliminate structural reservations.[16]

Many materials developed contemporaneously to the described structural materials. Ceramics is one of the oldest material types used by humans, younger only than wood and stone. Like brick, the quality of ceramics improved in accordance with the invention and refinement of kilns, and mechanized mass production greatly reduced their costs.[17] Glass beads also date back to 5,000 B.C., and glass blowing began in Syria around 200 B.C. However, widespread utilization of glass in buildings was limited by technological invention; the rise of glass windows became possible with the replacement of soda glass with potash and the development of sheet glass in the 1000s.[18] Later development of the float glass process, tempering, and laminating improved the span, performance, affordability, and safety of glass for widespread use.[19]

Perhaps most significant for building construction, however, was the development of metals. Despite associations of metals with modern aesthetics, metals have a long history of use. However, like glass, technological interventions were necessary to process the quantities of metals necessary to be feasible on an architectural scale. Copper and its alloy, bronze, were possibly the first metals to be used by humans, serving as plumbing, protective coverings, decorative finishes, structure, and tools around 5,000 B.C.[20] The discovery of smelting allowed large amounts of metals to be extracted and shaped for human ends. Metallurgy flourished throughout antiquity, and gold, silver, tin, iron, lead, and mercury, which with copper are known as "the seven metals of antiquity," likely served similar functional and aesthetic purposes. Later in antiquity, brass and pewter were developed and added to the array of known materials. Zinc, while known for its role in brass production, was not extracted as a metal in the Western world until 1742.[21] Likewise, aluminum compounds were used in ancient Egyptian cosmetics, medicines, and dyes, but aluminum was not extracted as a metal until 1808.[22]

The production of iron expanded in the 14th and 15th century due to the development of the blast furnace, water power, and demands for artillery and cannonballs. Metal began to spread into buildings by use for fasteners, hardware, cladding, fences, and balconies.[23] However, until industrialization, the vast structural members necessary for building construction were prohibitively expensive or impractical using metal.[24] Large-scale iron production began in England in the early 1700s and began to be used in buildings in the 1770s. The newly invented puddling process allowed a single skilled worker to produce a ton of wrought iron each day. Rolling techniques for steel soon followed, and the new Bessemer process removed impurities from iron to improve the properties of both metals.[25] The new production of architectural metal introduced the age of "modern" materials. While metal, concrete, and glass had existed as craft materials for centuries, the new scale and application of these materials within buildings indicated exciting innovation.

The recognition of the capabilities of technology to achieve unique and superior material performance likely contributed to rising interest in synthetic materials. According to Els Zijlstra, the age of synthetics began in 1860 with the development of Bakelite, an early thermoset plastic shaped in molds under high heat and pressure. Over the 20th century, a variety of plastics rapidly developed, including PVC, acrylics, polystyrene, polyester, epoxy, polyamides, silicones, Teflon, polyurethane, polycarbonate, and polypropylene, among others. In the 1950s, the use of plastic in furniture was controversial due to its poor patination relative to natural materials. However, its negative image faded with improved quality, flexibility, and lower costs, making plastic a popular solution for plumbing fixtures, siding, flooring, insulation, panels, and other building applications.[26]

Plastic also marks a trend of modern materials becoming "ultra light and super strong," according to Nicola Stattmann. Composites are currently the fastest growing category of advanced materials, in which material scientists combine materials to yield superior performance characteristics to any of its parts.[27] Similarly, the creation of new alloys and formulas of lightweight concrete seek new combinations of existing materials for improved capabilities.[28] Likewise, high-tech ceramics are harder, stronger, lighter, and more durable than many metals with additional benefits of rust-resistance and temperature-resilience.[29] Each manipulation is targeted to specific demands, including building higher, increasing strength, withstanding heat, or enhancing safety.[30] However, synthetic composition is not a prerequisite to fulfill "strong and light" criteria. Aluminum, magnesium, and bamboo are naturally occurring substances that, with different levels of processing, exhibit extraordinary performance.[31]

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[1] Weston, *Materials, Form and Architecture*. 12.
[2] Zijlstra, *Material Skills : Evolution of Materials*. 6.
[3] Ibid. 6.
[4] Davey, *A History of Building Materials*. 19-22.
[5] Ibid. 66, 69.
[6] Crouch and Johnson, *Traditions in Architecture: Africa, America, Asia, and Oceania*. 26-27.
[7] Davey, *A History of Building Materials*. 49-57.
[8] Ibid. 7, 16.
[9] Zijlstra, *Material Skills : Evolution of Materials*. 42.
[10] Ibid. 6-7.
[11] Ibid. 43.
[12] Davey, *A History of Building Materials*. 92, 122-123.
[13] Zijlstra, *Material Skills : Evolution of Materials*. 48.
[14] Davey, *A History of Building Materials*. 95-96, 112, 120.
[15] Zijlstra, *Material Skills : Evolution of Materials*. 48-49.
[16] Schröpfer and Carpenter, *Material Design : Informing Architecture by Materiality*. 19.
[17] Zijlstra, *Material Skills : Evolution of Materials*. 62.
[18] Ibid. 72.
[19] Weston, *Materials, Form and Architecture*. 32.
[20] Davey, *A History of Building Materials*. 211.
[21] Trivedi, *Materials in Art and Technology*. 29, 37, 55.
[22] Zijlstra, *Material Skills : Evolution of Materials*. 112.
[23] Ibid. 102.
[24] Weston, *Materials, Form and Architecture*. 27.
[25] Ibid. 27.
[26] Zijlstra, *Material Skills : Evolution of Materials*. 126, 127.
[27] Forester, *The Materials Revolution : Superconductors, New Materials, and the Japanese Challenge*. 175.
[28] Davey, *A History of Building Materials*. 219.
[29] Forester, *The Materials Revolution : Superconductors, New Materials, and the Japanese Challenge*. 7.
[30] Davey, *A History of Building Materials*. 219.
[31] Trivedi, *Materials in Art and Technology*. 61.

Appendix B[1]

Table A1. Materials Used for Wall Building.

	Survival	Insulation	Working	Load-bearing	Stability
Light vegetation	poor, prone to biological attack	moderate	easily cut, carried and manipulated	poor	excellent
Timber	moderate, prone to biological attack	moderate	requires heavy tools	moderate	good
Stone	excellent	poor, allows rising damp	difficult unless rock already fractured; laborious	excellent	poor
Mud	moderate, prone to weathering	good, but allows rising damp	easily shaped and manipulated	moderate	poor

Table A2. Materials Used for Roofing.

	Survival	Insulation	Working	Load-bearing	Stability
Pitched roofs—leaves or thatch	moderate	excellent	easy	moderate	moderate
Pitched roofs—shingle, slates	good	poor	easy	good	poor
Flat roofs—mud or bitumen	poor	good	easy	poor	good

From H. W. M. Hodges (1972), reprinted by permission of Schenkman Publishing Company.

[1] Crouch and Johnson, *Traditions in Architecture: Africa, America, Asia, and Oceania*. 384.

Appendix C[1]

Material	Current or proposed use in construction
Straw	Building blocks, masonry walls, thatching
Hemp shives	Stud type construction, insulation
Hemp fibers	Insulation, medium-density fiberboard, oriented strand board, beams, studs, posts
Wool	Roofing insulation
Flax	Roofing insulation
Reed mats	Plastering base
Reed	Thatching
Jute	Carpet, plastering mesh and scrim, wood substitute
Sisal	Carpet, sisal fiber-reinforced cement

[1] Yates, "The Use of Non-Food Crops in the UK Construction Industry." 1791.

Appendix D[1]

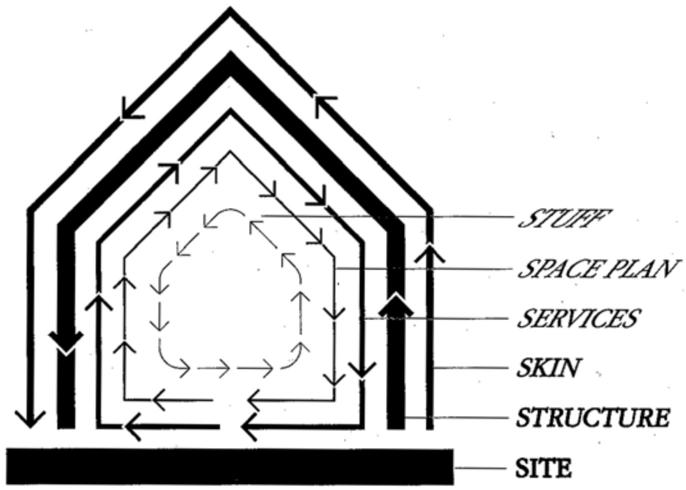
The significance of different elements of Zero Waste strategies to GHG emissions reduction

Design for Environment Strategies	Emission reduction potential (MtCO2e)
Increased feedstock efficiency (less energy intensive processes, reduced losses during materials production)	50 - 100
Increased material efficiency (high strength materials, new alloys, composites, improved quality control to reduce variations in materials quality, reduced waste of materials during production, higher design strength, less material intensive design, materials standardisation)	100 - 200
Increased product efficiency (such as new packaging concepts, car sharing, increased product life, multi functional products)	50 - 150
Materials recycling/energy recovery (mainly plastics recycling)	100 - 200
Product reuse (renovation of buildings, design for disassembly)	25 - 50
Feedstock substitution (biomass feedstocks for plastics, solvents, fibres)	50 - 100
Materials substitution (renewable materials, less CO2 intensive materials, materials with improved physical characteristics, recyclable materials, material innovations and substitution leading to emission reductions in the use phase of vehicles and buildings)	200 - 300
Product substitution (product service concepts, less material-intensive products, products requiring less maintenance, long life products)	100 - 200
Total	675 - 1300

Source: Gielen, Kram and Brezet (1999)

[1] Murray and Greenpeace, *Zero Waste*. 166.

Appendix E[1]



SHEARING LAYERS OF CHANGE. Because of the different rates of change of its components, a building is always tearing itself apart.

[1] Brand, *How Buildings Learn : What Happens after They're Built*. 13.

Appendix F[1]

LIST OF NATURAL AND NON-CONVENTIONAL CONSTRUCTION MATERIALS		
STRUCTURE / ENVELOPE / PARTITIONS		
Earth	Rammed Earth, Pisé	Super Adobe, Superadobe
	Pneumatically Impacted Stabilized Earth (PISÉ), Shot Earth	Earth Filled Tires, Earthships
	Poured Earth	Compressed Earth Blocks (CEB)
	Soil Cement	Cob
	Adobe, Chirpici	Expanded Clay Pellets
Earth / Vegetal	Wattle and Daub	Light Straw Clay
Vegetal	Straw Bales	Bamboo
	Reed Board	Cordwood
	Logs	Wood Frame (FSC Wood)
ROOFING		
Vegetal	Green Roof	Thatch
	Palm Tree	Wood Shingles
	Seagrass	
INSULATION		
Vegetal	Wood Fiber Insulation Board	Coconut
	Flax, Hemp	Cork
	Cobwood, Sawdust, and Lime	Seagrass
	Cellulose	
Animal	Sheep Wool	
PLASTER AND PAINT		
Earth	Clay Plaster	Loam Plaster
	Mud Plaster	Clay Paint
Animal	Casein, Milk Paint	
DECORATION / FINISHING		
Earth	Clay Board	
Vegetal	Coir	Jute
	Sisal	Reed Mat and Board
	Coconut	Linoleum

[1] G. Fabre, "List of Natural and Non-Conventional Construction Materials," (March 2010).

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