I, Erica F Stauffer, hereby submit this original work as part of the requirements for the degree of Master of Architecture in Architecture (Master of).

It is entitled: Reinterpreting Skins and Systems: Integrating Smart Materials with Traditional Construction

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Reinterpreting Skins and Systems: Integrating Smart Materials with Traditional Construction

A thesis submitted to the Graduate School of the University of Cincinnati in partial fulfillment of the requirements for the degree of

Master of Architecture

in the School of Architecture and Interior Design of the College of Design, Architecture, Art, and Planning

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Abstract

We have entered a period in history where the amount of existing building stock available for renovation is becoming equal to new construction. Yet there is currently little attempt in the profession to integrate the technologies of today with the existing buildings of tomorrow. On one hand, we acknowledge that we cannot simply keep building new buildings; we must find ways to effectively use what we already have. On the other hand, we continue to find ways to design new sustainable buildings that extend beyond just energy efficiency with innovative technologies. Either we engineer the most sustainable building with the most cutting edge techniques using smart materials and renewable energies; or we find ways to adaptively reuse what exists but rarely do the two camps overlap.

However, the situation of forcing the two positions together is a sticky one. The appropriateness of intervening in Historic structures has been debated long before the topic of sustainability became popular. Since 1977, when The Secretary of the Interior’s Standards were issued, the means by which we reuse an existing structure have been monitored. The interpretation of these standards, have made it difficult to make an existing historic structure efficient enough to sustain its operating costs. Yet, the irony of the situation is that when we talk about the larger picture of sustainability all arrows point to reuse as the answer. Urban density and connectivity, embodied energy, and the social and cultural value of a historic building make it a model example of sustainable development.

In the materials science and engineering world, advancements in smart materials and systems are being made, which begin to address the true nature of sustainability. Not just energy efficiency, but creating closed-loop systems and utilizing smart materials. However, it is not often that these materials and technologies are designed for existing structures or communities. Not only do the aesthetics of the products not fit, but at a very preliminary level they are not designed with retrofitting in mind.

In many ways, the disconnect between the innovation of materials and problems within the building industry, is due to a lack of collaboration between disciplines. Designers do not fully understand the capacity of new materials and technologies, and engineers continue to innovate without understanding the applications of their innovations. In order to create places that encourage this type of collaboration we need to design with
Abstract

dynamic workspaces in mind.

As a framework for my research I will discuss the current views and obstacles with preservation, the history of building materials, smart materials and technologies and their dynamic capabilities, and adaptable and collaborative programs in the contemporary work place. From these four areas I will develop a methodology for categorizing and selecting the appropriate smart material for a given situation. This methodology will then be applied to historic structure in Over the Rhine as a case study for integrating smart materials and technologies with traditional construction. The program for the case study will be a research and development center for new materials.
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Introduction
Reinterpreting Skins and Systems

Introductions

“Taking into account demolition, rebuilding, and overall growth about 50% of the building stock in 2050 will consist of buildings that exist today.” (1)

-Steve Barrows

I recently received Grimshaw’s second publication of “Blue” in the mail. Blue 02: Systems and Structures, is their second in a series of publications dedicated to architecture, as it faces various environmental issues. The projects they chose to illustrate largely consist of technological innovations and buildings that are sculpted from cutting edge materials, structures, and systems. There is only one adaptive reuse project that is showcased. A hypothetical diagram of building an additional exterior façade on an existing building and creating a “winter garden corridor.” (2) The project’s introduction page shouts in bold 36 point font, “Taking into account demolition, rebuilding, and overall growth about 50% of the building stock of 2050 will consist of buildings that exist today.” (3) Yet there is no attempt in the issue to integrate the technologies of today with the existing buildings of tomorrow.

There seems to be a reoccurring theme emerging in the profession. On one hand, we acknowledge that we cannot simply keep building new buildings; we must find ways to effectively use what we already have. On the other hand, we continue to find ways to design new sustainable buildings that extend beyond just energy efficiency with innovative technologies. The two approaches to solving our environmental dilemmas tend to separate like oil and water. Either we engineer the most sustainable building with the most cutting edge techniques using smart materials, biology, and renewable energies; or we find ways to adaptively reuse what exists by adding extra insulation and new mechanical systems, but rarely do the two camps overlap.

However, the situation of forcing the two positions together is a sticky one. The appropriateness of intervening in Historic structures has been debated long before the topic of sustainability ever came into the picture. Since 1977, when The Secretary of the Interior’s Standards were issued, the means

(1) qtd. in Whaley, Blue 02 Systems and Structure, 37.
(2) Whaley, Blue 02 Systems and Structure, 40.
(3) qtd. in Whaley, Andrew Blue 02 Systems and Structure, 37.
and methods by which we reuse an existing structure have been monitored. The interpretation of 
these Standards, in many cases, have made it difficult - even with traditional technologies and building 
materials - to make an existing historic structure efficient enough to sustain its operating costs. Yet, the 
irony of the situation is that when we talk about the larger picture of sustainability all arrows point to 
reuse as the answer. Urban density and connectivity, embodied energy, and the social and cultural value 
of a historic building make it a model example of sustainable development.

On the other side of the spectrum in the materials science and engineering world, advancements 
in smart materials and systems are being made, which begin to address the true nature of sustainability. 
Not just energy efficiency, but creating closed loop systems, smart materials that self assemble and grow, 
and finding ways to live and learn from nature. However, it is not often, if ever that these materials and 
technologies are designed for existing structures or communities. Not only do the aesthetics of the products not fit, but at a very preliminary level they are not designed with retrofitting or older building materials in mind.

In many ways, this disconnect between the innovation of materials and problems within 
the building industry is due to a lack of collaboration between disciplines. Designers do not fully 
understand the capacity of new materials and technologies, and engineers continue to innovate without 
understanding the applications of their innovations. In order to create places that encourage this type of 
collaboration we need to design with dynamic work spaces in mind. This includes overlapping research, 
design, and business professionals that can take an idea from concept to realization by working together.

I was quite surprised when I found the word “biomimicry” in the index of Jean Carroon’s book, 
Sustainable Preservation: Greening Existing Buildings. While the reference only appeared once as a 
definition, it gave me hope that maybe the two positions on sustainability were not completely alien to 
one another. While I didn't find the terms “adaptive reuse” or “historic renovation” in Jane Benysus’s 
Biomimicry; Innovation Inspired by Nature, I did stumble across this quote: “At first it was hard to see that 
we were fouling our own nest – we keep expanding into fresh new territory and leaving our tired land
and waters behind.” (2) I had a sneaking suspicion that if Jane were rewriting her book today after some of her recent work in the architectural field she might consider using the phrase “tired land, water, and buildings behind” (3) instead.

As a framework for my research I will discuss the current views and obstacles with preservation, the history of building materials and how these materials’ properties have transformed architecture over time, smart materials and technologies and their dynamic capabilities, and adaptable and collaborative programs in the contemporary work place. From these four areas I will develop a methodology for categorizing and selecting the appropriate smart material for a given situation. This methodology will then be applied to historic structure in Over the Rhine as a case study for integrating smart materials and technologies with traditional construction. The program for the case study will be a research and development center for new materials.

(2) Benysus, Biomimicry: Innovation Inspired by Nature 45.
(3) Benysus, Biomimicry: Innovation Inspired by Nature 45.
Chapter 1

Attitudes
Current Views on Preservation and Reuse

“The topic of sustainable development has moved from the sidelines to center stage in discussions about climate change, social equity, and economic prosperity. This focus on sustainability has enormous implications for historic preservation. It challenges us to think in new ways about the processes by which we decide what to protect and how to protect it, and about the vital role our historic resources can play in reducing our impact on the environment”(4)

-Richard Moe, President Emeritus National Trust for Historic Preservation

We have reached a point in our history where several issues are changing the way that we perceive the historical context. First, there is an ever-increasing emphasis on how the environmental impact of our designs determines the feasibility of a project. This is especially critical in terms of adaptive reuse and historic preservation. There is now an emphasis on finding a balance in how we tackle historic and environmental issues. Secondly, aesthetic and material mimicry as a strategy for historic preservation is no longer socially or culturally relevant. The interpretation of historic guidelines is starting to shift away from the literal, to finding deeper meanings in history. Architects must look for new ways of reinterpreting history in an abstract manner that displays respect to the context but also contributes a new perspective. Finally, this argument towards a more abstract representation of history has been propelled by the material history of architecture. We once designed with a very limited palette of predictable materials, which gave rise to the emphasis of defining typology through form. Today, we have boundless materials with capabilities that were not even imaginable a hundred years ago.

Jean Carroons recent book Sustainable Preservation: Greening Existing Buildings, is a comprehensive guide to the issues, tools, and guidelines in sustainable preservation. Everything, from the history of historic preservation to reducing and shifting electrical loads in existing buildings is discussed.

(4) qtd. in Carroon, Sustainable Preservation: Greening Existing Buildings 21.
Of particular importance are her chapters where she focuses on making a case for the “historically green,” describing “what makes existing buildings green,” and how to tackle the balancing act between historic and green design guidelines. While she respects the significance of The Secretary of the Interior’s Standards, she argues that in many cases they are widely misunderstood and that they are intended to provide a “philosophical consistency,” (5) rather than a concrete set of rules. She states that, “the standards and guidelines are intended to promote responsible preservation practices, but they are neither technical nor prescriptive.”(5) Furthermore that “in and of themselves (The Secretary of Interior’s Standards) cannot be used to make essential decisions about which features of the historic building should be saved and which can be changed.”(5) Bottom line, Jean Carroon is about saving buildings and bringing them into the 21st century while having a respect for their original character. However while she does present multiple case studies on various environmental issues, she does not present a theory on how to design for balancing historic character with modern day materials and innovations.

In Kate Lemos’s paper, Defining Context: Promoting a Greater Level of Innovation in New Design within Historic Districts, presented at the Third National Forum on Preservation Practice; A Critical Look at Design in Historic Preservation, she argues that “visual compatibility is not the only way that a new design can relate to historic character.”(6) Instead she states that, “there are many levels of meaning embedded in the historic fabric which allow endless possibilities for interpretation resulting in novelty and innovation in new designs.”(6) She argues that an abstract design that delves deeper into the contextual meaning of the place where the building exists is a much richer design than one that merely mimics the kit of parts of the existing architecture. “It is time to embrace a paradigm shift from protecting to enhancing their (historic buildings) aesthetic quality and preserving the authenticity of both old and new.”(8)

The time for mimicry in historic renovation and adaptive reuse is over. It has become an aesthetically as well as an environmentally unacceptable practice. We must look for new abstract ways of representing history that express the deeper meaning that Kate Lemos refers to. Furthermore, there has

(5) Carroon, Sustainable Preservation: Greening Existing Buildings 96.
(6) Lemos, Defining Context: Promoting a Greater Level of Innovation in New Design within Historic Districts 32.
(7) Lemos, Defining Context: Promoting a Greater Level of Innovation in New Design within Historic Districts 40.
recently been a renewed interest in the materiality of architecture, a movement that attempts to look at the “material history” of architecture instead of only looking at the history of form. Andrew Benjamin in his essay, Plans to Matter, argues that by understanding materials and material history in architecture we can open up a whole new potential of design possibilities. First, by better understanding “the potential of a given material.” (8) Second, “informing how we can utilize the properties of one material to open up the architectural possibilities within other materials.” (8) Finally, “allowing drawings or diagrams to suggest spatial relations given through material possibilities as opposed to form creation.” (8)

New strategies and design principles for adaptive reuse and historic preservation can be formulated through an understanding of a material and tectonic history of architecture. First, we must understand the historic palette of materials. The properties of these materials are largely what gave rise to the methods of construction and joinery that created the historical structures that we have today. Secondly, we need to understand how that palette of materials changed over time. With the development of new systems and materials the enhanced properties and capabilities of the architectural palette led to the creation of very different types of structures. This development continues today with smart materials and intelligent systems that have added a dynamic and interactive potential for design. In order to “utilize the potential of (new) materials to open up the architectural possibilities of (historic) materials,”(9) we must understand the history of materials in architecture. By looking back we will be able to reinterpret old systems and move forward with new designs.

(8) Benjamin, Plans to Matter, 17.
(9) Benjamin, Plans to Matter, 25.
“By understanding materials and material history we can open up a whole new potential of design possibilities. By better understanding the potential of a given material we can open up architectural possibilities in a new material.” (10)

-Andrew Benjamin

The materiality of built form and the extent of materials that designers now have at their disposal has changed quite drastically over time. Ancient civilizations built primarily with primitive ceramics, wood, and various textiles. While the possibilities and options of ceramics grew through the centuries, this palette remained relatively similar until the industrial revolution and the refinement of steel. It has only been within the last one hundred years that other metals such as aluminum were introduced on a large scale to buildings. Additionally, it has also been within the last century that polymers and many of the composite materials that we work with today have been incorporated into the construction industry. Finally, within the last ten years there has been an explosion of new smart materials and systems that add a whole new level to material property; one of dynamic real-time interaction.

The use of ceramics in construction dates back to the time of the Pharoahs in Egypt and beyond. Ceramics, specifically fired clays and stone, were the building blocks of many ancient civilizations. With the development of concrete and glass, the world of ceramics continues today to be a very important section of materials that we can choose to build with. Use of ceramics in traditional construction came with massive load bearing walls that were the primary structure as well as an environmental barrier. The type of layered construction that is typical in buildings today is a large departure from these traditional methods. In most cases stone, brick, and other ceramics are used as facing or veneer materials that give the appearance of traditional construction methods, but fit within our contemporary layered systems. Ceramics are known for their “high strength and low ductility, which necessitates careful attention to loading conditions and detail faces with other materials.” (11) Additionally, ceramics are “prone to sudden

(10) Benjamin, Plans to Matter, 25.
failure due to crack propogation.” (12) The material properties of ceramics and the types of construction that they are used in are important to understand when looking at adaptive reuse and historic preservation. Understanding how these materials behave in different conditions and in respect to other materials is crucial for the design.

There are several metals that were used in ancient times alongside ceramics, dating back to the discovery of bronze in 3500BC, and the discovery of iron in 1500BC. However, the significant use of metals in the building industry started with the refinement of steel and the industrial revolution. In

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Figure 1.0: Timeline of the introduction of different material families in construction. (12)
1850, the Kelly and Bessmer processes were discovered as a way of removing impurities from steel. This new and improved material allowed designers to span great distances that they had never dreamed of distances that they had never dreamed of with the limitations of ceramics. Additionally, Aluminum was discovered around the same time in 1808. However, it wasn’t until the 1920’s that aluminum was used in construction.

“Per unit volume more polymer resin is consumed today than steel, aluminum, and copper combined.”(13) During the 1800’s there were several industrial experimentations and applications of natural polymers such as that of Charles Goodyear and his Goodyear tires. However, it was not until 1908 that the first truly synthetic polymer was developed; Bakelite. Through the early 1900’s several different polymers were developed such as Neoprene, many of them were used initially as materials in the field of industrial design. Slowly but surely, polymers began to infiltrate into the construction industry through detailed products and finishes. Polymers, more than any other material class, have sprung from materials science research. The rapid development of polymers and their proliferation into almost every market describes “the sustained drive for new materials during the last 100 years and the indisputable evidence of the irreversible symbiosis between scientific research and the commercial enterprise.” (14) Smart materials and systems continue this trend of research driving the innovation and creation of new materials.

Part 3: A Material History of Architecture: Influences on Design

“There exists a dynamic exchange between the life of matter and the matter of our lives.” (15)

- Reiser and Unemeto

Reiser and Unemeto in their Atlas of Novel Tectonics, argue for a “materialist” view of architecture. They present a series of specific “conditions and cases,” that “suggests a way of operating in the profession.” They assert that “there exists a dynamic exchange between the life of matter and the matter of our lives.” (15) They believe that the means and methods by which we design along with the materials that we choose to design with should be expressed in the architecture itself. However, this does not mean that the architecture of today needs to be “literally animate.” Instead they argue that the “substance, scales, transitions and measurements should be marked by the dilations and contractions of the energy field.” (16) Simply put, they believe that each material has its own unique way of acting and reacting with its environment, and that that reaction should be appropriately expressed in each condition. Whether this expression is through scale, patterns, joinery, or structural expression depends on the nature of the material itself. Furthermore, materials should not be selected just because of the way that they perform, but that the condition of the site and the locality should be evaluated before the appropriate selection of materials is made. Yet, they do not believe that we need to be scientists or engineers to design with the complexity of today’s innovative materials but that we need a basic understanding of how that material works and reacts with other materials. “The chef does not need to understand the biological makeup of an egg to cook a great omelet.” (17)

One example of this Materialist point of view can be seen in the Parco della Musica Auditoria in Rome, Italy. The project, designed by the Renzo Piano Building Workshop in 2002, consists of three separate concert halls that were “designed with specific acoustic and functional qualities, and with differently sized and shaped curved outlines, reminiscent of boats in form and construction.” (18) On the exterior the building is constructed out of timber framing that is then wrapped in “traditional

Roman lead roofing.” On the interiors, a warm palette of local materials was chosen for their high acoustic performance. The innovative use of the lead and timber framing system in a contemporary form showcases how tectonics can provide a framework for exploring new potentials for materiality and joinery. Additionally, the way that this project attempts to speak to the history of the place through forms and materials starts to “delve deeper” into the abstract interpretation of historic fabric that Kate Lemos discusses. While the Parco della Musica project is a great example of tectonics and regionalism, it solves the problem of using traditional materials in a new way, but what if we want to design with new materials in a traditional context?

How can we gain enough understanding of these innovations to effectively utilize them and translate them into architecture? Jane Benysus’s book, Biomimicry: Innovation Inspired by Nature, starts to look at sustainable materials by asking a simple question: How would nature do it? When it comes to materials, Benysus has defined “four tricks of the trade,” that nature uses in its manufacturing process. These include “life-friendly manufacturing processes, an ordered hierarchy of structures, self-assembly, and templating of crystals and proteins.”(19) She does not believe in merely “copying down the angles and the architectures of natures designs,” but instead she suggests that we “build materials in natures image.”(20) One of the many architectural applications that she discusses in her book involves the use of ferritin, “a protein that sequesters iron oxide in our bodies, leading to crystallization.”(21) When applying ferritin to flexible polymers we could potentially stiffen them with inorganic crystals resulting in an extremely hard yet flexible transparent material. “Imagine a living room window that is as rigid as glass, yet able to bend and bounce back when assaulted by your neighbor kid’s ball.”(22) As architects we do not necessarily need to understand the chemical makeup of materials such as the “ferritin polymer window,” but we do need to understand the potential and the implications that these materials have for design.

Performative wood, a system developed by Achim Menges looks at the biological properties of wood and investigates the way that a pinecone performs in nature. “Spruce pinecones can open and close time and again due to changes in moisture content of the material and in reaction to relative humidity of the environment.” (23) The interesting quality about the pinecone is that this opening and closing is a

(20) Benysus, Biomimicry: Innovation Inspired by Nature 100.
(23) Menges, Performative Wood: Integral Computational Design for a Climate-Responsive Timber Surface Structure. 550
“behavioral response that is latent in the material.” “The system works without any contact with the tree and the opening and closure can be repeated over a large number of cycles without material fatigue.”(24)

Based on the pinecone’s natural design, Menges developed a series of wood veneers that behaved in the same way. He then investigated and used the thermodynamic behavior of the veneers open and closed states to develop a surface that can perform as a pinecone does for a building skin. The interpretation that Menges used to develop his skin and the application of the behavioral properties of the material to develop the design is a model example of using biomimicry in combination with architectonic theory to develop smart materials applicable to the built environment.

The considerations and concerns of adaptive reuse have been changing due to environmental, economic, and social factors of the time. In addition, there has been a rapid development of new materials in the last century that stems from the same underlying factors. Understanding the historical context and the current attitudes in adaptive reuse and historic preservation, along with a knowledge of material history can lead us to new designs that combine adaptive reuse principles with new materials. However, to exploit the possibilities of new smart materials we must have a basic knowledge of their properties and capabilities so that we can choose the appropriate technologies for different applications. Once we understand the potential of these materials we can begin to find ways to articulate and create systems that can express the tectonic nature of the design.

(24) Menges, Performative Wood: Integral Computational Design for a Climate-Responsive Timber Surface Structure. 549
Figure 1.5 Performative Wood System Image (24)
Figure 1.5 Pinecone Image (23)
Figure 1.6 - 1.14 Performative Wood System Image (24)
Chapter 2
Smart Materials and Technologies
Part 3:  

Smart Materials: An Introduction to the Atomic Level

“Regardless of the classification system used, designers must be exposed to the essential determinants of material behavior. Knowledge of atomic and molecular structure is essential to understanding the intrinsic properties of any material, and particularly so for smart materials.” (25)

-Michelle Addington

Before the discussion of the properties and applications of smart materials can begin it is important to understand what we define as a “smart material.” Michelle Addington and Daniel Schodek in their book, Smart Materials and Technologies for the Architecture and Design Professions, define smart materials as; “highly engineered materials that respond intelligently to their environments.” (26) They also discuss a series of common characteristics of smart materials including; “immediacy, transciency, self-actuation, selectivity, and directness.” (27) The introduction of these materials changes the whole ball game when it comes to the selection of materials for the built environment. As designers, we tend to choose materials pragmatically, for their utility and availability, or formally, for their appearance and ornamentation. In the case of smart materials we can start to design with transient needs in mind. How do we want a building to respond and react to various stimuli in real time?

In discussing the properties of smart materials it is important to recognize the difference between intrinsic and extrinsic qualities. Intrinsic qualities are those that are “dependent on the internal structure and composition of the material.” (28) Extrinsic are those that are dependent on “energy transformation functions.” (29) In other words, an intrinsic material reaction is one that involves the transformation of one or more of the materials properties in response to external stimuli. These type of transformations result in a chemical, mechanical, electrical, magnetic, or thermal response and are primarily related to advancements in the field of nanotechnology. An extrinsic change, involves a material that can transform energy from one form to an output energy in another form, such as a photovoltaic cell. To fully understand the principles of intrinsic properties, especially when it comes to nanostructured smart materials, we

(26) Addington, Smart Materials and Technologies, for Architecture and the Design Professions. 9.
(27) Addington, Smart Materials and Technologies, for Architecture and the Design Professions. 10.
(28) Addington, Smart Materials and Technologies, for Architecture and the Design Professions. 38.
(29) Addington, Smart Materials and Technologies, for Architecture and the Design Professions. 39.
Properties:

DEFINITION: The transformation of one or more of the materials properties in response to external stimuli

EXAMPLES: color changing, phase changing, heat capture

INTRINSIC

DEFINITION: A material that can transform energy from one form to another

EXAMPLES: photovoltaics, thermoelectric materials, LEDs

EXTRINSIC

An Introduction to the atomic level: Bonding

- Ionic - One atom transfers electrons to another to form charged ions
- Covalent - Two atoms locally “share electrons”
- Metallic - Same concept as covalent, but are shared between more than just two atoms
- Van Der Wahls- bonding between molecules

Figure 2.0 Individual Properties Diagram (30) (30) Fernandez, Material Architecture, Emergent Materials for Innovative Buildings and Ecological Construction, 90.
must have a basic understanding of the atomic structure of materials.

The three most basic types of atomic bonding are ionic bonding, covalent bonding and metallic bonding. In ionic bonding, “one atom transfers electrons to another to form charged ions.”(30) In covalent bonding, “two atoms locally share electrons.”(30) Metallic bonds are similar to covalent bonds, but the sharing of electrons occurs in a “non-localized, non-directional nature.”(30) What this translates to is that electrons are not shared between two atoms like they are in covalent bonds. They are shared by multiple atoms and are free to move about. The Van Der Wahls bond, while not as common as the first three types, is a type of bonding that is very pertinent to materials science. In a Van der Wahls bond, a covalent bond forms between molecules instead of atoms. What is important to understand is not the exact science of how this bond is formed, but that Van Der Wahls bonds because of their weak nature allow for the breaking and reforming of materials.

The question is what does this have to do with architecture and material selection? For example, on a very basic level understanding what types of materials are formed by covalent bonds gives the designer immediate insight into the material. The very atomic nature of the material means several things. First, the material is a very good conductor of heat and electricity compared to ionic and covalently bonded materials because of the freedom of the electrons. Secondly, the atomic structure also speaks to the strength and ductility of the material. In materials that we have been using for thousands of years such as ceramics, we have already become familiar with these properties. However, beginning to understand how materials react on an atomic level can give us insight into new design solutions. Additionally, in new materials that are not widely used it is important to understand the underlying compositional structure so we can design with specific reactions and behaviors in mind.

If we return to the discussion of the classification and history of materials we can start to draw several informative parallels about the use of these materials in the built world and their compositional makeup. First, metals are materials that are classified by metallic bonds. Explaining the high strength and ductility as well as the conductive properties of heat and electricity. Secondly, Ceramics are

(31) Addington, Smart Materials and Technologies, for Architecture and the Design Professions, 33.
“polycrystalline” materials that are based on ionic and covalent bonds. The atomic makeup explains their high strength, low ductility, and insulative properties. Finally, polymers are “molecular structures that are covalently bonded through the Van Der Wahls bond.” (32) This structure explains the ability that polymers have to be melted and reformed and the low strength and high ductility properties.

Figure 2.0 Individual Properties Diagram (30)
Figure 2.1 Material Family Diagram (33)

Smart materials can provide several advantages in architectural applications that were never available before. Addington and Schodek organize these advantages into two different categories, property change and energy exchange, depending on the previously discussed intrinsic or extrinsic reactions. Property change materials include a wide range of products including chromic or color changing materials, phase-changing materials that can capture and release energy and advance polymers that have conductive and heat emitting capabilities. Energy exchange materials include materials such as photovoltaics, LED’s, transitors, and thermoelectric materials. They also discuss a range of different sensors and systems that incorporate two or more of these technologies. From a design perspective we can organize these materials phenomenologically by the different types of environments that they affect; the luminous environment, the thermal environment, the acoustic environment, and the kinetic environment.

Currently, many of the applications of smart materials in the built environment come in terms of façade systems or products that can be applied and molded into typical building conventions. Additionally, many applications have been experimented with in terms of lighting possibilities with LED’s and fiber optics. Yet, the true potential of smart materials and systems has not been exploited from a design standpoint. The dynamic properties of these materials challenges us to think in new ways about the physical boundary versus the environmental boundary, and how we can design systems that are impermanent or reversible. Instead of thinking of facades and building skins in planes of permanently applied materials, we can start to think of them as multi-state conditions that can change over time due to the changing conditions of the environment and the use of the building.

The potential of these materials lend themselves to new possibilities for solving issues with

adaptive reuse. Specifically, in terms of creating interventions in existing buildings that are impermanent or reversible, finding ways to organize programmatic elements through environmental considerations instead of programmatic, and creating new ways of layering onto existing construction. At a very conceptual level, smart materials allow designers to think of the adaptivity of their designs in terms of environments and function and how they can change over time, which are primary concerns for adaptive reuse and adaptable and collaborative programs in the contemporary work place.

Figure 2.2 Smart Material Diagram Intrinsic vs. Extrinsic (35)
There are certain characteristics and properties that stem from the molecular structure of a given material. This holds true for all materials, whether they have been deemed “smart” or not. The key difference between a “normal” material and a “smart” material lies in a material’s ability to interact with and transform the perceived human environment. It is important to note the word perceived when discussing the phenomenological aspects of the human environment. Michelle Addington’s more recent work following her book Smart Materials and Technologies, has resulted in the formulation of an equation that defines the variables that make up the environments that we perceive around us.

**PHYSICAL PHENOMENON X MATERIAL PROPERTIES = PERCEIVED HUMAN ENVIRONMENT**

Physical Phenomenon such as light, thermal, and kinetic energy, interact with a certain material’s given properties and voila! We have the perceived human environment. Of course, the typical human environment is a complex situation with multiple physical phenomenon and materials interacting all at the same time. However, if we can isolate specific phenomenon and the material which it is interacting with, then we can begin to make more informed decisions about how the material will perform in a given situation.

For example, imagine yourself in a white box. Now someone turns the lights on. Even in this extremely simple environment, there are many different possible perceptions dependent upon the level and type of lighting, as well as the materials on the walls. A naturally lit room with cloth panelling, is going to be a much different experience than a room with flourescent lighting and a high gloss finish on the walls.

While this formula is useful for all materials, it is especially useful when working with smart materials. Smart materials have the capacity to capture energy, transform physical phenomenon, or transform their own internal properties when exposed to certain physical phenomenon. These behaviors
or effects that are exhibited happen at a molecular level, but we experience them through shifts and changes in physical phenomenon. In many cases, there are multiple materials that exhibit a particular effect or behavior. Additionally, there are often multiple available products for each material that exhibits the effect slightly differently. Therefore, when a designer is handed a catalogue of “smart” products, it can be very difficult to decipher what a product is actually useful for. While there are thousands of smart products available on the market today, there only a handful of smart behaviors and physical phenomenon that are relevant to the design of the human environment. When we begin to design with smart materials we need to first understand the types of physical phenomenon that we are working with and how we wish to manipulate the environment with selected materials to achieve the desired outcome. Furthermore, smart materials should be organized by the type of behavior that they exhibit and the type of physical phenomenon that they manipulate or transform. Once this is achieved we can start to formulate a method for selecting materials based on the situation that we want to apply them to.

1) Define the type of physical phenomenon or the type of behavior that is desired to work with, based on programmatic, climatic, or aesthetic considerations.

2) Investigate the available materials and gain an understanding of limitations/advantages of each material.

3) Once the appropriate material is selected, investigate the available products and make selections based on economical and aesthetic considerations.

4) Smart materials have the ability to transform /exchange energy. The design and articulation of each material and product should articulate this exchange, through scale, orientation, or aesthetic considerations.
Based on considerations involving the dynamic program that I am working with and the limitations of applying certain technologies to historic structures, I have selected three specific effects to work with; piezoelectricity, shape memory alloys, and printable solar. The specific programmatic elements of the building and the articulation and design of each material will be addressed in the design portion of my thesis. However, it is important to introduce these behaviors and the physical phenomenon that they involve before the application of each material can be developed. Both the piezoelectric effect and shape memory alloys, involve the transformation of kinetic energy which will have applications in the interior of my building and the transformation of spaces to accommodate various programmatic elements. The printable solar, will be investigated as an external application. The material was selected due to the structural and economical limitations of applying technologies such as solar power to adaptive reuse projects.

**PIEZOELECTRIC EFFECT**

The term piezo is greek for pressure. Piezoelectricity is simply explained as pressure electricity, or the generation of an electrical charge due to a mechanical deformation or applied pressure to a material. There are several different types of materials that exhibit this effect, that stems from the crystalline structure of each material. Materials ranging from certain ceramics to silicon exhibit the piezoelectric effect, each material has different limitations and different ranges in the amount of energy that it is generated per unit of pressure applied. There is a certain understanding of the effect that needs to be ascertained before the appropriate selection of a specific material can be made.

The output energy is proportional to the amount of stress applied to the material. Therefore, if we
take a square of piezoelectric silicon 1 inch X 1 inch X .05 inch thick. Then there will be a much higher output of energy generated from bending the material and straining the cross sectional area of the silicon rather than applying pressure directly to the material and stressing the larger area. Additionally, most materials that exhibit the piezoelectric effect exhibit directionality. In other words, if we bend the material in one direction we will get a negative charge, if we bend it back in the opposite direction then we will produce a positive charge.

Understanding the basics of the effect and the energy inputs and outputs involved is extremely important when attempting to achieve an effective design. The fact that stressing a smaller cross sectional area of the material produces a larger voltage has very specific implications for the scale of the material that we want to work with and the type of movement that we want to capture. For example, designing a tactile wall with thousands of piezoelectric tablets that can vibrate back and forth when an individual is moving through the space has the potential to develop a much larger charge than a flooring application that captures the pressure of an individual walking on top of it. Additionally, the directional nature of the material means that if we can create a design in which the tablet essentially vibrates back and forth, then we can begin to create an alternating current rather than a individual charge. Throughout my design iterations I will develop applications for an exterior facade application that generates a charge from the capture of wind energy, a flooring application that creates an aesthetic expression of the movement that is occurring within the building, and a wall application that allows the transformation of spatial elements in conjunction with the movement of individuals within the space.
SHAPE MEMORY ALLOY

Shape memory alloys are already used in multiple everyday products that we overlook. Applications such as bendable eyeglass frames and the mechanism that ejects disks from laptops currently use shape memory alloy technology. The "shape memory effect refers to the ability of a particular type of alloy material to revert, or remember, a previously memorized or preset shape." (36) The effect is caused by a "solid state phase change - a molecular rearrangement - which occurs in the shape memory alloy that is temperature dependent and reversible." (36)

Many of the current shape memory alloy applications occur in the form of actuators, which are small springs that can be stretched and then snap back into shape once heat is applied. For instance, there are multiple products in which an actuator is used as a switch that shuts off a mechanism when over heating becomes an issue.

There have also been recent developments in shape memory polymers, but these are still underdeveloped and relatively expensive compared to the alloy technology. Additionally, there are certain actuators that react specifically to the range of human body temperature. Therefore, I plan to use this technology in the design process to develop interior applications that react to the dynamic human movement within the space. Possibly looking into wall systems that are rearrangeable and reversible, or ventilation and heating systems that are specifically engineered to sense an individual within a certain proximity and alter the environmental conditions accordingly.

(36) Addington, Smart Materials and Technologies, for Architecture and the Design Professions, 105.
In addition to the structural and economical considerations of applying solar power to an adaptive reuse project, I chose to work with “printable solar” in order to investigate the possibilities of nanomaterials in architecture. Nanomaterials and nanotechnology are relatively new terms, not only in the architecture community, but the scientific community as well. “The prefix “nano” indicates that the dimensional scale of a thing or a behavior is on the order of a few billionths of a meter and it covers a territory as large, if not larger, than that represented by micro-scale.” (37) However, to understand the basics of solar technology we must first discuss the photovoltaic effect.

The photovoltaic effect involves “basic semiconductor phenomena” that also “forms the basis for other technologies such as transistors.” (38) “Basic semiconductor materials, such as silicon, are neither good conductors or insulators, but with the addition of small impurities called dopants, they can be made to possess many fascinating electrical properties.”(38) One of these properties includes the photovoltaic effect, in particularly strong in silicon crystals. With the addition of heat to semiconducting materials the conductivity of the material increases, which is the opposite of most materials.

In a typical solar panel there are thousands of photoresistors in which are enclosed three of the silicon crystals. The silicon crystals are charged negatively, neutrally, and positively. When light creates heat within the solar panel excited electrons move from the positively charged crystal, through the neutrally charged to the negatively charged creating a complete circuit.

Typically, harsh chemicals such as arsenic are used to add the dopants to the silicon crystals. There have been recent advancements in the manufacturing process of the silicon that allow for the creation of large blocks of silicon that are negatively, positively, or neutrally charged. The manufacturing process is complicated, and not necessary for this discussion. However, the advancements in technology with regards to the large blocks of pre-charged silicon is relevant. Several universities, including the engineering department at the University of Cincinnati, are developing nano-printed solar with the large

(37) Addington, Smart Materials and Technologies, for Architecture and the Design Professions, 44.
(38) Addington, Smart Materials and Technologies, for Architecture and the Design Professions, 100.
blocks of pre-charged silicon. Basically, each block of silicon is put through a process in which it is ground down to nano sized particles. Then the nano-particles are mixed with a standard latex paint. Enter a printer, and insert an 8 1/2 X 11 inch sheet of paper. First, a layer of positive nano-paint is printed, then a layer of neutral, and finally a layer of negative. Hook up two electrodes to the sheet once it dries, and you have a disposable solar panel that can generate a charge for a laptop or a cell phone.

Gregory Beaucage is the lead professor on this project at UC. The engineering department has been making advancements in this technology and has started a program in conjunction with the University of Cape Town in South Africa to apply this technology as an emergency power source for villages that do not currently have a reliable source of electricity. When I met with Professor Beaucage, I immediately thought of the application that this technology could have on existing buildings due to its light weight and very inexpensive cost. I will investigate the possibilities of using this technology as an impermanent exterior application that can be used to offset energy use within the building.
Chapter 3

A model for creating innovative materials
In the late 1930’s Joseph Schumpeter was one of the first economists to define an entrepreneur. Schumpeter saw an entrepreneur as one who was able not only to innovate, but to convert his innovations into an enterprise. Schumpeter and several other economists of the time were largely responsible for developing the study of entrepreneurship in economics. He developed several theories around the idea of entrepreneurship. He believed that entrepreneurs were the leaders of technological change and innovation. However, he also saw that research and development was a crucial step in innovation and was mainly supported by large corporations. He realized that it was largely through funding from these large companies that many innovations came about.

It wasn’t long after the development of the study of entrepreneurship in economics that programs and centers to support such enterprises were created. Throughout the early to mid-twentieth century business incubation programs were created by publicly and privately funded institutions to offer resources and support for entrepreneurial endeavors. Running parallel to this initiative was the development of research parks that were a hub for technological innovations.

Over the past fifty years the idea of both the business incubator and the research park, which exemplifies Schumpeter’s concept of innovation, have slowly began to be hybridized into one institution. This hybridization is largely due to the amount of entrepreneurial activities that now revolve around technology and research. Having both the research element and the business element under one roof, allows for a collaborative effort that spurs innovation.

The program for my thesis involves creating a hybridized business incubator and research park that also incorporates a design element which can serve to support the innovation and technological commercialization of smart materials and technologies. In the following chapter I will discuss both the program of a business incubator and a research park describing the aims, types of programs, and the historical development of each institution. Then I will elaborate on the condition of such programs in
Cincinnati. Several of the programs that I will discuss are currently lacking a physical space and are potential clients. Next, I will present the concept and mission statement of my proposed hybridized business incubator and research park and the key players that would ultimately influence the program and funding for such a project. Finally, I will discuss this new type of hybridized program and how it transforms the traditional workplace, as well as implications of a dynamic program within an existing structure.
Business incubators are programs that help to spur the development of entrepreneurial enterprises. Most incubators offer various resources and services, as well as connections to local or national funding opportunities. There are several different types of incubators, varying in the way that they are structured as an organization and the types of clients that they take on. Additionally, the type of funding that supports a business incubation program varies greatly across the board. Incubators are started and funded by a variety of sources including economic development groups, government organizations, and academic institutions and Universities. In most cases there are at least two or three sources involved in a collaborative effort to create business development for a specific geographic location or in a certain market sector. For example, the Linder College of Business offers an incubation program called Cincinnati Creates Companies, in conjunction with BioStart, Cincinnati Business Incubator Inc, Cincytech, C-Cap, and Hamilton County Business Center. The University allows the incubators access to its connections and resources, while the other organizations provide funding, additional resources, and office space at a reduced price.

Another variable in the business incubator program is the type of businesses that the program is trying to incubate. Some incubators are much more focused on scalable enterprises. Meaning the business idea has the potential to become a national or even global company. These incubators are typically focused in connecting clients with angel investors and resources for patenting and development. Businesses are high risk and time sensitive, but have the potential to be a huge return on investment to the investors. On the other end of the spectrum, some business incubators are more focused on creating local non-scalable businesses. Many of these programs come in the form of 8-10 week classes that are essentially a blast class on how to start and maintain a small business. Everything from accounting to branding is discussed.

In 1959 Joseph Mancuso opened the Batavia Industrial Center in Batavia, New York. It was one of the first formal business incubator in the United States. Since that time the number of business incubators
in the United States and around the world has skyrocketed. Many of these incubators are held either in a warehouse or office park type environment. However, there has recently been development in the spatial and environmental qualities of these spaces. There is an increasing interest in how design can enhance a sense of creativity and innovation in a working environment.

The Innovation Depot in Birmingham, Alabama is one example of a facility that is trying to go above and beyond the typical warehouse space. Innovation Depot combines the two original Birmingham business incubators; the Entrepreneurial Center and the OADI. The Depot is a public-private economic development effort that is funded by the Birmingham regional business community, the UAB, the City of Birmingham, and various other private foundations. It is focused on engaging business professionals with the academic community. The Depot is located in what Birmingham has coined as the “Birmingham Entrepreneurial District.” (39) It is a newly renovated warehouse building that focuses on providing a facility that includes research labs, meeting space, open offices, and other various amenities. The design of the renovation goes beyond your typical office park and incorporates strategies for creating a naturally lit, well ventilated facility that encourages a creative spirit and innovative atmosphere. (39)

A research park is a facility that is dedicated to technological or scientific research in a specific field. These parks are geared towards development of research into a commercial product or strategy. Typically these parks are established either in conjunction with a University or a large company. The larger research parks often provide numerous resources and amenities from convention centers and management offices, to uninterrupted power supplies.

The first research park in the United States was started by Stanford University in the 1950’s. It was started in an area known as Silicon Valley. The original research center has closed, but the area has become a hub for innovation and research and has developed some of the most widely used innovations of our time. Most notably Xerox PARC was founded in 1970. The Palo Alto Research Center is responsible for inventing GUI (the graphic interface for computers) as well as the computer mouse. On the other side of the world, Pierre Lafitte founded the Sophia Antipolis Science Park in France in 1960. Lafitte was inspired by the concept of the collaboration between science and the arts. He believed that creativity was a product of the exchange between different disciplines including industrial, scientific, philosophical, and artistic individuals.

Today’s research parks vary widely in size, type, and location. I have selected two to present from a design perspective including. Including the Balearic Innovation Centre in Spain and the African Centre for Health and Population Studies. The Balearic Innovation Centre is located on the Island of Mallorca. It is a privately owned enterprise that focuses on high-tech design. The building is submerged underground housing all of the services which enables the offices to be completely clear of clutter. The building is inwardly focused with the open plan offices positioned around the courtyard space. Furthering the idea of the central focus, the entire outline of the site is a raised stone wall. Spatially, it is expressing the importance and privatization of information while still trying to allow for a feeling of openness within. (40) In terms of materiality, local materials are employed in a simplistic way to keep true to the character of clean orderly spaces. This particular precedent is the extreme of privately owned innovation and research spaces. It is reminiscent of a “fortress of information.” (40) The stone wall on the outside

expresses the idea of protecting the information within. However, the courtyard and organization of offices allows for beautiful open office spaces that supports the program of innovation and research.
The African Centre for Health and Population Studies is a public initiative to study the health and population problems in the KwaZulu-Natal district in Africa. The Centre is a “distinguished and aesthetically pleasing” building that combines “modern, sustainable design using local labour and materials, and provides a vibrant environment for interaction and research.” In plan, the building is organized into four “research pods” that are clustered “around a cruciform space containing social functions.” A fifty foot tower sits at the middle of the building that creates a focal point and “acts as a thermal stack that allows the area to ventilate naturally.” Other sustainable building strategies include natural lighting and ventilation as well as a grey water storm water management system. The building is a model for sustainability and research in the community.

Figure 3.5: African Centre for Health and Population Studies, Exterior Image (41)
Figure 3.6: African Centre for Health and Population Studies, Interior Image (41)
Figure 3.7: African Centre for Health and Population Studies, Elevations (41)
Figure 3.8: African Centre for Health and Population Studies, Plan (41)
Cincinnati has a longstanding tradition of entrepreneurship and innovation from the founding of P&G to Carl Linder and American Financial Group. There have been several waves and various programs for business incubation in the past. However, there has recently been a resurgence of incubation and innovation contests and programs. These include but are not limited to Cincinnati Innovates, XLAB, the Brandery, and Spring Board. There are also several more longstanding institutions like the Hamilton County Business Center.

On the contest side of development, Cincinnati Innovates differs from the XLAB competition in that it provides direct funding awards for the winners. XLAB offers the selected contestants various networking opportunities and resources such as access to temporary meeting and office space. In terms of programs that are available the Brandery and Spring Board, select businesses from a pool of applicants and offer 8-10 week classes that give a crash course in entrepreneurship from various perspectives. In addition to these programs, both the University of Cincinnati and Xavier University offer support to their students and recent graduates who are pursuing the development of small businesses. BioStart is one initiative at UC that focuses on businesses that are developing innovations in the Biomedical field.

In terms of Research Parks, there has yet to be a typical Research Park established in Cincinnati. The closest is NEXTEDGE that has locations in both Columbus and Dayton and offers clients connections with the surrounding Universities. The University of Cincinnati has established the Office of Entrepreneurial Affairs and Technological Commercialization as an effort to offer a resource for taking scientific innovations from concept to reality. Their efforts include; the creation of an entrepreneurial agenda for the University, regional entrepreneurial programs, intellectual property protection and management, commercialization strategies, and networking opportunities and university-industry collaborations. However, this effort is not a research center in and of itself but simply a resource for those who are already conducting research in an academic environment.
The lack of a physical space for many of the existing business incubation programs as well as a research center that can support and facilitate innovation in Cincinnati requires a mixed used program that involves multiple clients. These clients would include the University of Cincinnati and Xavier University, as well as local businesses and existing incubation programs. CITE, or the Center for Innovation, Technology and Entrepreneurship would become a source for entrepreneurship, talent, and economic growth. It would provide a location where private companies could collaborate with each other and local universities, in order to enhance the development and commercialization of technology and innovative materials.

CITE would be a mixed-use facility that would encourage universities to partake in broader activities creating a valuable site for companies to access research, design, and business students. The center would serve as a resource for generating economic impact in Cincinnati through the facilitation of university-industry-community relationships in a research setting and support the generation of start-up companies. CITE is intended to serve as the physical hub for the concentration of research, design and entrepreneurial activities in Cincinnati. Providing a place for “a meeting of the minds,” in a setting that encourages the cross polinization of information and leaders from multiple fields and industries. Yet, there is a deeper investigation necessary to understand how physical space can encourage this cross collaboration.
The type of work and research that we are doing today has changed significantly since the prototypical office and research facility were created. For clarity and consistency, I will use the term “workplace” to refer to both business and research type facilities. The modern workplace is no longer one designed around a static unchanging set of linear processes. Instead it is one that is dynamic and an ever-changing set of functions and requirements. The knowledge based work that we do today depends more on critical thinking and applied knowledge, rather than a specific process or formula. Yet, many spaces do not incorporate these principals and are instead still using the process driven factory model.

There are several factors that play into this shift in working and learning. First, much of the manual and process work that was once housed in the workplace, is being outsourced to developing countries due to technological advances. These job types are being replaced by workers that focus on finding ways of sharing and exchanging knowledge. The focus on the creation and retention of knowledge leads to two secondary factors in modern workplace design; individuality and collaboration. Workers want to feel a sense of self-realization, and employers want to encourage innovation through the spontaneous collaboration of these individuals. For many people the workplace has become more than just a job, it’s a lifestyle. Offices are becoming peppered with lounges and recreation areas that create a more inspirational environment. Mobility and adaptability are also factors in an ever-changing workplace. The space requirements and activities in a particular office can change rapidly. Finally, the general shrinking of technology has helped to lead to the mobile and adaptable types of workplaces. The large monitors that once tied us to our desks are no longer necessary. All of these factors lead to a transformed idea of what types of activities and functions are performed in the modern workplace.

The idea of a collaborative office is not new. IDEO, Google, and Pixar are all companies that have been very successful and thrive on this concept. Theses companies tend to focus on building up areas of different disciplines, and finding ways to create overlap and cross-polinization between groups. I have developed three main areas of concentration for my program; Research, Design, and Business. In each
of these three areas I have identified both the activities and the corresponding spaces that go along with them. Additionally, there are auxiliary spaces that function to support the Research, Design, and Business program elements and activities. While the segregated program elements can encourage collaboration through proximities and transparencies, it is in the auxiliary spaces that there is opportunity for creating chance meetings and spontaneous collaboration.

**Daily Activities**

**Research Activities**
- Digital Research
- Reading, Articles, Internet Library Research
- Laboratory, Prototyping, Testing

**Design Activities**
- Studio work
- Design Development
- Synthesis of Business/Technical ideas
- Brainstorming Activities
- Prototyping

**Business Activities**
- Correspondence
  - email, telephone calls
- Meetings
- Team Based
- Client Based
- Presentations/Conferences

**Auxiliary Spaces**
- Stairs
- Lounge
- Cafe
- Service Spaces

“How to create chance meetings and opportunities for spontaneous collaboration”

Figure 3.9: Programmatic Diagram, By Author
Out of the programatic elements that I have identified, there are certain elements that are more
dynamic and easily adapted than others. For example, a studio space can be transformed into an open
office space with little to no alterations. On the other end of the spectrum, a staircase, once constructed,
is a relatively permanent and static part of a building without a major intervention. The diagram shown
below, organizes functional spaces based on three levels of “dynamics.” The Primary level are those
functions that can change size and location with relationship to the other functions, with relative ease.
The secondary level, are those functions that may expand and contract to swallow up or give square
footage to neighboring functions, but have certain equipment or environmental restrictions that tie them
to a certain location. The third level, or tiertiary functions are those that cannot change size or location.
Additionally, these functions are normally “supportive” functions that are help to facilitate the other
functions within the program.

In an adaptive reuse, one of the main issues that we encounter is trying to fit the program within
the given volume. Yet, what if we could add a level of adaptivity to a project and a program by identifying
these “primary, secondary, and tiertiary functions” and allowing for the building to be readapted on a
yearly, monthly, and possibly even daily basis. The following series of diagrams on the next page shows
the programatic elements in a hypothetical “state 1” showing relative locations and sizes within a given
volume (grey). The diagram then goes through a series of changes and adaptations when certain elements
switch locations and grow ending with “state 14.” In the diagram it is important to not how the tertiary
functions stay in the same location with the same size, while the secondary function also remain in the
same location but are allowed to change size. The primary functions have complete freedom to move,
grow, and shrink in the rest of the given volume. The areas inbetween these functional spaces would
serve as circulation spaces and spaces for spontaneous collaboration.
Figure 3.10: Programmatic Diagram, By Author
Chapter 4

St. Paulus Kirchen as a Case Study
Located in historic Over-the-Rhine at the corner of 15th and Race, St. Paul’s is Cincinnati’s oldest remaining Protestant Church building. Dedicated in 1851, and founded by an offshoot group of North German Lutherans, the church was called St. Paulus Kirche, or St. Paul’s German Evangelical Protestant Church. In 1948, due to declining membership and movement of the congregation to outlying neighborhoods, the congregation merged with that of St. Peter’s Church located at the intersection of McMiken and Main Streets. The combined congregation took the name of Saints Peter and Paul United Church of Christ. The last service of the combined congregation was held in this building in 1950, at which time the congregation moved to a new church that they built in Westwood. Since 1950, the building has been used by various other churches, the last of which was the Freedom Baptist Church. The congregation allowed a Rexall drug store to open in the first floor to help support the church. The drug store remained open for a period of about 75 years. During this period the recotry building was removed on the south side of the site. It exists in the heart of Over the Rhine located only a block from several important landmarks in the community including Washington Park, Music Hall, and Memorial Hall.

Figure 4.1: Aerial Map of St. Pauls (42)

Figure 4.2: Exterior Photograph St. Pauls, By Author
Figure 4.3: Exterior Photograph St. Pauls, By Author
Figure 4.4: Exterior Photograph of Tower at St. Pauls, By Author
Figure 4.5: Exterior Photograph of Front Entrance at St. Pauls, By Author
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The brick building is Greek Revival and features, Gothic pointed arch windows to hold stained glass. Its three-story bell towers rises 116 ft. and was originally intended to have a 30 ft. steeple, which was never completed. As is typical of German churches, the sanctuary is located on the second level of the building. The first floor was used for services as the sanctuary and its more elaborate interior spaces were being finished. The sanctuary rises 40 ft and is lined on three sides by a balcony. At the rear of the sanctuary, on the balcony level was the original location of the organ podium.

Figure 4.6: Exterior Photograph of Rectory Building at St. Pauls (43)
(43) Original work by Michelle Avery Keely, 2005 Ken Jones Architects. Cincinnati, Ohio.
Figure 4.12: CAGIS Zoning Map of St. Pauls (44)
Figure 4.13: CAGIS Zoning Map of St. Pauls Close Up (44)
Figure 4.14: Existing Elevation Drawing of St. Pauls (45)
Figure 4.15: Existing Section Drawing of St. Pauls (45)
(45) Original work by Michelle Avery Keely, 2005 Ken Jones Architects, Cincinnati, Ohio.
Figure 4.16: Existing Elevation Drawing of St. Pauls (45)
Figure 4.17: Existing Section Drawing of St. Pauls (45)
(45) Original work by Michelle Avery Keely, 2005 Ken Jones Architects. Cincinnati, Ohio.
Figure 4.18: Existing Basement Level Plan of St. Pauls (45)
Figure 4.19: Existing First Floor Plan of St. Pauls (45)
(45) Original work by Michelle Avery Keely, 2005 Ken Jones Architects. Cincinnati, Ohio.
Figure 4.20: Existing Second Floor Plan of St. Pauls (45)
Figure 4.21: Existing Third Floor Plan of St. Pauls (45)
(45) Original work by Michelle Avery Keely, 2005 Ken Jones Architects. Cincinnati, Ohio.
Figure 4.22: Existing Truss Level Plan of St. Pauls (45)
Figure 4.23: Existing Roof Plan of St. Pauls (45)
(45) Original work by Michelle Avery Keely, 2005 Ken Jones Architects. Cincinnati, Ohio.
St. Paulus is currently owned by 3CDC. After an incident in which part of the roof blew off due to disrepair, the developers decided to replace the roof with a new metal truss system in order to prevent further decay of the building. All of the remaining floors within the building have deteriorated beyond repair due to water damage. 3CDC plans to remove the remaining flooring and replace them with a metal system, but they have yet to define a use for the building. The building is a perfect urban location for my project. Additionally, it is in the hands of a developer interested in bringing new business to the area. While they have the funding to build out the floors, they do not have the funding to completely build out the project. It is a shell waiting for an adaptable program to be inserted within it.

Figure 4.24: Interior Photograph from the Tower at St. Pauls (45)
(45) Original work by Michelle Avery Keely, 2005 Ken Jones Architects. Cincinnati, Ohio.
Figure 4.26: Interior Detail Photograph from the Tower at St. Pauls (45)
Figure 4.27: Interior Detail Photograph from the Tower at St. Pauls (45)
Figure 4.28: Interior Photograph from the Tower at St. Pauls (45)
Figure 4.29: Interior Photograph from the Tower at St. Pauls (45)
(45) Original work by Michelle Avery Keely, 2005 Ken Jones Architects. Cincinnati, Ohio.
Part 4: Inserting A Dynamic Program

There are several important considerations and design principles that come into effect when trying to insert a new program into an existing building. Furthermore, there are additional considerations involved in designing for a dynamic program that is adaptable and changeable. These considerations include, but are not limited to:

1) Creating interventions that are impermanent or easily reversible, with the exception of code compliant interventions such as fire stairs.

2) Designing new elements within the space that interact/compliment the original design in terms of scale, aesthetics, or historical relevance.

3) Selecting the appropriate materials/smart materials that allow for specific interventions to be adaptable and easily reversible to compliment ever-changing user needs.

4) Modifying programatic elements to create the most effective design within the space.

It is extremely important with adaptive reuse projects that we consider the opportunity for future programs within the building. The goal is to create a design that compliments the original design while allowing for efficient use of the given space. Additionally, programatic elements may have to be altered in terms of square footages and space requirements in order to create a better fit within the building. Smart materials and systems allow designers new opportunities to make these design considerations possible. Spaces can respond and reconfigure based on user needs and a common space can be adapted to accomodate multiple programmatic functions. Additionally, smart materials can be used to offset energy consumption and the need for invasive mechanical systems within the building.
Conclusions
There are close to 25% of the architecture thesis in my class that are focused on adaptive reuse or historic preservation. As architects, my generation is going to have to face several new issues that the profession has not dealt with before. Preservation projects no longer come only in the form of a historical landmark. The amount of existing building stock that we will be redeveloping in the coming years forces us to think of new solutions for adaptive reuse. Additionally, attitudes to the standards and guidelines for historic preservation and reuse are evolving, we no longer see mimicry of history as a solution.

In addition to the changes in attitudes towards preservation, we are in a time where the materials that we design with and the types of spaces that we are designing for are rapidly changing. There has been an explosion of new materials on the market including smart materials and systems, that allow us to think of how architecture can adapt and be responsive to it’s users. The typologies that we are used to dealing with are also being blurred and redefined. People do not just work at the office anymore, or just sleep and eat at home. We live in a mobile society where we are constantly readapting and reconfiguring the spaces around us.

In adaptive reuse, one of the main concerns is how the program can change over time. Smart materials and systems offer ways to create an architecture that can readapt itself. If applied correctly, these materials can help to create systems that can be inserted into an existing structure and be transformed or removed as the functions within the building change.

Yet, it is currently extremely difficult to get a handle on the materials and systems that are available and what their design potential is. We are trapped in a classification system that breaks down each component and material within a building as a static one-function element. Smart materials do not fit into this system and neither do the dynamic and adaptable types of spaces that we should be designing for. Instead, we need to gain a new understanding of material properties and how they interact and influence our environments. Once we define the desired outcome or change, we can choose the appropriate material to achieve this.

Given the right methodology and tools for design, we can begin to engage the possibilities of these
new materials and how they can create solutions for adaptable environments and exiting buildings.

Imagine a building that lives and breathes with its users. It knows when someone enters it’s premises and responds accordingly. Overtime, it changes and redefines itself as the program changes. My thesis creates a methodology for selecting and working with smart materials in a given situation, and defines principles for integrating these materials with existing construction. By creating a way to access and utilize the knowledge available to us we can create new design solutions for current obstacles in the profession.
Bibliography


