Architectural Research@NDSU

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Introduction to the Architectural Research Studio at North Dakota State University

Architectural Research

Architectural research is different from basic or applied research, in that design processes are involved as part of the research. Architectural research attempts to solve a research problem, answer a research question, or address a design issue, using designs as the vehicle for the inquiry. The instruments of the research are often drawings, animations, models, simulations and other design artifacts. The researcher attempts to solve a design problem, answer a research question, or address a design issue, using these design artifacts as research instruments.

The Architectural Research Studio

The Architectural Research Studio is a viable curricular offering in a professional, graduate, accredited curriculum in Architecture. It provides the benefits of boosting research productivity in a department, strengthening ties with architectural firms that have an alumni presence, providing career networking opportunities for graduate students, generating valuable intellectual property, fostering research careers, and adding to the knowledge base of the Architecture profession. The all-around benefits far outweigh the challenges that have to be overcome in offering this studio.

This experiment with an architectural research studio was first conducted during the fall semester of 2010 in the Department of Architecture and Landscape Architecture at North Dakota State University. The studio course was taught by Dr. Ganapathy Mahalingam, then an Associate Professor of Architecture and Landscape Architecture, who holds a Ph.D. in Architecture, and has extensive experience with research projects. In order to facilitate a wide range of research topics to be covered by students in the course, Dr. Mahalingam approached the Advisory Board of the department, consisting mainly of alumni of the department, and asked them to provide research problems, questions, and issues, from the world of their professional practice that the students could address. Two firms with an alumni presence responded with research topics, one of which was selected by two different students to pursue. Considering that this was a brand new initiative, this was a good beginning. As the studio evolved, with more active participation by alumni firms, a much richer intellectual discourse was enabled. The various projects featured in this book were completed by the students in repeated offerings of the course. The research projects cover a diverse range of topics that utilize many different research methods to address the issues that the students have taken upon themselves to resolve.

NOTE: As of the fall semester of 2015, the Sponsored Programs Administration at North Dakota State University has ruled that sponsored projects cannot be part of academic coursework in the Architectural Research Studio, so some of the benefits outlined in the next three sections are no longer viable at North Dakota State University. Since 2015, the students have been working on research projects from the context of their Master's thesis instead.

Advantages of the Architectural Research Studio:

- Graduate students can utilize the studio to complete research projects fit for publication. Often this experience will be their first attempt at a research publication.
- Faculty members who teach the studio can co-author research papers with the graduate students for presentation at conferences, or for publication. As much as a dozen papers can be co-authored in a semester, which is a high level of productivity for a faculty member, especially one who is to go up for promotion and/or tenure.
- Students can work on research problems, research questions, or design issues, supplied by alumni firms. This allows the graduate students to work on real world problems, questions, and issues, drawn from the world of professional practice. This also allows the graduate students to network with alumni firms for future employment.
- The research work completed in this studio can be compiled annually and provided to member firms that participate in a research consortium managed by the department, by paying an annual membership fee. Alternatively the research projects can be featured on the department's web site, creating high profile exposure of cutting edge work being done by the graduate students.
- The students, faculty, department and university can benefit from the creation of intellectual property, which can be transferred to architectural firms, using a licensing system, or be sold outright.
- The studio can become a vehicle for the high research productivity in sponsored research that is demanded from departments at a research university. A department's typical annual quota of publications can be met easily with this studio being offered annually.

Financial Benefits of an Architectural Research Studio

The Architectural Research Studio can provide all around financial benefits for students, faculty, the department and the university, when it is offered.

- For the research work, a graduate student can be paid a stipend of a minimum of $1600 per semester (160 hours at the rate of $10 per hour), which constitutes a quarter-time assistantship, which, in most institutions qualifies for a tuition waiver. This stipend can be sponsored by the architectural firm submitting the research question, problem or issue to be resolved. For a class of 12 graduate students, a sponsored outlay of less than $20,000 can support the entire studio.
- The architectural firm sponsoring the graduate student can also negotiate to acquire the intellectual property being generated by the graduate student and the faculty member teaching the studio. It is customary that the university and department would receive shares of this intellectual property for the resources they provide in generating the intellectual property.
- All the participants in the studio stand to benefit financially from the offering of the studio:
- The university would be in a position to generate income from licensing fees for the intellectual property generated by the studio.
- The department would be able to recover indirect costs in generating the intellectual property.
- The faculty member teaching the studio would be in a position to receive his or her share of the intellectual property earnings in the form of royalties, or a portion of the licensing fees.
- The student would be in a position to receive a stipend, and a tuition waiver for completing the research. In addition, the student may also be eligible for a share of the income generated by the intellectual property generated.

Process Framework for the Architectural Research Studio

The following is a template for the process of implementing an Architectural Research Studio:

- Solicit research problems, questions and issues from architectural firms with an alumni presence
- Augment list of problems, questions and issues with topics that are relevant to the professional practice of architecture
- Prepare a detailed description of the research topics collected
- Allocate research topics to the graduate students
- Identify liaisons in architectural firms who will work with the graduate students
- Identify projects that require participation of human subjects
- Prepare students for training in using human subjects in their research as established by the university's Institutional Review Boards
- Identify appropriate research methods for each research topic and locate research resources
- Create a schedule for the semester in which the studio is offered
- Execute the research projects
- Make sure the liaisons in the architectural firms are engaged throughout the execution of the project
- Document the research projects using the submission format of reputed journals such as the Journal of Architecture and Planning Research

Faculty Resources Required for the Studio

- A faculty member, preferably with a Ph.D. degree, who is well versed with structuring and executing a research project.
- A faculty member, who has taught courses in design research methods, or is otherwise well-versed in the various research methods that can be brought to bear in architectural design. A good resource for the faculty member would be a textbook such as Architectural Research Methods by Linda Groat and David Wang.
- A faculty member with a breadth of expertise to tackle the different research projects that may emerge in the process of working with alumni firms.
- A faculty member who has practiced, or has worked with practitioners, and who is familiar with the issues facing the real world of architectural practice.
- A faculty member who has experience in working with the sponsored research office at the university, and the Institutional Review Boards that govern research with human subjects.

Short Descriptions of Research Projects from 2017 to 2013

From Ecology to Architectural Design: a framework for translation of ecological principles

Abstract: This project is part of an on-going research study in the field of architectural design that is attempting to bridge the gap between ecology and designing architectural environments. The study of architecture and ecology together is a way to approach the built environment as a more dynamic system that responds to the needs of the inhabitant. It is positioned in such a way that by studying the organization of successful ecological processes of natural organized systems, an innovative set of design principles can be implemented successfully in the practice of architectural design. This report will begin by analyzing the natural processes that are a part of ecosystems and then, with architecture as the vehicle, explore if it is possible to create a new model that will shift the paradigm toward a more dynamic and responsive built environment.

Through a comparative literature study and compiling, reviewing, and analyzing ecological principles, the research results that have been reported have been broken down in to six principles. These principles will be used as a framework for understanding how ecology can be abstracted as a design methodology. This research paper shows how this innovative model will allow the architectural profession to go beyond sustaining current practices and encourage natural ecological processes as a vital component in architectural design.

Researcher: Kaitlyn Aberle

Faculty Advisor: Dr. Ganapathy Mahalingam

Term: Fall 2017

Act for Children: A Study of How Architecture Can Foster Development During Stages of Early Childhood

Abstract: What role does architecture play in fostering the stages of early childhood development? The first five years of a child's life are the most crucial years of their developmental process as they grow not only physically but also cognitively, socially and emotionally. Children are impressionable human beings drastically impacted by their surrounding environments. Through design, we can enhance the lives of the users through well informed environments that are not only healthy but safe, functional and beautiful. This project seeks to investigate the stages of development and identify key prepared environments that facilitate learning in early child development. The results suggest that, in terms of the ideal environment for children, not one prepared environment takes precedent over the others. Scale, light, color, safety, security, spatial arrangement, and nature all play an integral role in the development of children. Designing for children is no simple task. As designers we have the responsibility and ethical duty to provide a comprehensive analysis on the needs of our clients. It is our role to ensuring a healthy and nurturing environment while providing a developmentally appropriate and stimulating environment to our nation's youngest generation.

Researcher: Kelsey Jarrett

Faculty Advisor: Dr. Ganapathy Mahalingam

Term: Fall 2017

Visitor Driven Exhibitions

Abstract: Museums are facing a rapidly changing set of expectations from visitors regarding the presentation of information in the exhibit space. Technology is one of the largest factors driving the change from traditional printed and physical artifacts to more immersive mediums. Technology can also be a driving force in the design of museums, beyond the means of producing drawings to build from. Analysis of visitor behavior within exhibit spaces can assist planners in creating exhibits that better react to how people engage with museums with agent-based simulation of planned exhibits allowing evaluation of designs before a living person ever sets foot in the space.

Researcher: Brady Laurin

Faculty Advisor: Dr. Ganapathy Mahalingam

Term: Fall 2017

Quantification of Gentrification

Abstract: This research aims to provide a concise way to quantify gentrification for the purpose of application in the design professions to help mitigate and reduce negative effects seen with gentrification. First, by researching into the major types of gentrification and understanding the factors that contribute to them, a core model can be created. Then, by utilizing case studies of urban areas undergoing urban redevelopment in their cores and analyzing major factors, we can crossreference expected forms of gentrification from actual results. By honing in on the factors leading to gentrification issues, we can then apply a quantifiable factor to such contexts which can be used to compare to other like contexts and compare design strategies.

Researcher: Alex Malnaa

Faculty Advisor: Dr. Ganapathy Mahalingam

Term: Fall 2017

Adaptive Architectural Value Engineering

Abstract: A study to develop an understanding of architectural design through the definition of correlated economic and value variables by the application of simplex methods of optimal analysis. The adoption of interactive simplex models using Microsoft Excel and Solver applications.

Researcher: Christopher Meyer

Faculty Advisor: Dr. Ganapathy Mahalingam

Term: Fall 2017

Evaluating performance of greenhouse design through digital simulation: a case study of a USDA facility at the North Dakota State University

Abstract: The goal of this architectural research study is to simulate the thermal performance of a multi-story greenhouse design. To do this, the study must first verify the authenticity of digital simulation, then apply the solver technology to additional designs. It does this in three phases:

The first is a quantifiable, measurable field investigation which will lead to conclusions about the varying temperatures surrounding a greenhouse facility. The study data describes a distinct difference in temperature between the interior and exterior, demonstrating a clear control of the internal environment across all weather conditions. The second phase of the study simulates the greenhouse's performance in Autodesk CFD using comparable conditions as found in the first phase. The resulting simulation data has minimal deviation from reality: 92% of the results were within 10°F of the actual recorded data. In the third and final phase of the study, CFD is used to evaluate the thermal performance of three new designs. This provides an incredible amount of insight into the impact of design factors such as massing, HVAC placement and solar orientation. This study attempts to prove that digital simulation can accurately predict the thermal performance of a design. Based on the success of the three phases, it can be concluded that CFD has the ability to reflect reality in a consistent and accurate manner.

Researcher: Alexandra Mills

Faculty Advisor: Dr. Ganapathy Mahalingam

Term: Fall 2017

Cancer Center: Healing through Architecture

Abstract: Designers play an important and specific role in the design of health-related facilities. Specifically, for diseases such as cancer which has its own criteria within the field of health care design. Besides the physical equipment and correlating spaces required, there are psychological, emotional, and philosophical requirements. It is very much a human-centered design problem that necessitates delicate care and empathy from the designer. Cancer is one of the most frightening and stress-inducing diagnoses a person can receive. Providing a space that can help to improve outcomes, would be beneficial to people battling cancer.

Researcher: Stina Ostlie

Faculty Advisor: Dr. Ganapathy Mahalingam

Term: Fall 2017

Disaster Response: Casualty Collection System for Post Disaster Aid

Abstract: What role can architecture play in post disaster response? This project involves how designed response system that includes a response system smartphone application, casualty collection units, and temporary couchette units, which can provide the aid required in areas that have experienced disasters. As a base for the project past events have been studied to gain insight on how disasters have been responded.

Researcher: Elizabeth Rae

Faculty Advisor: Dr. Ganapathy Mahalingam

Term: Fall 2017

Life and Architecture in the Public Realm

Abstract: While one might think of the public realm as any and all space outside one's front door, the reality has never been as simple. Throughout history, different activities and philosophies have shaped the ways societies interact with public space, which has in turn contributed to the ever-changing state of public architecture and public space planning. Even in the modern day, the public realm is ill-defined, and really exists as more of a spectrum from public to private. Though many activities once thought of as public have moved into the private domain, cultural differences and the differing urban character of cities continue to contribute to sometimes massive differences in how the public realm is regarded between nations or even nearby cities.

These differences that develop throughout place and time cannot be attributed to one single law or idea, but rather a collection of factors. The public life of cities is shaped as much by the decisions of government officials and city planners as it is by the ways people simply choose to interact with the public realm. Social interaction, political demonstration, religious life, cultural events and exchanges, commercial transactions, and environmental quality all contribute in major ways to how the public perceives the public realm, and how designers design for it. In examining societal views of the public realm, it is of the utmost importance to examine how these factors have contributed to the shape of the public realm over time. The public space of an ancient Middle Eastern city, will be different from that of a medieval European city, which will in turn be different from a cosmopolitan western city, but ideas from all times and eras will undoubtedly still be reflected in the modern shapes and perspectives of the public sphere.

Researcher: Nicholas Saddler

Faculty Advisor: Dr. Ganapathy Mahalingam

Term: Fall 2017

A Preliminary Analysis of the Craft Beer Brewing Process

Abstract: There is a lot of knowledge out on beer production. However, there is a lot of digging need to be done in order to get an idea of how it all works. Some sources will give you basic information but do not go into detail the different portions and vice versa. This study focuses on an inclusive study of the basics and the more detailed via research and case study work. In addition, it will look at the efficiencies of the brewing process through analysis of the equipment.

Researcher: Kenneth Stephenson

Faculty Advisor: Dr. Ganapathy Mahalingam

Term: Fall 2017

Designing for Humanity

Abstract: The purpose of this research is to look at the current architecture of correctional centers around the world and how it relates to the wellbeing of inmates. If American prisons followed the examples Scandinavian prisons set, there could be a better future for individuals who encounter the penal system. The main premise of this argument is that there are simple ways we can improve the lives of inmates. Through access to nature, sunlight, and exercise, they are given the opportunity for a healthier lifestyle while incarcerated. In most cases, healthier means happier and happier inmates lead to less incidents between inmates and guards. Recently, American prisons have used more evidence based design when deciding how to construct prisons. It has proven to be a better solution to create healing spaces rather than oppressive spaces.

Researcher: Elizabeth Thordson

Faculty Advisor: Dr. Ganapathy Mahalingam

Term: Fall 2017

A Quantitative Index for Comparing Quality of Life in American Cities

Abstract: Most standard Quality of Life measurements operate based upon national objective data or localized subjective surveys. The goal of this project was to develop an objective urban analysis system that can be applied to any US Census defined Core-Based Statistical Area. By adapting the objective categories from the Eurostat's (Statistical Office of the European Union) "8 + 1 Dimensions of QoL" model, an index was derived where each category would be represented by 1-3 datasets. Raw data was input into a spreadsheet to calculate 16 datapoints for each city. The index was tested utilizing data for Fargo, ND; Moorhead, MN; Grand Forks, ND; and Bangor; ME. While these are similarly sized cities, the analysis shows that for best results a comparison should be limited to a select region. The most statistically significant factors followed the ratios of school buildings to public parks and to center based childcare. While the resulting scores and charts do not immediately translate to community directives, the importance of dense development is supported.

Researcher: Daniel Todd

Faculty Advisor: Dr. Ganapathy Mahalingam

Term: Fall 2017

Integrating an ArchiCAD Model with Specifications

The Research Problem: There is no direct relationship between what is modeled in ArchiCAD and the materials and products specified in the Specification Manual on a job. The model is usually created first, and a spreadsheet or folder will hold information dumps about various product options. Towards the end of design development, those products get organized so that they can be given to a specification writer who then looks at the drawings in the CD phase and tries to make sure that products shown are accounted for in the Manual.

The Goal: We need a stronger automated (or two linked) interface between ArchiCAD and a specification writing software. When something is modeled in ArchiCAD, there needs to be a way to identify it as needing to be shown in the specification, and a way of passing information or properties associated with it into the specification. There should also be a way to compare the information being brought to the specification with what has been used in the past or is preferred as a way of identifying elements of the model that should be constructed of different materials or products.

Requirements:

- Interface with popular specification writing formats such as MasterSpec
- Have a process that is iterative and cumulative so that a specification may be built up over time
- Have a way for auditing the information and comparing it with historical specification data

Sponsoring Firm: Levi+Wong Design Associates, Boston, Massachusetts

Graduate Research Assistant: Ryan Gram

Principal Investigator: Dr. Ganapathy Mahalingam

Date: Spring 2016

Integrating an ArchiCAD Model with Cost Estimating: Development of a Workflow

The Research Problem: We as Architects are responsible for designing within an owner's budget, but we are not in control of either price estimate or project delivery costs. Pricing in the design process, when done at all, is created by a paid consultant who itemizes information on a pricing set of drawings, and assigns cost to it based on experience building other jobs, the current cost of materials, and labor rates. This process is slow, and it can be difficult to repeat the process as a way of understanding cost implications of specific decisions. Knowing cost implications earlier and making decisions earlier leads to less redesigning later, and therefore will help projects remain more profitable.

The Goal: What we need is an automated (or two linked) process that will take information held in the ArchiCad model/database and merge it into costing software to create a Budget Price, which can be updated frequently with little effort.

Requirements:

- Interface with popular cost estimation software such as Sage Software's Timberline Estimating or other
- Update-able process that allows for frequent repetition
- Have a breakdown of cost that allows for a design team to be informed in balancing scope vs budget
  Principal Investigator: Dr. Ganapathy Mahalingam

- Have a quick bottom line number for the building

Sponsoring Firm: Levi+Wong Design Associates, Boston, Massachusetts

Graduate Research Assistant: Ryan Gram

Principal Investigator: Dr. Ganapathy Mahalingam

Date: Fall 2015

Development of a Simulation Model to Determine Number of Dock Bays in a Hospital

Project Goal: Development of a simulation model to determine the number of dock bays needed at a hospital based on hospital patient volume and materials delivered or picked up from the dock. Clean and soiled separation should be considered in the development of the model. The simulation model should allow for real time adjustments and results display

Background: It is becoming increasingly difficult to get user input in the development of a healthcare facility. Clients are expecting a more robust way of determining the number of dock spaces needed based on patient volume and the associated volume of materials received on the dock, or being picked up from the dock. Clean and soiled dock separation is now an industry standard, and dock planning and simulation should accommodate this. As healthcare support service experts HKS needs a tool that can be used to help the client understand the exact number of bays needed based on volume. Output of this simulation will help the design teams plan for sufficient space to allow for all materials management receiving and dispatch functions.

Software: The simulation will be developed using ExtendSim OR software

End product/Deliverables:

Results of literature review - delivered to HKS Knox Advisors (Literature review should focus on best practices for dock bay usage, dock hours of operation or any other evidence that will support the study)

- A dock bay simulation model
- Final presentation materials

Sponsoring Firm: Knox Advisors- HKS Inc., Dallas, Texas

Graduate Research Assistant: Shannon Hanson

Principal Investigator: Dr. Ganapathy Mahalingam

Date: Fall 2015

Methodology for Studying IEQ Impact as a Design Tool

Project Goal: To study the impact of indoor environment quality on occupants in school design

Tasks and Deliverables:

- Conduct a literature search to summarize existing research on the impact of indoor environmental quality (IEQ) factors on learning and productivity in K-12 schools
- Develop a methodology to study IEQ design impact
- Create rules of thumb for design

Sponsoring Firm: LHB Corporation, Duluth, Minnesota.

Graduate Research Assistant: Alicia Fadley

Principal Investigator: Dr. Ganapathy Mahalingam

Date: Fall 2015

A Study in the Adaptive Reuse of a Medium Sized Building in a Blighted Urban Area to Create a Vibrant Urban Node

Project Description: A study in the reuse/repurposing of medium sized boxes in a deteriorating urban context coupled with creating an urbanscape of urban park opportunities in and around these nodes within an older lesser desirable neighborhood. Las Vegas may be a prime setting offering opportunities of the like. Fargo may not possess any of these blighted areas however a shrinking Midwest city might offer similar opportunity.

Sponsoring Firm: Klai Juba Wald Architects, Las Vegas, Nevada.

Graduate Research Assistant: Pedro Armendariz

Principal Investigator: Dr. Ganapathy Mahalingam

Date: Fall 2015

Integrating Cost Estimating in BIM

Project Goal: To integrate cost estimating with a Revit model using Assemble

Tasks and Deliverables:
- Creating a master cost table with costs for all Assembly Codes in Revit for regular construction, selecting costs from the RS Means database
- Assigning costs to a Revit model of a project in Assemble and creating a cost estimate for the project
- Creating master cost tables for various other types of construction such as demolition and renovation

Sponsoring Firm: R. L. Engebretson Holding, Inc., Fargo, North Dakota

Graduate Research Assistant: Hue Chee Vang

Principal Investigator: Dr. Ganapathy Mahalingam

Date: Fall 2015

Integration of Uniformat to Masterspec Mapping Database with e-Specs Using the Binding Manager

Project Description: Integration of the Uniformat to Master Spec mapping database that has been developed with the e-Specs system by creating Binding Sets using the Binding Manager in e-Specs. Binding Sets for an RLE Master Specification document, and the Scheels and RDO specification section sets, will be completed.

Sponsoring Firm: R. L. Engebretson Holding, Inc., Fargo, North Dakota

Graduate Research Assistant: Joshua Donnelly

Principal Investigator: Dr. Ganapathy Mahalingam

Date: Spring 2015

Flexibility and Adaptability in Modern Office Environments

Project Description: Conduct a comprehensive literature review on design strategies for planning office environments and buildings to accommodate flexible spaces (i.e., reconfigurations) and adapting to changes in technology, staffing needs, and resources. Study will include a detailed case study on the decade-old MN DHS Elmer L. Andersen building in downtown Saint Paul. Student will provide an analysis of multiple reconfigurations that have occurred over the past ten years, reasons for reconfiguring layouts and floors, and the process involved with coordinating substantial facilities reconfigurations.

The resulting deliverable will be a literature review, business case narrative, and case study for employing "flexible and adaptable" design strategies for new office buildings. Strategy examples include raised floor, demountable walls, modular furniture planning, lighting layouts, etc.

BWBR will provide floor plans (PDFs offered by DHS facilities) of multiple floor reconfigurations for analysis. Analysis data may include SF/person/floor and how that has changed throughout the years as staff has been added and the need for paper storage has been reduced. Student may also engage in interviews with the facilities personnel to discuss the process, factors, and time/cost involved with substantial reconfigurations.

Sponsoring Firm: BWBR, St. Paul, Minnesota

Graduate Research Assistant: Alexandra Schrader

Principal Investigator: Dr. Ganapathy Mahalingam

Date: Fall 2014

Study in using the AnyLogic software for Analyzing the Spatial Arrangement of the Surgery Center and Clinic in an Ambulatory Care Center in Ogden, Utah

Project Description: HKS is interested in the application of AnyLogic to research the implications of alternative configurations of the surgery center and clinic to inform design choices.

A 100,000 bgsf Ambulatory Care project comprised of an ambulatory surgery center with 8 operating rooms, two multidisciplinary clinic modules supporting 10 orthopedic/sports medicine physicians, rehabilitation and return to sports center with gym, pools, sports enhancement and therapy areas, and a 20 bed short stay patient care unit. The site is near McKay Dee Hospital Center in Ogden, Utah with some variation in topography and extensive natural views of mountains.

The goal of the research project was to use AnyLogic, a process modeling software, to model and simulate ambulatory care facilities. Using different metrics such as employee utilization, employee walking distances, room utilization, patient waking distances and wait times, the spatial arrangement of the ambulatory care facilities could be analyzed and adjusted accordingly to improve the characteristics of the room.

Sponsoring Firm: HKS Inc., Dallas, Texas

Graduate Research Assistant: Gregory Bednar

Principal Investigator: Dr. Ganapathy Mahalingam

Date: Fall 2014

Spatial Study of Alzheimer's and Dementia Patients' Treatment Units to Maximize Sensor Coverage

Project Description: During the course of the fall semester of 2014 the Design Team of North Dakota State University will investigate the spatial arrangements of designs for Alzheimer's and Dementia patients' treatment units to maximize sensor coverage.

The Design Team will create various computer-based 3D models of spatial arrangements of treatment units and analyze them for coverage by CCTV cameras, RF sensors, and other types of sensor-based surveillance equipment. The emphasis will be on the efficient and effective coverage of all patient treatment areas by the equipment, while maximizing coverage.

A set of ideal candidate solutions for treatment units of various sizes and occupancy levels will be provided as the deliverable for the project, along with a measure of the effectiveness of the sensor coverage for each solution.

Sponsoring Firm: Klai Juba Wald Architects, Las Vegas, Nevada

Graduate Research Assistant: Timothy Halvorson

Principal Investigator: Dr. Ganapathy Mahalingam

Date: Fall 2014

Daylight and Energy Analysis of Groat Point Project

Project Description: Creation of a computer-based 3D model of the Groat Point residential project, simulating the daylight access in the model with high-end renderings, and performing daylight and energy analysis using the model, with appropriate simulation software.

Deliverables include publication-fit material in the form of high-end renderings, analytical diagrams and charts, and analysis reports.

Sponsoring Firm: Kristi Hanson Architects, Palm Desert, California

Graduate Research Assistant: Jennifer Watters

Principal Investigator: Dr. Ganapathy Mahalingam

Date: Fall 2014

Study of Wind Pressure Distribution on Skylights of Scheels project in Billings, Montana

Project Description: Creation of a detailed 3D model of the skylight over the atrium in the Scheels project in Billings, Montana, simulation of wind forces on the skylight, and mapping of wind pressure distribution on the various surfaces of the skylight, with changing wind conditions during the different seasons.

This project examines questions regarding wind pressure on roofs, around a building site, and in entry vestibules. The problems that arose consisted of high pressure areas on the roof, snow drifts developing in undesirable locations, and interior ceiling tiles in the vestibule blowing out of their tracks because of high wind pressure. The simulations performed sought to determine the location and amount of the highest wind pressure exerted on the roof's surface as well as in the vestibule. This study also analyzed the impact that the inclusion of an outlet had for the wind

Sponsoring Firm: R.L. Engebretson Holding Inc., Fargo, North Dakota.

Graduate Research Assistant: Amy Klindworth

Principal Investigator: Dr. Ganapathy Mahalingam

Date: Fall 2014

Mapping Uniformat Assembly Codes onto MasterSpec Specification Sections

Project Description: Mapping of Uniformat II Assembly Codes onto appropriate MasterSpec specification sections and creation of mapping table and binding manager in e-Specs for Revit.

The goal of this research is to connect two different types of construction standards, MasterSpec specifications and Uniformat Assembly Codes. There is an emphasis on Uniformat Assembly Codes in this research as Revit uses these codes for its components and families. By connecting MasterSpec to these codes, entire specification books can be produced through the information contained in the digital model. Completing a master database of these connections will enable a design firm to complete the specification phase simultaneously with the design of the digital model.

Sponsoring Firm: R. L. Engebretson Holding, Inc., Fargo, North Dakota

Graduate Research Assistant: Joshua Donnelly

Principal Investigator: Dr. Ganapathy Mahalingam

Date: Fall 2014

Implementation of BIM Integration in Practice

Project Description: The Design Team assigned to the project in the Department of Architecture and Landscape Architecture at North Dakota State University shall help R. L. Engebretson Co. implement the integration of the various software pieces identified below, according to a framework and work flow to create an integrated building information model for its projects using the Revit software as a base, and which includes the following:

1. Development of a deployment framework for the integration of various BIM tools for practice.
2. Deployment and training in the use of the Assemble software platform for practice.
3. Deployment and training in the use of BIM Glue 360 for practice.
4. Deployment and training in the use of Bluebeam Revu for practice.

The deployment and training shall occur with weekly meetings at the R. L. Engebretson Co. office in Fargo, North Dakota. The graduate research assistant from the Design Team shall meet with personnel from R. L. Engebretson Co, on Mondays and Thursdays of the week from 1:30 PM to 5:30 PM for the deployment and training. The faculty advisor and the graduate research assistant shall also meet with the implementation team at R. L. Engebretson Co, once every week on Monday afternoon at 2:00 PM for up to 2 hours to review progress with the implementation.

Sponsoring Firm: R. L. Engebretson Holding, Inc., Fargo, North Dakota

Graduate Research Assistant: Joshua Muckenhirn

Principal Investigator: Dr. Ganapathy Mahalingam

Date: Spring 2014

Study of Collaboration in Higher Education

Project Description: Collaboration in Higher Education

This project involves identifying the architectural characteristics of spaces that facilitate collaboration in higher education, deriving the spatial organization and circulation patterns that facilitate collaboration, and simulation of collaborative environments. This project is in partnership with the architecture firm BWBR located in St. Paul Minnesota. BWBR has been hired for the new Science and Technology building to be built at North Dakota State University. BWBR is responding to the request, by NDSU president Dean Bresciani, that the new building become a center for higher education collaboration.

Scope of Work: This project will involve identifying the architectural characteristics of spaces that facilitate collaboration in higher education, deriving the spatial organizations and circulation patterns that facilitate collaboration, and simulating collaborative environments using AnyLogic to determine how they perform under different conditions. The purpose of the project is to come up with the best strategies to design collaborative spaces for higher education. The student will proceed with an in-depth exploration of collaboration in higher education environments, addressing the following research questions:

Mentors: Stephanie McDaniel, AIA, LEED AP BD+C and Stefnee Trzpuc, MS, CID, EDAC, LEED AP

- Where does collaboration happen in higher education environments?
- What are common design elements to those areas/spaces? (e.g., what facilitates collaboration – places, properties, actions, attitudes)
- How will collaboration change over the next decade? Subsequently, how does that impact space needs in a learning environment?

The following methods (in addition to others as approved by firm and faculty) should be considered: (BWBR has some tools developed – could look at building on those...)

- Literature review
- Observations
- Interviews/Focus Groups/Surveys
- Simulation Tools (AnyLogic) to study agent-based and discrete-event simulation to study how people cluster
- Behavioral MappingSpace Syntax Theory

Deliverables:
- A report with findings from the above tools, including a literature review.
- Graphic reporting of findings (e.g., easy to read graphic analysis – info graphics, etc.)
- Proposed design strategies to support future collaboration needs in higher education (what types of spaces could be potentially 'sandbox' tested (e.g., create ad hoc study spaces on campus and study effectiveness) the following semester to inform the current NDSU project

Student/Firm/Faculty Interface:
- Bi-weekly email/WebEx
- Mid-term Report Review
- Final Report Review

Sponsoring Firm: BWBR, St. Paul, Minnesota

Graduate Research Assistant: Matthew Dunham

Principal Investigator: Dr. Ganapathy Mahalingam

Date: Fall 2013

Implications of Changes in the Energy Code

Project Description: Implications of changes in the energy code

Scope of Work: The student will proceed with an in-depth exploration of implications of recent changes to the energy codes as it relates to building insulation requirements. The student will address the following research questions:

- What are the current required U values for building assemblies in each state in the Upper Midwest?
- What changes have been made in each of these states recently? Are future changes coming?
- What is the return on investment for 3" vs. 2" of extruded polystyrene?
- What are the benefits of the available insulation options including extruded polystyrene, polyisocyanurate, and mineral wool (cost / performance, embodied energy, carbon effect...)
- How do the comparison developed by the student compare to those developed to modeling developed for the Energy Design Assistance program?

Recent changes in the energy code have led our practice to revise our typical exterior wall insulation from 2" extruded polystyrene insulation to 3". After developing an understanding of the code issues we would like to understand the return on investment for additional insulation and the most effective types of insulation. The student will address the following research questions:

The following methods (in addition to others as approved by firm and faculty) should be considered:

- Literature review
- Simulation Tools to study thermal performance of wall assemblies (Autodesk Simulation 360 Pro, Energy Plus)

Deliverables:

- A summary of applicable codes and standards [State energy codes, ASHRAE, NFPA (flame spread issues relative to exterior wall insulation)].
- Graphic reporting of findings (e.g., easy to read graphic analysis – info graphics, etc.)

Student/Firm/Faculty Interface:

- Bi-weekly email/WebEx
- Mid-term Report Review
- Final Report Review

Sponsoring Firm: BWBR, St. Paul, Minnesota

Mentors: Eric West, AIA, LEED AP and Jesse Turck, AIA, LEED AP BD+C

Graduate Research Assistant: Leah Fagerland

Principal Investigator: Dr. Ganapathy Mahalingam

Date: Fall 2013

Construction Scheduling of BIM Model

Project Description: The Design Team assigned to the project in the Department of Architecture and Landscape Architecture at North Dakota State University shall develop a construction schedule based on the BIM Model of the Groat Point residence, which includes the following:

1. Incorporating parts and assemblies into the various building components of the BIM model of the Groat Point residence.
2. Enabling the construction scheduling of the BIM model of the Groat Point residence, with the aim of reducing construction time from 26 months to 18 months.

Industry Foundation Classes, or IFCs for short, exist for the safe transfer of digital building information between professions. The language of IFC has been prevalent between some architectural firms and their corresponding engineering firms since the inception of BIM (Building Information Modeling). The transfer of this IFC data between persons, programs, and business systems has allowed for a much-enhanced project delivery, resulting in less waste, less frustration, less money spent, and consequently less construction time. However, as it is, only few firms utilize BIM technology, and fewer understand and/or utilize Industry Foundation Classes. Though there is relatively clear dialogue between the designer and engineer via standardized technology, there is much dissonance between 'architecture language' and 'contractor language.' This project provides analysis into the topic of Industry Foundation Classes as the interoperable language between architect and contractor, and how IFCs can be utilized effectively by both architect and general contractor in creating a smarter construction schedule, thereby reducing construction time. It aims at providing hope for the dissemination of this knowledge to all professions involved in the building trades, and for better communication of information between architect and contractor.

Sponsoring Firm: Kristi Hanson Architects, Palm Desert, California

Graduate Research Assistant: Matthew Weiss

Principal Investigator: Dr. Ganapathy Mahalingam

Date: Fall 2013

Integrated BIM Models

Project Description: The Design Team assigned to the project in the Department of Architecture and Landscape Architecture at North Dakota State University shall develop a framework and work flow to create an integrated building model using the Revit BIM software, which includes the following:

1. Integration of specifications with a BIM model using Revit and e-Specs.
2. Integration of cost data with a BIM model using RS Means cost data and proprietary information.
3. Integration of construction scheduling information with a BIM model and linking it to project management software.
4. Integration of operation and maintenance documents with a BIM model with an easy to use dashboard.

Student Statement: The goal of this Graduate Research Assistantship is ultimately to discover and document various methodologies for integrating and linking numerous documents to one 3D Model. Through this investigation, I hope to successfully document, step-by-step, how such integrations can be implemented and utilized to increase the efficiency of BIM modeling. Virtual 3D modeling is no longer sufficient for the Architecture and Construction industries. Project members and owners are demanding a more cohesive methodology for communicating throughout the design and construction processes, and even into post-project occupancy. Throughout the design and construction of a project, there are numerous models each illustrating a different system within the building such as an Architectural model, a Mechanical model, a Structural model, and so on. Having separate models can hinder the construction process by slowing down communication between offices. With holistic BIM modeling, the communication process can be revitalized and revolutionized by merging all models into one cohesive and integrated model with access to all necessary documents and information used both during the construction process, and after the building has been completed.

Sponsoring Firm: R.L. Engebretson Holding, Inc., Fargo, North Dakota

Graduate Research Assistant: Joshua Muckenhirn

Principal Investigator: Dr. Ganapathy Mahalingam

Date: Fall 2013

Integration of LEED Performance Criteria in a BIM Model

Project Description: The Design Team assigned to the project in the Department of Architecture and Landscape Architecture at North Dakota State University shall develop a framework and work flow to integrate LEED performance criteria into a building model using the Revit BIM software, which includes the following:

1. Identification of relevant LEED performance criteria.
2. Investigation of methods to integrate the LEED performance criteria with building components.
3. Integration of performance criteria into the building model to provide for easy extraction for LEED certification analysis.

Building Information Modeling, or BIM, is the best way to manage every aspect of a project building. The only aspect that is missing is sustainability. While it may be apparent, it is not easily managed my most programs under the BIM envelope. LEED is the prominent resource for managing sustainable criteria for a project building, with incentive to award a building certification for being green. There is currently no easy or well-defined way to incorporate LEED criteria with the BIM environment. This research explores the fusion of LEED and BIM using Autodesk Revit as the central management system for a project building. The core methods in this fusion include creating a LEED template for Revit to manage supplementary documentation and using Revit parameters to define critical green building criteria for a project.

Sponsoring Firm: R. L. Engebretson Holding, Inc., Fargo, North Dakota

Graduate Research Assistant: Jakob Lawman

Principal Investigator: Dr. Ganapathy Mahalingam
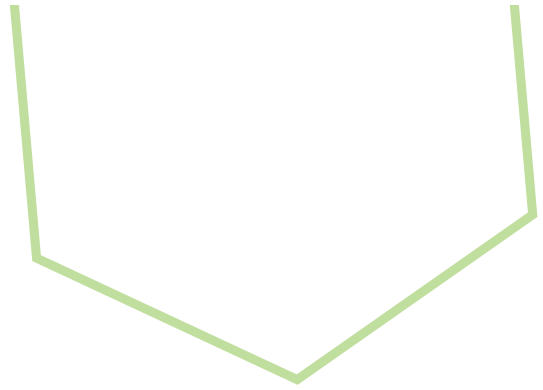
Date: Fall 2013

Selected Research Reports of Research Projects from 2017 to 2013

ACT FOR CHILDREN

A Study of How Architecture Can Foster Development
During the Stages of Early Childhood

Kelsey Jarrett
ARCH 771. Fall 2017
Dr. Ganapathy Mahalingam.

DEFINITIONS

DAYCARE

"The care of a child in a residence outside the child's own home for gain or otherwise, on a regular basis, for any part of a 24 hour day"(Minnesota administrative rules, human services department, chapter 9502.0315).

INFANT

"A child who is at least six weeks of age but less than 12 months of age" (Minnesota administrative rules, human services department, chapter 9502.0315).

CHILD

"A person ten years of age or younger" (Minnesota administrative rules, human services department, chapter 9502.0315).
Newborn

NEWBORN

"A child between birth and six weeks of age"
(Minnesota administrative rules, human services department, chapter 9502.0315).
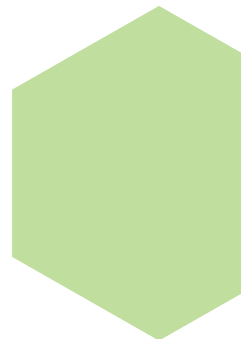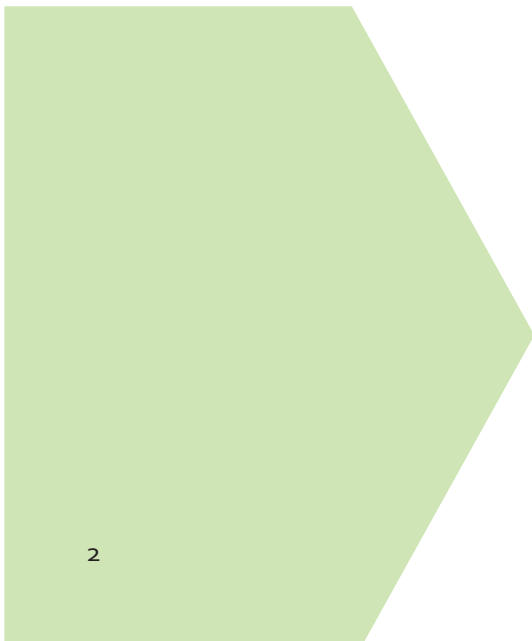
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ABSTRACT

What role does architecture play in fostering the stages of early childhood development? The first five years of a child's life are the most crucial years of their developmental process as they grow not only physically but also cognitively, socially and emotionally. Children are impressionable human beings drastically impacted by their surrounding environments. Through design, we can enhance the lives of the users through well informed environments that are not only healthy but safe, functional and beautiful. This paper seeks to investigate the stages of development and identify key prepared environments that facilitate learning in early child development. The results suggest that, in terms of the ideal environment for children, not one prepared environment takes precedent over the others. Scale, light, color, safety, security, spatial arrangement, and nature all play an integral role in the development of children. Designing for children is no simple task. As designers we have the responsibility and ethical duty to provide a comprehensive analysis on the needs of our clients. It is our role to ensuring a healthy and nurturing environment while providing a developmentally appropriate and stimulating environment to our nation's youngest generation.

KEYWORDS

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EARLY CHILDHOOD DEVEOPMENT

"From birth through age five, moving from the bassinet to the schoolyard, young children develop at a faster pace than any other time in their life" (Shonkoff & Phillips, 2000). Each day, month and year of a child's life represents the beginning of a new stage of development. Every year of a child's life is precious, but the first three are important because of the rate of growth and learning (Olds, 2001). Four key areas of study for developmental psychology are cognitive, which is the mental process of knowing; social, which looks at how individuals interact with others and social situations; emotional, which studies how people process and cope with understanding emotions of oneself and of others; and lastly physical, which concentrated on gross and fine motor skills as well as puberty (May, 2011). It's important to realize that "every child grows and develops at his or her own pace. Still, development tends to follow a predictable path" (Mayo Clinic Staff, 2010).

A comprehensive study of the developmental milestones of a children's life will enable a thorough understanding of what built environments support and enhance optimal development. The following content provides insight into a children developmental stages from birth to five years of age, as this is the age range of children enrolled in child care centers.

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BIRTH TO EIGHTEEN MONTHS

FIVE-YEAR-OLD

EIGHTEEN MONTHS TO TWO YEARS

FOUR-YEAR-OLD

THREE-YEAR-OLD

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BIRTH TO EIGHTEEN MONTHS

"In the first eighteen months after birth, an infant makes miraculous progress" (California Department of Education, 2016). Erickson referred to this time as the oral sensory stage where newborns use their reflexes; sucking, grasping, staring, and listening to begin to experience and discover the world around them (as cited in Morrison, g. s. 1991). During this time, mothers loving and caring attention towards a child is crucial in establishing a trusting relationship. Failure to experience trust will result in feeling worthlessness and mistrust (Morrison, g. s. 1991). Also, during this time in development, infants begin to experience the world through taste, smell, sight, and sound. One way to help foster learning amongst infants is provide a stimulating environment but not overwhelm them. If a child becomes over stimulated, the brain begins to experience stress which is not optimal for enhancing development. Remember, the foundation of learning is laid during the first five years as children are experiencing profound changes (Olds, 2001). Any little or big obstruction could be detrimental later in life. "A newborn infant is born into a new world with no prior knowledge or experiences of time, space, color and form. Such ideas must be built upon sensory experience and the ability to submerge oneself into independence and distinguish things in his environment and what the purpose is" (Standing, E. 1962). As professor William James said, "the universe is nothing but a big, buzzing, booming confusion" (as cited in Standing, E 1962) for infants. Parents, and caregivers are responsible for providing interactions during these first few months which will provide a foundation for greater successes.

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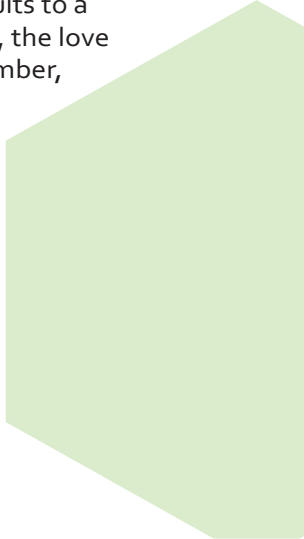|	Birth to Eighteen Months
Social and Emotional	-"Infants at this age develop feelings of trust and attachment through being held or having someone talk to them and respond when they fuss or cry" (Brotherton, S.,2006). -"Learning to read emotion and express it through observation and imitation" (Brotherton, S.,2006). -"By one month of age, infants display emotions" (Brotherton, S.,2006). -By 4 months, can recognize faces and feelings of caregivers (Brotherton, S.,2006). -Temper tantrums (Centers for Disease Control and Prevention. 2017). -Soon after a discovery is made, one-year-olds will try and make it happen again (Centers for Disease Control and Prevention. 2017). -Imitate caregivers weather it may be making similar faces or copying similar sounds (Oesterreich, L.1995) (Centers for Disease Control and Prevention. 2017).
Language	-Children show what they want through pointing or shaking their heads "yes" or "no" (Centers for Disease Control and Prevention. 2017). -Imitation of adult conversations and actions (Oesterreich, L.1995). -First words are mentioned by 12 months (Oesterreich, L.1995). -Mama and dada (Centers for Disease Control and Prevention. 2017). -Points to objects they want (Centers for Disease Control and Prevention. 2017). -Vocabulary is limited but can speak several singular words. (Centers for Disease Control and Prevention. 2017).
Cognitive	-"Points to one body part" (Centers for Disease Control and Prevention. 2017). -Identifies ordinary things (Centers for Disease Control and Prevention. 2017). -Smiles at 2 months (Morrison, g. s.1991). -At the age of one, writing is still not developed but experimenting with writing utensils often takes place (The Public Broadcasting Service. n.d.).
Physical	
0-3 months	-Arms and legs begin to move actively (Centers for Disease Control and Prevention. 2017). -Suck and grasp everything within reach (Morrison, g. s.1991). -Holds head up (Centers for Disease Control and Prevention. 2017). -Lifts head up and begins to follow objects (Bee,1992)
3-6 months	-Rolling over (Morrison, g. s.1991) (Centers for Disease Control and Prevention. 2017). -Sits up properly (Centers for Disease Control and Prevention. 2017). -Grasps for objects (Morrison, g. s.1991). -Sits propped up with support of pillows (Centers for Disease Control and Prevention. 2017) (Oesterreich, L.1995). -Reaches for objects (Bee, 1992). -Lifts head and chest when experiencing tummy time (Centers for Disease Control and Prevention. 2017).
6- 9 months	-Sits without assistance of a pillow (Oesterreich, L.1995). -Moves around by crawling (Morrison, g. s.1991). -Begins crawling even upstairs (Olds, 2001). -Moves objects from one hand to the other (Bee, 1992). -"Rolls from back to stomach and stomach to back" (Oesterreich, L.1995). -Grabs for drinks but stills needs assistance well drinking (Oesterreich, L.1995). -Teeth appear (Oesterreich, L.1995).
9-18 months	-"Pulls up to stand" (Centers for Disease Control and Prevention. 2017). -Walks and pulls toys without assistance (Centers for Disease Control and Prevention. 2017) (Morrison, g. s.1991). -"Rolls ball to adult (Bee, 1992).

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EIGHTEEN MONTHS TO TWO YEARS

At this age, toddlers begin to experience a vast amount of new emotions including; frustration, anger, excitement curiosity, independence, shame and guilt (Lee, 1977). This flood of emotions will often lead to resistance to suggestions by adults and lead to extensive mood swings such as; dependence to independence; eagerness to irrigation; and friendly co-operation to resistance (Lee, 1977). Though, children are experiencing a variety of different emotions, they are beginning to think about how they feel, and how feelings relate to words. Intense curiosity about everything, including the environment, allows for exploration and investigations but is often interrupted by the short attention span of young children (Lee, 1977).

Generally, children at 18 months are busy imagining and creating through pretend play such as feeding a doll (Center for Disease Control and Prevention, 2017). It is very common to see young children at this age engaging in occupations or roles such as; sweeping the floor, vacuuming the carpet or stirring a pot (Standing, E. 1962). Each ordered movement has an attended purpose, in this case, linking the mind and body as one instrument (Standing, E. 1962). This assumption of the mind and body becoming one instrument can be linked to walking alone, eating with a spoon, undressing, drinking from a cup and pulling toys when walking (Center for Disease Control and Prevention, 2017).

Around two years of age, children are increasingly active by walking up and down stairs and running (Center for Disease Control and Prevention, 2017). Independence is beginning to form when toddlers start self-feeding and controlling their bladder (Lee, 1977). Although, children begin on this adventure towards independence, occasional tantrums, nightmares and irrational fears way serve as hurdle (Lee, 1977). It is no wonder why parents refer to this stage of development as the "terrible twos". The struggle between reliance on adults to a sudden desire for independence can occur with a "flick of a light switch". However, the love and affection demonstrated by children outweighs all the temper tantrum. Remember, during each stage of development children need role models.

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	Eighteen Months to Two Years
Social and Emotional	-Experiences new emotions; anger, guilt, shame, excitement, joy, and sadness through temper tantrums (Dosman C, Andrews D, 2012) -Anxiety fades from separation (Mayo Clinic Staff. 2010) -Begins to recognize and manage feelings (The Public Broadcasting Service. n.d.). -Finds pleasure in completing tasks (The Public Broadcasting Service. n.d.). -Imitates peer's actions (The Public Broadcasting Service. n.d.). -Enjoys affection from adults because of increased separation anxiety (Dosman C, Andrews D, 2012) -Begins to understand symbolic representation (Dosman C, Andrews D, 2012)
Language	-"Says several single words" (Centers for Disease Control and Prevention. 2017). -"Says sentences with 2 to 4 words" (Centers for Disease Control and Prevention. 2017). - "Speak about 50 words" (Mayo Clinic Staff. 2010). -Quickly learning new words established by their environment. Pronunciation is still challenging (The Public Broadcasting Service. n.d.). -Understands simple sentences much as "I want mum" and "no" (The Public Broadcasting Service. n.d.). -Absorbing the language all around them (The Public Broadcasting Service. n.d.).
Cognitive	-"Finds hidden objects" (Mayo Clinic Staff. 2010). -Demonstrates understand that specific objects belong together (Centers for Disease Control and Prevention. 2017 -Enjoy sensory exploration (The Public Broadcasting Service. n.d.). -Points to others for attention (Centers for Disease Control and Prevention. 2017). -Manages toys by shape and color (Mayo Clinic Staff. 2010).
Physical	-"Walks alone" (Mayo Clinic Staff. 2010) -Crawling up stairs, climbs on object, and begins to run (Mayo Clinic Staff. 2010) -Walks on his or her own but may struggle to move around objects (Centers for Disease Control and Prevention. 2017) -Pulls toys as a means of walking (Centers for Disease Control and Prevention. 2017). -Fine motor skills are developing but still are immature (The Public Broadcasting Service. n.d.).

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THREE-YEAR-OLDS

At the age of three, children can generally be classified as happy and companionable little human beings who demonstrate the need for opportunity which afford them an increasing level of independence (Lee, 1977). During this age children learn primarily through exploration utilizing all the five senses; smell, touch, sound, taste and sight. While playing, child can ignore distractions and continuing completing the task on hand. Preschoolers at the preoperational stage of development use their perceptions of the environment, along with bits of information gathered during their past experiences, to understand their world (Miller, n.d.).

Also, during this age language begins to take off making major improvements with pronunciation, grammar, sentence structure and rhyming (Mayo Clinic Staff, 2016). Children also become eager to initiate conversations with parents, peers and teachers discussing areas of interest and personal experiences (Centers for Disease Control and Prevention. 2017). Their interactions with family and those around them help shape their personality and help develop their own way of thinking. As mentioned earlier language begins to take off during this stage, meaning that children are aware of numbers often represented by proudly raising the correct amount on their fingers. Thus, children begin to recognize numbers from one to nine often counting items in groups while labeling each object with a number or two (Mayo Clinic Staff, 2016). The complexity of counting without seeing physical objects will often be accomplished closer to kindergarten but should not be limited by the intelligence of a three-year-old.

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	Three-Year-Old
Social and Emotional	-Imaginary companions (Dosman C, Andrews D, 2012). -Group and peer play (Dosman C, Andrews D, 2012). -Begin to build and show affection to familiar peers; teachers, parents, and friends (Centers for Disease Control and Prevention. 2017). -Children will show a wide range of emotions. During this time a sense of individuality and personal preferences are developed. (Centers for Disease Control and Prevention. 2017). -"Imitates parents and playmates" (Mayo Clinic Staff. 2010). -Expresses feelings, needs and opinions. Emotions are not limited to sadness, anger, happiness or boredom. (Mayo Clinic Staff. 2010) (Centers for Disease Control and Prevention. 2017). -Grasps the concept of "mine" and "his/hers" (Centers for Disease Control and Prevention. 2017). -Seeks approval by parents (Oesterreich, L.1995). -Play with other children but prefers to play independently (Oesterreich, L.1995).
Language	-"Carries on a conversation using 2-3 sentences" (Centers for Disease Control and Prevention. 2017). -Identifies and names familiar objects (Centers for Disease Control and Prevention. 2017). -"Speaks 250 to 500 or more words" (Mayo Clinic Staff. 2010). -"Vocabulary growth in number words, emotional state words, common category names, and common family member names" (The Public Broadcasting Services. n.d). -"Continues to increase their vocabularies for nouns, pronouns, action words, descriptive words, quantifiers, location words, connecting words, and question words". (The Public Broadcasting Services. n.d).
Cognitive	-Enjoys listening to stories, conversations and music (The Public Broadcasting Services. n.d). -Fantasizes and enjoys dramatic play (The Public Broadcasting Services. n.d). -"Understands the concept of same and different" (Centers for Disease Control and Prevention. 2017). -Repeatedly asks why questions (Mayo Clinic Staff. 2010) -Can work with simple 3 or 4-piece puzzles (Centers for Disease Control and Prevention. 2017). -Identifies and speaks the names of colors (Mayo Clinic Staff. 2010) -Recognizes common sounds (Oesterreich, L.1995).
Physical	-Weights on average of 25-44 pounds (Oesterreich, L.1995). -Very active in climbing and running (Mayo Clinic Staff. 2010). -The ability to walk up and down stairs (Mayo Clinic Staff. 2010). -"Move with greater sureness" (The Public Broadcasting Services. n.d). -"Climbs well" (Centers for Disease Control and Prevention. 2017).

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FOUR-YEAR-OLD

"Preschoolers are avid learners, eager to master skills, agile to their feet, able to manage tools and implements, and beginning to show interest in child-to-child social life and play" (Olds, 2001). When it comes to learning, four-year-old are developing self-control and ingenuity (Public Broadcasting Services, n.d). Their pretend play is more complex and imaginative and can be sustained for longer periods (Public Broadcasting Services, n.d). Play becomes a critical key component to the development of a child. A simple plastic toy seen as an object by many, simply transforms into an object manipulated by a child's imagination (Centers for Disease Control and Prevention. 2017) (Mayo Clinic Staff, 2016) (Public Broadcasting Services, n.d). For example, a boat is merely not just a boat in the complex minds of a child, it is the wind whispering past the ears and the crew members, imaginary playmates, suddenly taking cover to avoid the piercing winds amongst their faces. Though this seems simply abstract during this age, it demonstrates learning and imagination in and of itself.

Additionally, four-year-old begin to experience significant social and emotional growth. During this time, child continue to learn what actions trigger certain emotional responses while acknowledging that others may react to the same situation differently (Public Broadcasting Services, n.d). Over time children will become more independent in managing their own feelings well utilizing a variety of different coping strategies (Public Broadcasting Services, n.d). Children develop self-control and appropriate emotional expression by observing how others manage their emotions and experiences. For instance, if a child experiences a routine checkup at the doctor's office, he or she may imitate the experience with Barbie's or stuffed animals. Also, four-year-olds are socially beginning to show progress in developing friendships while continuing to seek guidance from adults if problems with other children arise (Centers for Disease Control and Prevention. 2017) (Mayo Clinic Staff, 2016).

As children near the age of five, the transition to kindergarten can be a difficult time for any parent, child, and educators. During these significant changes, children need love, patience, understanding and genuine attention (Centers for Disease Control and Prevention. 2017). Though this transition is a bit overwhelming, with new rules and new friends, support and guidance from parents and educators are sure to assist in this difficult process.

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	Four-Year-Old
Social and Emotional	-Develops self-control over emotions (Dosman C, Andrews D, 2012) -Children develop independence, self-control and creativity (The Public Broadcasting Service. n.d.). -Engages with others and shows consideration in pleasing friends (Centers for Disease Control and Prevention. 2017). -Copes with emotions (The Public Broadcasting Service. n.d.). -Shows vast improvement in social interactions (The Public Broadcasting Service. n.d.). -Enjoys participating in new things (CWenters for Disease Control and Prevention. 2017). -Expresses interests and likes/dislikes (Centers for Disease Control and Prevention. 2017). -Engages in make-believe play (Centers for Disease Control and Prevention. 2017).
Language	-Understand words associate with sounds (The Public Broadcasting Service. n.d.). -Begins to ask questions (Oesterreich, L.1995). -Recognizes similar words in the environment Oesterreich, L.1995). -"Can say first and last name" (Centers for Disease Control and Prevention. 2017). -Understands basic grammar (Centers for Disease Control and Prevention. 2017). -"Tells stories" (Centers for Disease Control and Prevention. 2017).
Cognitive	-Ability to track and differentiate between the seasons and different times such as morning, afternoon and night (Mayo Clinic Staff. 2010) (Centers for Disease Control and Prevention. 2017). -During story time children will being to pay attention to the story sequence; beginning, middle, and end (Centers for Disease Control and Prevention. 2017). -Understanding and practicing pre-math skills (The Public Broadcasting Service. n.d.). -"Understands the idea of counting" (Centers for Disease Control and Prevention. 2017). -Hands on exploration helps distinguish reality from fantasy (The Public Broadcasting Service. n.d.).
Physical	-Starts to get ready independently (Mayo Clinic Staff. 2010) -Fine motor skills continue to develop such as using scissors (Mayo Clinic Staff. 2010) -"Hops and stands on one foot up to 2 seconds" (Centers for Disease Control and Prevention. 2017). -Shows improved hand-eye coordination (Centers for Disease Control and Prevention. 2017) (The Public Broadcasting Service. n.d.). -Hopping, walking, jumping, running, climbing trees and walking with confidence (The Public Broadcasting Service. n.d.).

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FIVE-YEAR-OLD

Every day, every hour, every minute you and your children will learn a little more about each other. "School-age children physically are a ball of energy seeking any games or environments which provide them unstructured free play" (Lee, 2017). Playtime outdoors has become I whole new scene with scooters, bicycles, and jump ropes. (Lee, 2017) (The Public Broadcasting Service. n.d.). At this stage of development, children gain strong social-emotional capacity (self-confidence, self-control, communication and cooperation), become motivated to learn and lastly develop intellectual skills (Dosman, C. F., Andrews, D., & Goulden, K. J. 2012). This new-found courage encourages continuous exploration and pushes children to expand on their abilities. It is no surprise that your once shy toddler has turned into a social butterfly. Though, "often content to play alone for long periods, mastering a skill, but also plays with other children, especially in building and imaginative play" (Lee, 1977). A noticeable shift in the child's social and emotional development becomes evident through the empathy and concern shown for others. Because of an increase in self-confidence, the language skills are well developed, and children begin to ask deeper questions as a mechanism for cognitive development (The Public Broadcasting Service. n.d.). Because of the increased awareness of the world around them, children begin to understand that other people can form opinions about them and acceptance from others becomes more important (The Public Broadcasting Service. n.d.).

"Five-year-old children have left their teetering toddler years behind them and are well on their way to becoming more coordinated and precise in their movements as they enter their school-age years" (Lee, 2017). "The average five-year- old can hop and stand on one foot briefly, walk with alternating feet on a balance beam, and catch an 8-inch ball with elbows near the body" (Olds, 2001). Fine and large motor skills, continue to become more refined as children cut pictures out of magazines, skip, jump, climb, use a fork and spoon and string beads on a strand of yarn (Centers for Disease Control and Prevention. 2017). As five marks the beginning of a new adventure for most children, learning to cope with a new environment can be overwhelming. The environment where 4 strands of development occur; emotional and behavioral, cognitive and intellectual, physical and motor, and social and language deserve close attention to insure a proper setting that stimulates development and progression (May 2011).

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|	Five-Year-Old
Social and Emotional	-In Nelsons textbook of pediatrics by Feigelman it states that children manage feels and emotions with greater independence. (as cited in U.S. National Library of Medicine. 2017) -Social beings who enjoy learning new things and prefer engaging in activities with other children. -"Improved skills for forming and maintaining friendships with adults and other children" (The Public Broadcasting Service. n.d.). -Desire to be like friends (Centers for Disease Control and Prevention. 2017). -Understands the difference between genders (Centers for Disease Control and Prevention. 2017). -Understands the difference between "right" and "wrong" and begins to follow the rules (Mayo Clinic Staff. 2010). -Begins to experience initiative versus guilt (Morrison, G.S. 1991) -Continues to push the boundaries in attempt to try new things. (Centers for Disease Control and Prevention. 2017).
Language	-"Pronounce words clearly, speak in complex and compound sentences, use grammar for the most part and have good-sized vocabularies that continue to grow rapidly" (The Public Broadcasting Service. n.d.). -Understands the concept of rhyming and begins to use it (Mayo Clinic Staff. 2010) -Pronounces words clearly (Centers for Disease Control and Prevention. 2017). -Speaks words using future tense and compound and complex sentences (Mayo Clinic Staff. 2010). -"Says name and address" (Centers for Disease Control and Prevention. 2017). -Development of language is remarkable (The Public Broadcasting Service. n.d.). -Initiate conversations (The Public Broadcasting Service. n.d.).
Cognitive	-Understands basic shapes and numbers (The Public Broadcasting Service. n.d.). -Begin to do simple subtraction and math (The Public Broadcasting Service. n.d.). -Understands at least 6 body parts (Centers for Disease Control and Prevention. 2017) -Sequence events chronologically (Mayo Clinic Staff. 2010) (The Public Broadcasting Service. n.d.). -"Can count 10 or more objects" (Centers for Disease Control and Prevention. 2017)
Physical	-"Increased abilities to balance and coordinate movements allow them to ride a bike with training wheels, swim, jump rope and perform most ball-related skills". (The Public Broadcasting Service. n.d.). -Balance increases (Centers for Disease Control and Prevention. 2017) -Finger flexibility allows children to engage in writing, (The Public Broadcasting Service. n.d.). -"Hops, swings and somersaults" (Mayo Clinic Staff. 2010). -Engages in most gross motor skills including; jumping, running and climbing. (Centers for Disease Control and Prevention. 2017)

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RESEARCH

The purpose of this project is to illustrate the importance of the built environment on early childhood development. The research presented represents a synthesis of existing research through literature reviews along with observations and interviews. Upon receiving approval form North Dakota State University Institutional Review Board, personal interviews were conducted with two NDSU faculty members. Each interviewee had extensive knowledge and or experience working with young children. The researcher compelled a list of questions which addressed a range of topics that provided insight into the background of early childhood development and optimal learning environments. Based on the information gathered, prepared environments were developed to help inform the design of child care centers that are intended to support the activities of both children and adults.

The target audience for this study includes primarily directors of child care centers, parents, teachers, and architects or other related design professionals. This research can provide insight into ways of improving indoor and outdoor environments which promote optimal early childhood development. It is hoped that children will experience positive outcomes from professionals who apply and review the information obtained from the study.

The procedure for the research study was completed in the following order: (1) Review literature sources supporting the research, (2) Developing the methodology and research instruments. (3) Approval by North Dakota State University Instructional Review Board, (4) Data collection through interviews, case studies, and literary reviews, (5) Documentation and transcription of results, and (6) Analysis and make informed conclusions of the finding.
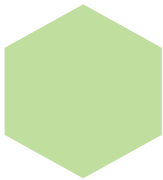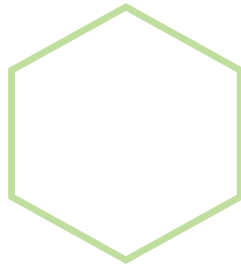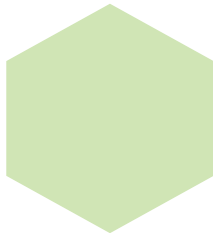

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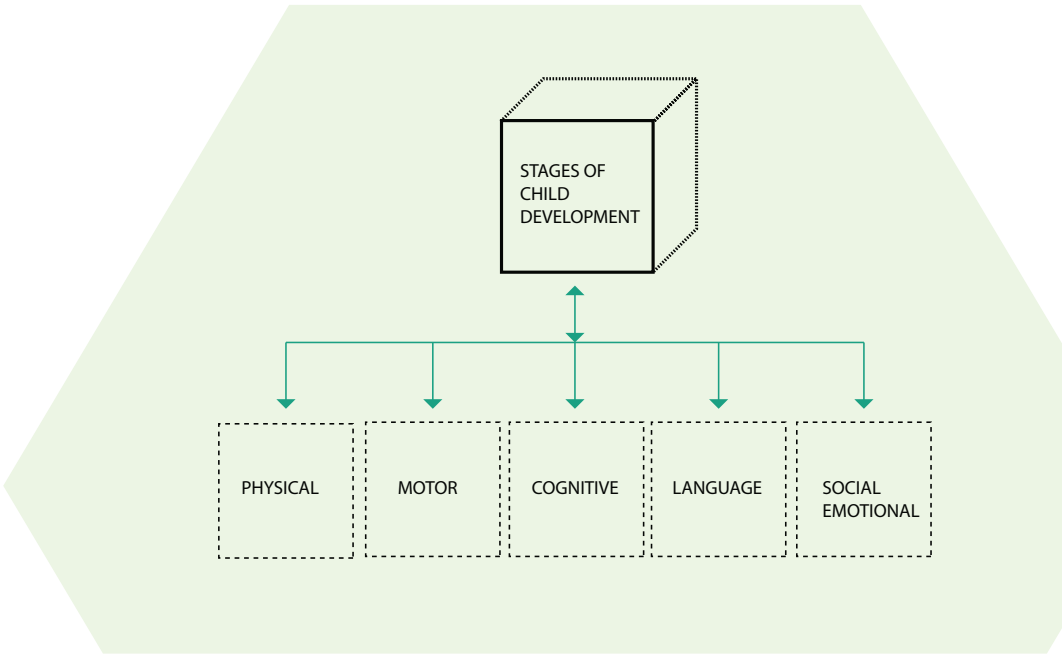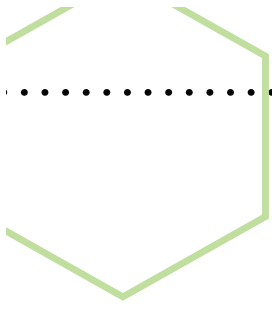
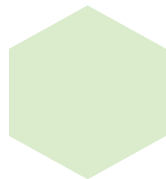COLOR, TEXTURES AND MATERIALS
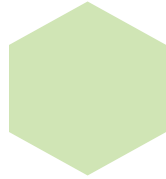
SCALE AND PERSPECTIVE
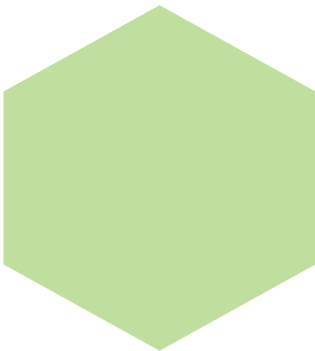
NATURAL AND ARTIFICIAL LIGHTING

ACCESS TO OUTDOORS &
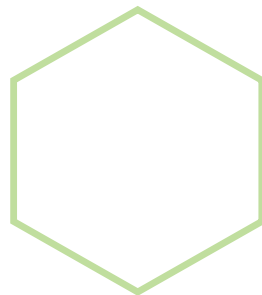CONNECTION WITH NATURE

HOME-LIKE ENVIRONMENTS

OPTIMAL SPATIAL ARRANGEMENTS

ENVIRONMENT WHICH ENCOURAGES
MOVEMENT, COMFORT, COMPETENCE
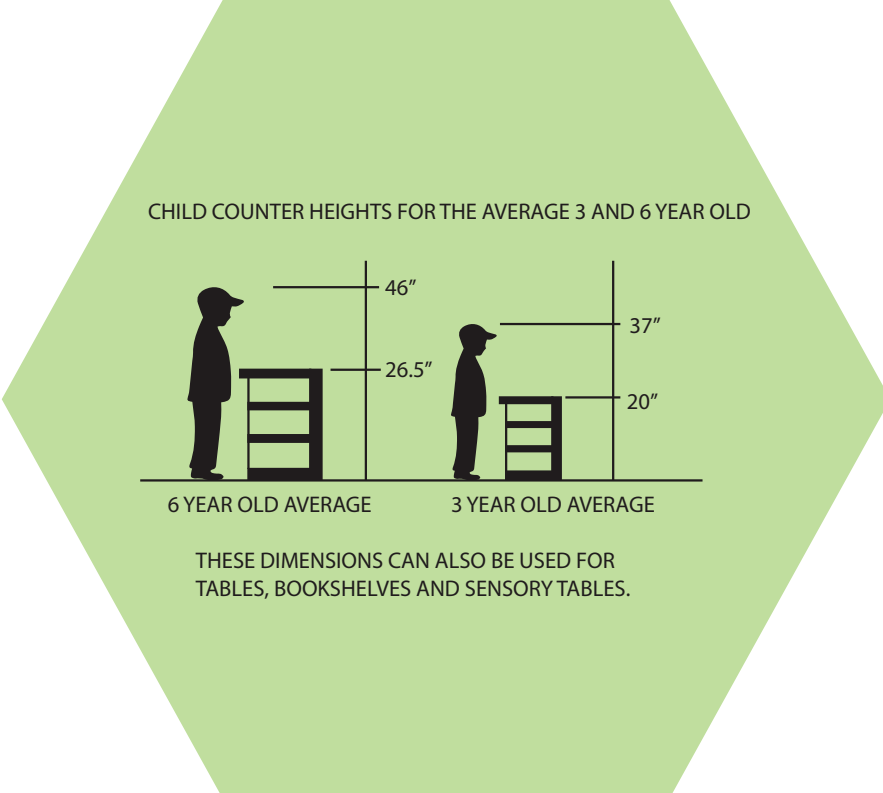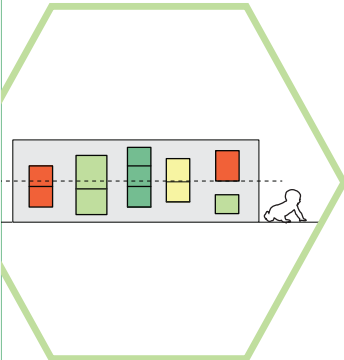AND SENSE OF CONTROL

CONTROL NOISE LEVELS
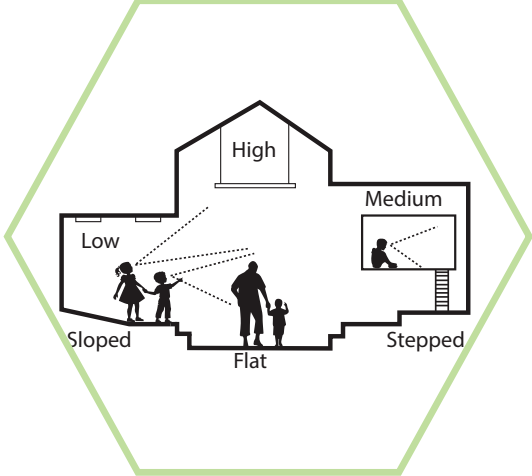
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SCALE AND PERSPECTIVE

Whether we realize it or not, children are affected by their environments which can either produce beneficial or detrimental impacts on children. Architects need to adopt and adjust the buildings scale to fit the growth of a child in terms of not only functionality but also aesthetic value. Any space available for children is viewed as a playground. "Children experience spaces in different ways, and that different spaces have different meanings for children. Experience and meaning both play a role in how knowledge about a space is acquired" (Bell, 2012). For example, take a simple long corridor, adults view this space to get to further spaces or an end destination. Children on the other hand, view this space as a gymnasium or running space. Providing a variance in spatial heights and widths will allow children to discover and explore within.

Scale is an essential element in the design of child care centers because of its prominent effects on the emotional, social and cognitive development of children. Once children start walking and talking, they don't look at people's faces as much (Anonymous 2. 2017, October 18). Providing opportunities for children to get a little higher to the adult level instead of the caregivers always having to get down to the child's level (Anonymous 2. 2017, October 18). In a previous study (Clark, 2007), one of the common design issues identified was scale and perspective in day care facilities. From the research, it was concluded that children paid greater attention to the ground, rooftops and the sky (Clark, 2007). Also, within the environment there were multiple examples that served as a disadvantage to young children. For example, "a typical school entranceway with brick walls appeared very daunting from the perspective of a 3-year old" (Clark, 2007). When designing, it's important to take in account close-up details and consider far-away spaces.

Some architectural solutions to address scale and perspective includes; designing floating clouds on the ceiling to mimic the sky, providing lower shelves and cupboards and lastly provide unique flooring patterns such as circles (Clark, 2007). According to interviewee 1, North Dakota State University achieves scale by draping materials along the ceiling tiles and hanging mobiles or toys from the ceiling. NDSU child care center is located on main campus in E. Morrow Lebedeff Hall. Since the building was originally designed to accommodate adults and college students, unique solutions have been implemented to help lower the ceiling and soften the environment for children of all ages (Anonymous 1. 2017, September 26).

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CHILD COUNTER HEIGHTS FOR THE AVERAGE 3 AND 6 YEAR OLD

46"

37"

26.5"

20"

6 YEAR OLD AVERAGE   3 YEAR OLD AVERAGE

THESE DIMENSIONS CAN ALSO BE USED FOR
TABLES, BOOKSHELVES AND SENSORY TABLES.
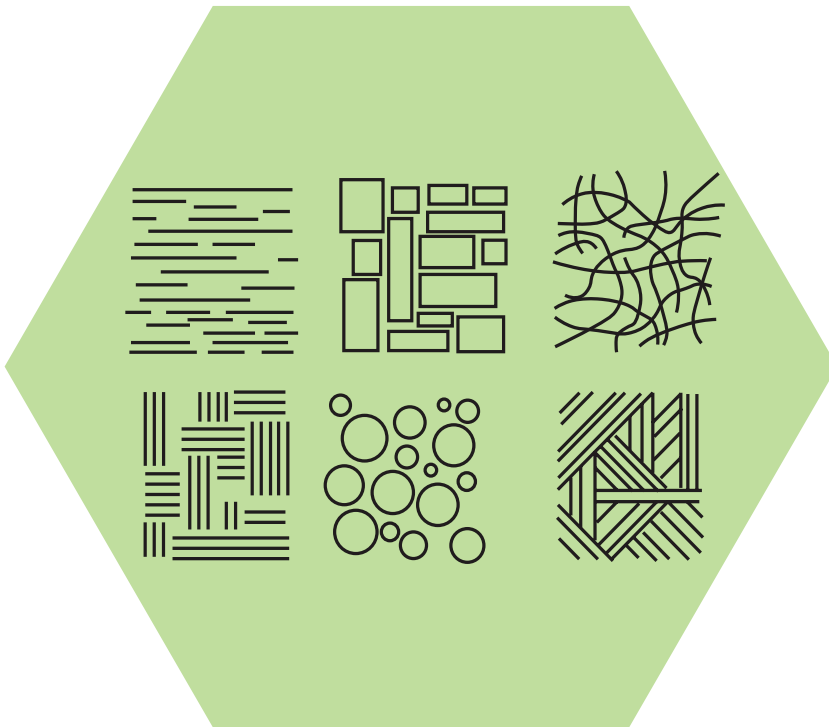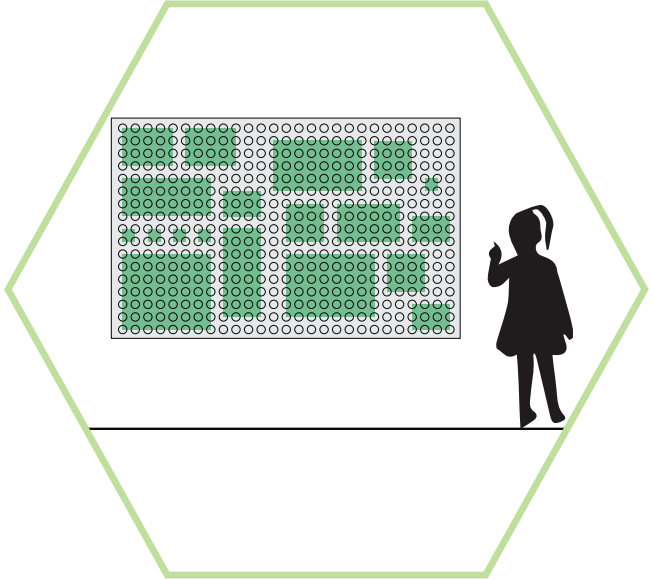
Olds, 2001

High

Medium

Low

Sloped

Flat

Stepped

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COLOR, TEXTURES AND MATERIALS

Color selection in child care centers is a critical component not only for architects but also for interior designers. Color can evoke emotional appeal and if used improperly it becomes very clear physically, cognitively and emotionally. Offering a balance of bright colors and neutral colors will provide children will a comfortable yet an engaging environment. Bright colors should be applied primarily to draw the child's attention to an area, space or object. Softer colors can be used in areas in which the activity evokes and reflects a calmer atmosphere; reading space, napping area and quiet play space. Research as shown that "children are wonderfully sensitive and responsive to nuances in both lighting and color. For example, children are particularly attuned to the colors of nature and human skin tones" (Nair, p & Fielding, R. 2005). As designers we need to be aware that color-aesthetics are highly subjective, and each user may or may not experience different emotional responses. Based on direct observations of the North Dakota State University day care center and based on an interview conducted, neutral colors were used for the toy shelves, carpet, and walls to ensure that the children and the toys within the space can be the color (Anonymous 1. 2017, September 26). From the research conducted, conclusions can be formed that the furnishings and finishes should serve as backdrop to the bright bold toys within that space. However, color is not the only element to consider when design a facility.

Textures and materials are equally important to color. According to interviewee 2, textures is one way to help encourage the sharing of information between children to children or between children to adult. (Anonymous 2. 2017, October 18) Different types of surfaces within an environment allow children to physically touch and explore the environment. Providing these opportunities for children will assist in neurodevelopment. (Anonymous 2. 2017, October 18) "Everything in the outside world shapes development through experiences that a child's senses-vision, hearing, smell, touch and taste-absorb" (Brotherson, 2005). Once these experiences are made, the neural circuits become wired which facilitate learning (Brotherton, 2005). The optimal time for visual development is during the first few months, which allows children to perceive and interact with the world. As indicated from the research, textures are important for the physical, social and emotional development of young children from birth to twelve years of age (Brotherton, 2005).

The Appropriate use of Colors, textures, and materials serve to assist in wayfinding, spatial orientation, space definition and prevent overstimulation. By successfully implementing these tools, architects will not only positively influence development but also provide features which separates the typical institutional space as well as add richness to the environment.

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INTERIOR COLORS, TEXTURES AND MATERIALS

WALLS	- Add a small amount of colors to prevent the institutional feelings - Children's spaces shall be warm symbolizing energy (Earth tones). - Brighter colors should have a matte finish
FLOORS	- Dark colors appear heavy, while light tones show dirt easily. Find a mixed hue color- red, orange, yellow, blue, green or violet with analogous colors -Wood floorings should be used in messy play areas, offices and communal areas - Vinyl Resilient flooring should be used in toilet areas, messy zones, and food preparation spaces. - Carpet should be used in quiet and active areas to ensure comfort
EXTERIOR	- The exterior color scheme should represent the geographical location and should incorporate small drops of color.
Information obtained from Olds,2001 guidelines for color	

(Ogawa, . 2015)

(Krischner & Oberhofer photography, 2015

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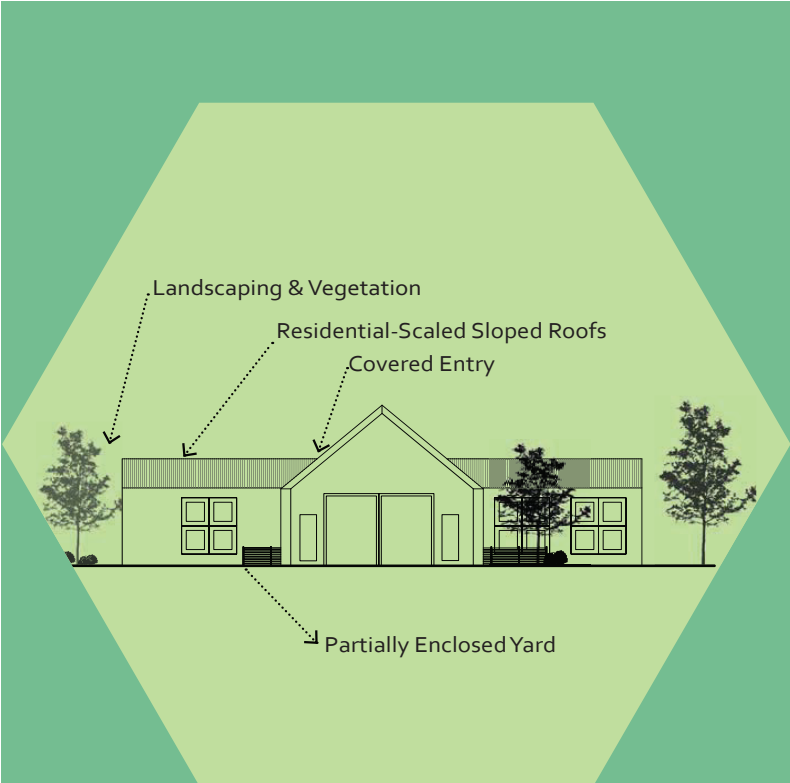
(Sönnecken, E. 2015)

(Tiainen, J. 2014)

(Mørk, A. 2014)

(Huthmacher, W. 2015)

Landscaping & Vegetation

Residential-Scaled Sloped Roofs

Covered Entry

Partially Enclosed Yard

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HOME-LIKE ENVIRONMENTS

Home-like environments have become a template for new educational facilities (Moore and Lackney, 1994). Transitioning from home environments to institutionalized educational facilities is a very difficult time for any young child (Moore, Gary T. and Lackney, Jeffrey A, 1994). Unpredictable environments "increases children's ack of ease and control" (Olds,2001). Providing home-like features such as front yards, front porches, and a friendly entry conditions can help reduce a child's anxiety and help reassure both the child and parent that the interior aesthetics will also successfully reflect a warm and welcoming environment (Moore, Gary T. and Lackney, Jeffrey A. 1994).

Research has shown that children establish symbolic meanings on built elements during their early years (Olds, 2001). "Floors represent support and emotional security, walls represent both separation and enclosure, and a roof symbolize shelter (Olds, 2001). Every object within the built environment teaches children "properties of the physical world and is incorporated into a child's thoughts and feelings (Olds, 2001). Children naturally establish properties and emotional thoughts and feelings towards homey environments. Identification markers such as a gable roofs, reflects the typical form of a home. Also, a low, visible, sloping roofline provides feelings of security (Olds, 2001). By providing children with friendly and welcoming environments this will allow children to establish their own sense of place, sense of belonging and sense of stability. "When children feel comfortable in their physical surrounding, they will venture to explore materials or events around them" (Olds,2001).

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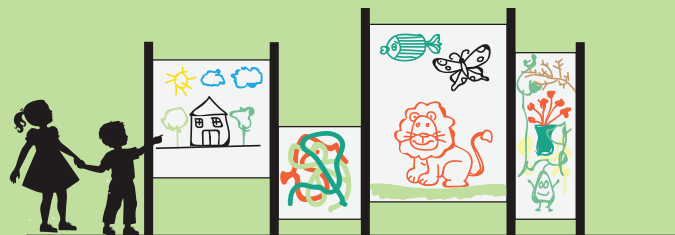
OUTDOOR ENVIRONMENT & NATURE

Doctor Maria Montessori once said that "every child is born as an explorer" (Standing, E. 1962). Any child who is two or three years of age will engage themselves in exploration, experimenting and discovering" (Standing, E. 1962). As architects, they should assist in the natural tendency of children and provide space which will enable them to travel alone maximizing the opportunities for individual growth and research (Standing, E. 1962). Providing easily accessible natural spaces provides many cognitive, social, physical and emotional benefits. Some design strategies to seamlessly integrate nature into the built environment along with successfully design outdoor play areas include;

• Provide a variety of different surfaces so children can take their little scoters out on the cement or have a nice softer material such as grass to watch the clouds go by (Anonymous 1. 2017, September 26).
• Provide transparency between the indoor and outdoor spaces which creates an extension of the indoor learning (Nair, p & Fielding, R. 2005).
• Provide children with specialized equipment.
• Private spaces for individual children (Olds 2001)
• Design spaces for small gardens (Muzaffar, F., & Mirmoradi, S. 2012).
• Allow for areas with different shading (Anonymous 1. 2017, September 26).
• Create views to the natural spaces from the indoors, transparency (Muzaffar, F., & Mirmoradi, S. 2012).
• Divide the play yard into different age groups (Olds,2001)
• Provide landmarks to assist in wayfinding (Olds, 2001)
• Easily accessible storage space (Olds, 2001)

Although this is not a complete compilation of the benefits of connection children to natural environments, one thing is known, outdoor environments are crucial in the development of young children. Regardless if a child is indoors or outdoors, space needs architectural expression well addressing and meeting the needs of young children (Muzaffar, F., & Mirmoradi, S. 2012)

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DEVELOPMENTAL BENEFITS OF PLAY

PHYSICAL

• Healthy body
• Fine & large motor skills
• Stress management
• Confidence
• Coordination
•Establish own interests & passions

EMOTIONAL

• Self confidence
• Empathy
• Impulse control
• Environmental concern
• Awareness
• Increased motivation
• Ability to conquer fears

COGNITIVE

• Inquiry
• Language skills
• Idenpedent thinkin
• Improved concentration
• Reasoning skills
• Observational skills
• Development of senses
• Problem solving
• Increased creativity
• Increased imagination

SOCIAL

•Cooperation
• Collboration
•Socialization
• Increased Language
• Coordination
• Self-efficacy

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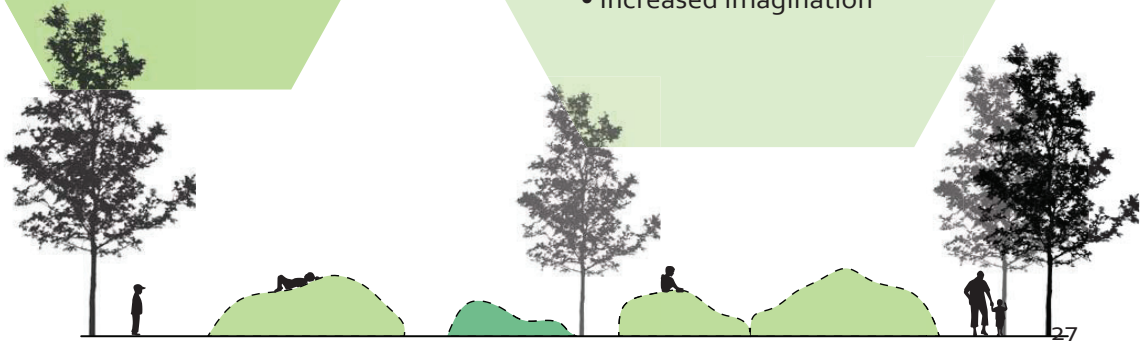
ADEQUATE LIGHTING

Adequate natural and artificial lighting For children to perform their best, light needs to be bright enough but remain comfortable. "Daylighting is important because there are direct connections between our physiological well-being as humans and the amount of daylighting we get" (Nair, p & Fielding, R. 2005). Too much light in a space plays a significant role in harming visual development (Siegel, na). This can cause stain on the eyes resulting in fatigue, crankiness, headaches and visual perception. Because of infants and toddlers limited mobility and limited amount of outdoor time, classrooms should be located on the south side of the building to optimize sun gain and classrooms should have easy access to the outdoors (Olds, 2001). Since children spend a vast amount of time trapped in educational buildings, understanding the direct correlation between development and lighting is crucial (Nair, p & Fielding, R. 2005). The lighting within a space should reflect to the activities being performed within a space. For example, spaces where children are playing on tables or painting should use task-oriented lighting which is designed for a specific task. Although, lighting is often overlooked in many child care centers because of budget, the lastly effects of lighting are prominent and should always be considered.

One way to increase the amount of natural lighting is through transparency. If children can see activities within a space, this can help reduce and relieve anxiety and apprehensions (Clark, 2007). Transparency using windows creates a sense of openness and brightness within a space. Also, daylighting can be implemented into the facility through skylights, windows, and light selves (Nair & Fielding). In addition to natural and artificial lighting, noise also substantially influence and effect children's comfort and performance in child care centers.

Natural Lighting

Reading Room

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Page 51
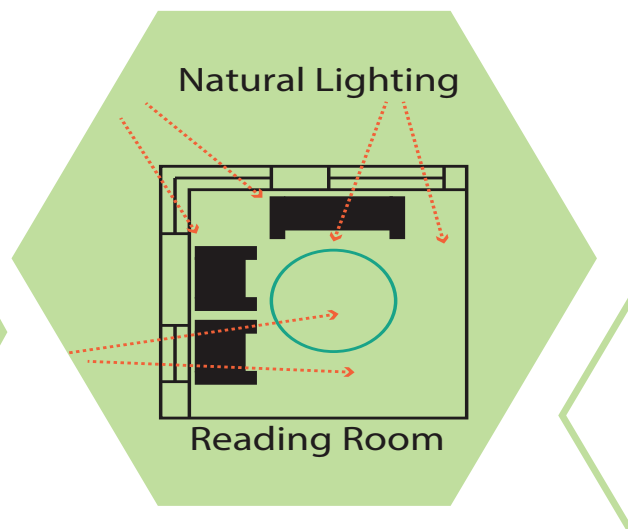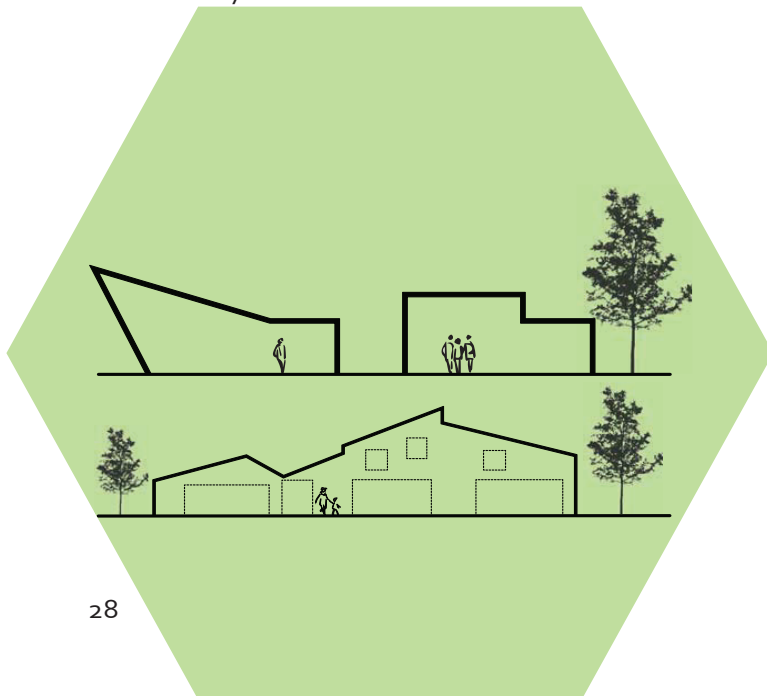
CONTROL NOISE LEVELS

Noise occurs all around us, but the most common noises children are exposed to are transportation, music, and other people (Evan, E. W, 2006). Chronic noise which occurs repeatedly within an environment can have effects on cognitive development, long-term memory, reading abilities and speech perception (Evan, E. W, 2006). In addition, teachers are also directly impacted by chronic and acute noise exposure. "Teachers in noisy schools are more fatigued, annoyed, and less patient than teachers in quieter schools (Evan, E. W, 2006). Finding solutions in addressing noise-related problems in child care centers is important in preventing elevated blood pressure levels and neuroendocrine stress hormones in children. "Babies need to be able to hear words that are spoken to them. Having an abundant amount of background noises within a space is going to obstruct and overwhelm the hearing of young children" (Anonymous 2. 2017, October 18).

A variety of design solutions can be implemented to manage the amount of noise in a classroom. For example, carpet on the floors versus concrete or wood allows absorption of noise, absorbent tile on the ceiling and spatial arrangement can all drastically reduce the amount of acoustics in a room. Noisy activities such as music and blocks should be in transition areas or away from quiet spaces. Considering noise levels in classrooms are often forgotten by designers. "The architect, along with acoustical engineers, needs to consider design options that help reduce sound transmission within and between spaces" (Siegel, na). Acoustical goals for designers should include; "to create a harmonious and pleasing acoustic environment" (Olds, 2001) and lastly "to control, absorb, or dissipate unwanted noises" (Olds, 2001).

Indirect

Sound

Direct

Double Partion Wall Insulation

Bushes or Trees

Screen or Fence

Double Glazing

Noise Source

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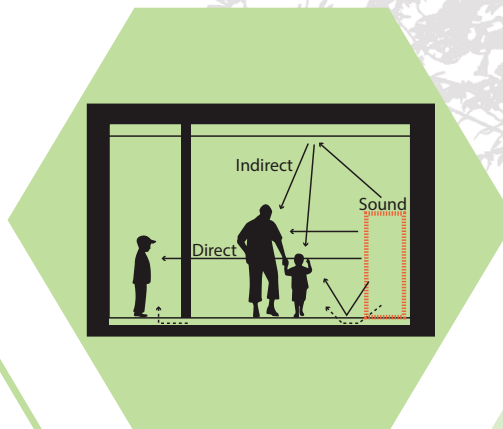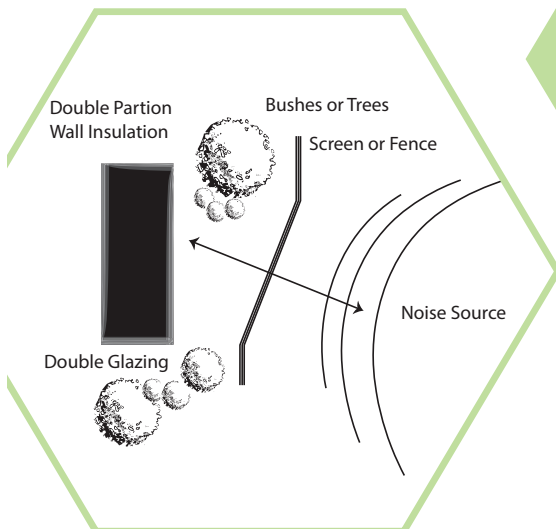
OPTIMAL SPATIAL ARRANGEMENTS

Room size, scale, proportions, arrangement, furniture all play a significant effect on the development of young children. Awareness of the needs of children during each stage of development is important in designing environments that support them. A poorly designed room can create obstacles not only for the staff but also for children's growth and development. Below is a discussion of design considerations suggested for infants, toddlers and preschoolers.
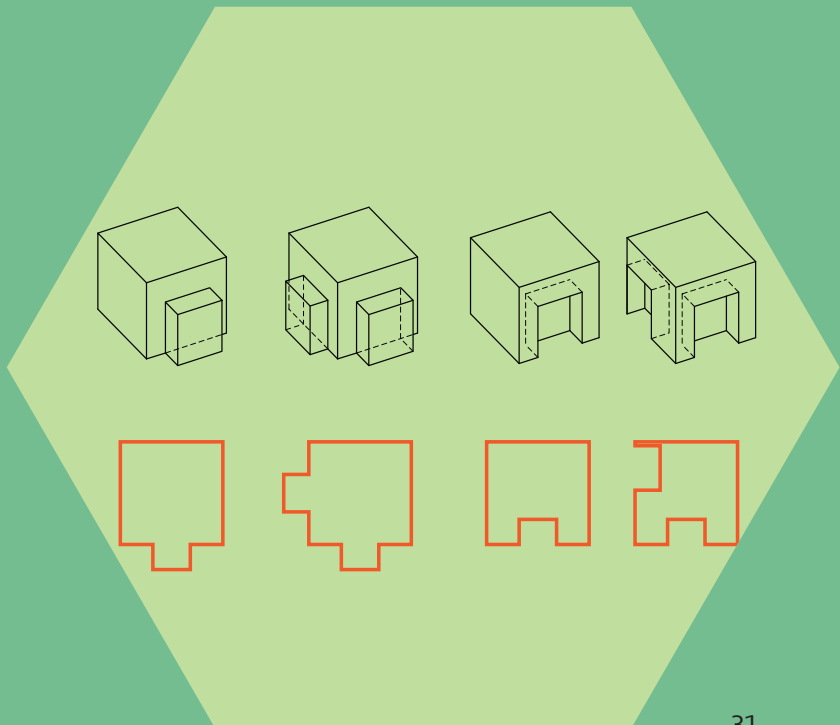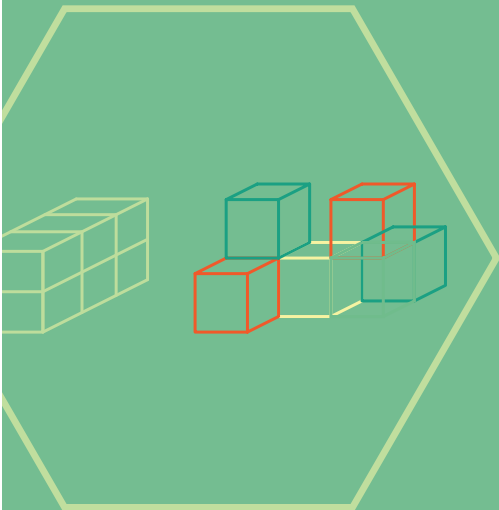
"The needs of infants and toddlers can be most easily discussed in three separate areas: the need to be held and carried, the need for sensation, and the need for movement" (Olds, 2001). The need to be held provides children with the most basic human experiences of safety, security, and love (Olds, 2001). Often, child care centers recommend that infants remain in the care of their mothers for the first six months to help promote the need for physical contact (Olds, 2001). Although, design cannot provide physical contact for infants, design can provide solutions to help supplement experiences of physical contact (Olds, 2001). For example, group size, opportunities for fostering movement, optimal sensory experiences and comfort are all ways to foster or distract from physical contact. (Olds, 2001) Also, another important thing is ensuring infants and toddlers are within sight and sound always (Anonymous 1. 2017, September 26). Architecturally, avoiding any sharp angles, columns or spatial layouts which create visual obstructions should be avoided at all costs. (Anonymous 1. 2017, September 26) Clear sight lines most be provided for all teachers throughout the whole room. (Anonymous 1. 2017, September 26)

Furthermore, infants and toddlers are also undergoing the sensorimotor stage. During this period of development, infants are discovering the relationships between their bodies and the environment (Olds, 2001). Sounds, colors, light, shadows and tactile experiences are all ways to ensure a plentiful environment for young children. Also during this crucial year in development children are mastering movement; bending, crawling, climbing, and walking (Olds, 2001). To help foster this stage of development providing a nurturing environment which fosters safe movement is essential. Ways to achieve this include;

1)   "Use walls to support play panels, vertically mounted toys, grab bars, textures, mirrors, and reflective surfaces at different heights" (Olds,2001).
2)   Use a variety of different flooring surfaces.
3)   Walls can be subtracted to provide unique alcoves or seating.
4)   Provide changes in levels and platforms (Olds, 2001).

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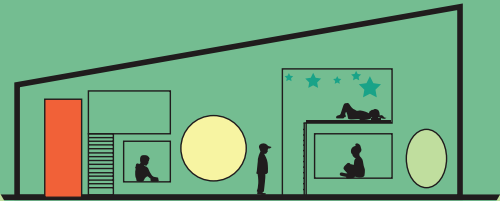
"Preschoolers and kindergartens grow at a relatively calmer and more steady pace compared with the rapid changes they experienced during their first three years" (Olds, 2001). Children are developing a greater sense of independence and self-control well slowly expanding their social circle to other peers besides their immediate family. Providing spaces that facilitate a wide range of activities will accommodate a variety of interests well promoting exploration (Olds, 2001). According to interviewee 1, When it comes to language development, more affordances for movement, interactions and motor skills will allow language to be produced naturally (Anonymous 1. 2017, September 26). For example, wide open spaces versus contained spaces allows and encourage children to share information between children to children or between children to adult. (Anonymous 2. 2017, October 18) There are many different types of children, some are shy, quiet, timid, outgoing, friendly and self-confident (Anonymous 2. 2017, October 18). Providing opportunities for a variety of different types of children would be helpful. For example, cozy nooks for timid children or large spaces for the children who are very exuberate. Also, windows to the next classrooms, can offer children visual sight to other children and allow them to visualize other activities being performed (Anonymous 2. 2017, October 18).

Olds, 2001

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Outdoor Play

Preschool

Infant

Laundry

Storage

Kitchen

Gross Motor

Bathroom

Bathroom

Nap

Bathroom

Outdoor Play

Common

Staff

Conference

Admin.

Vestibule

Parents

Storage

Toddler

Support Spaces   Classroom

Office & Admin.   Outdoor Play

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(Olds, 2001)

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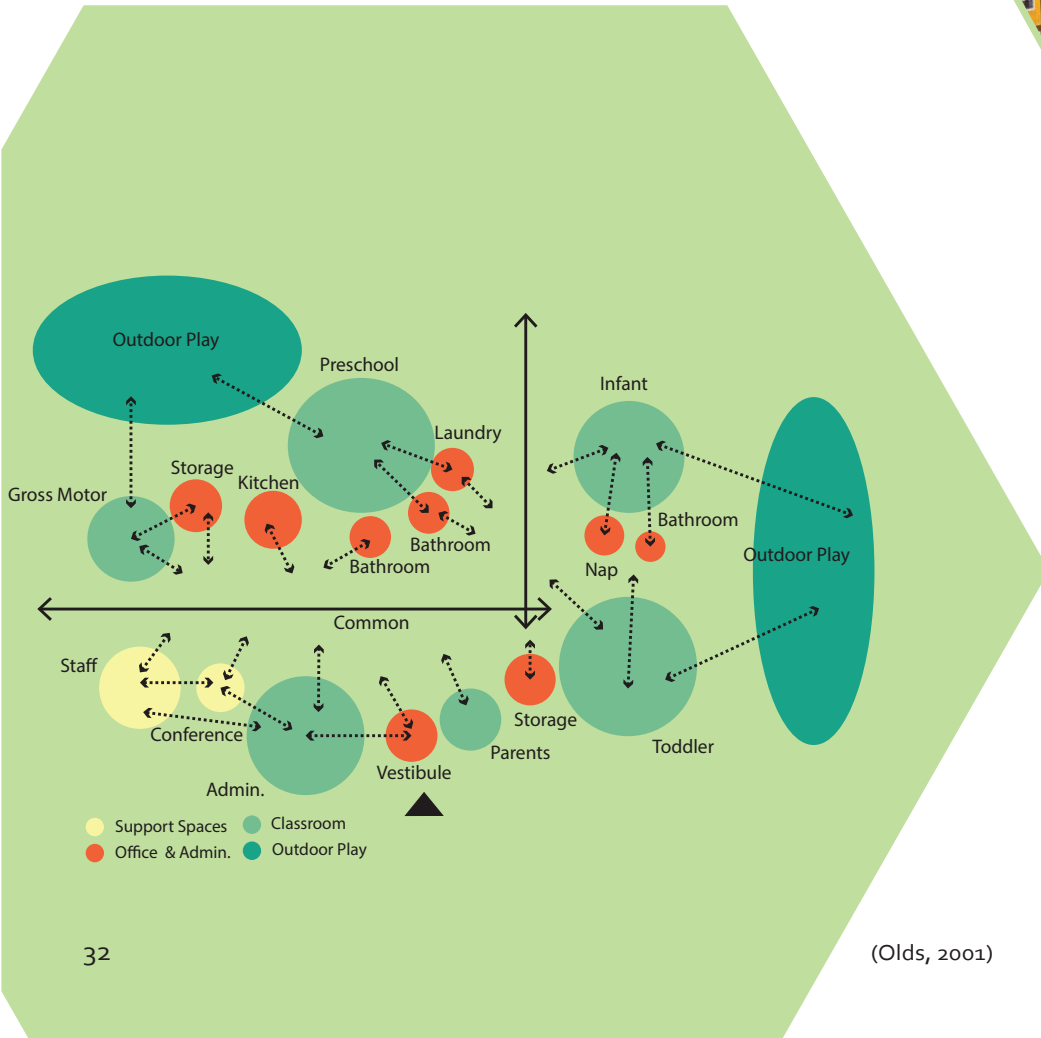
ENCOURAGES MOVEMENT, COMFORT, COMPETENCE & SENSE OF CONTROL

One key design element is to allow for more affordances for movement. Providing a safe and secure environment serves as an invitation for children to move freely, create boundaries, and explore (Olds, 2001). Ramps or stairs can be incorporated into the built environment to help foster motor development (Anonymous 2. 2017, October 18)
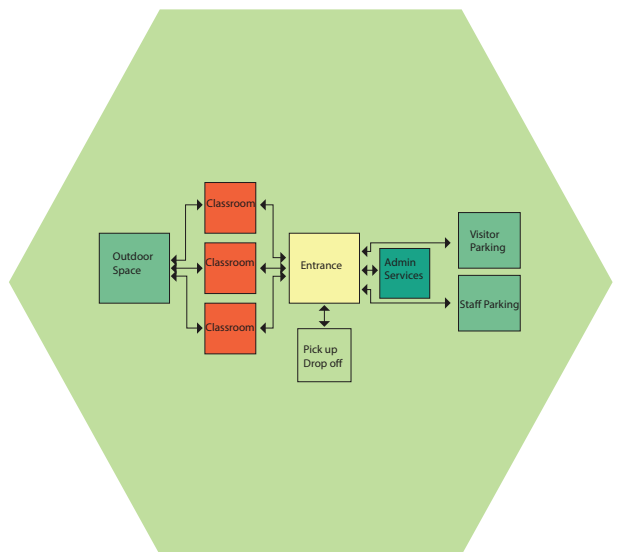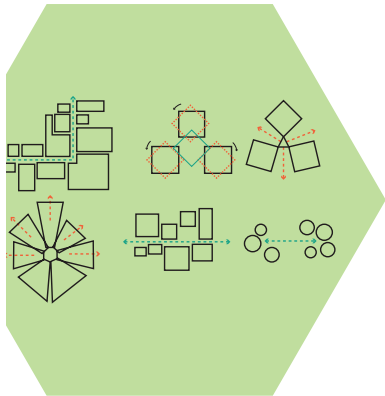Restricting movement repetitively can create a variety of learning and behavioral deficiencies such as hyperactivity, attention deficits and poor motivation (Olds, 2001).

The second design component which is essential is providing comfort. "When children feel comfortable in their physical surrounding, they will venture to explore materials and events around them" (Olds, 2001). According to interviewee 1, for a child to engage in independent play, children must have a trust worthy relationship with the teachers. Children must have the basis of feeling comfortable and safe to participate in play. No play usually begins until this relationship is established. According to study conducted by Olds, as performance increases so does stimulation. Having changes in stimulation is better than having a static environment based on optimal levels of responsiveness. Architecturally, this can be accomplished through variations in elements such as scale, ceilings, textures, materials, furnishings, height, light and noise. Each space within a child care center offers a unique opportunity for children to seek out different levels of stimulation.

The third basic environmental need is to provide a facility that promotes and fosters competence. As discussed previously scale is a constant design problem forcing young children to feel intimated, frustrated and helpless. The normal day to day things which adults take for granite such as a light switch, faucet, drinking fountain and chair are inadequately designed to accommodate the needs of children (Olds, 2001).

Lastly, providing an environment which encourages a sense of control through privacy, predictability and orientation is important in the development of young children. children's need for privacy is directly linked to the development of sense of self. Infants, have no knowledge of privacy because they are unaware that other individuals exist. Also, another important attribute to consider when designing is predictability. A well-designed center will have predictable paths and wide-open spaces for children to interfere future activities.

In summary, balancing all four basic needs; movement, comfort, competence and sense of control are important in designing any child care center. Every child care center provides an opportunity to improve the concept of design. Quality design needs architects, interior designers, developers, corporations, educators and specialists to look beyond budgets, schedules, time-frames and look at the welfare of the users- the children.

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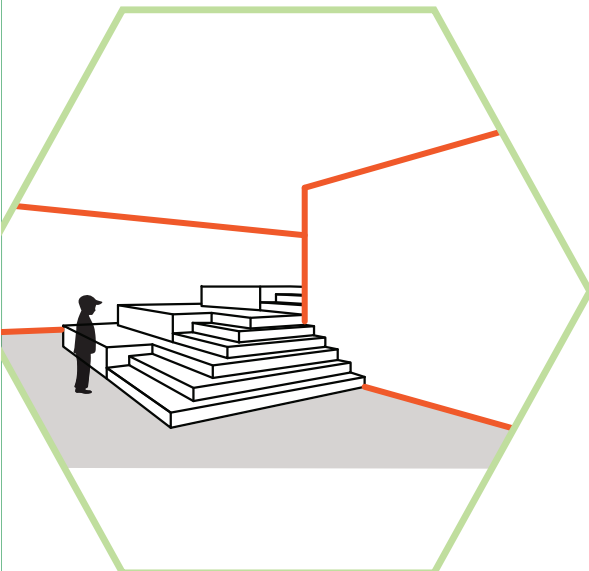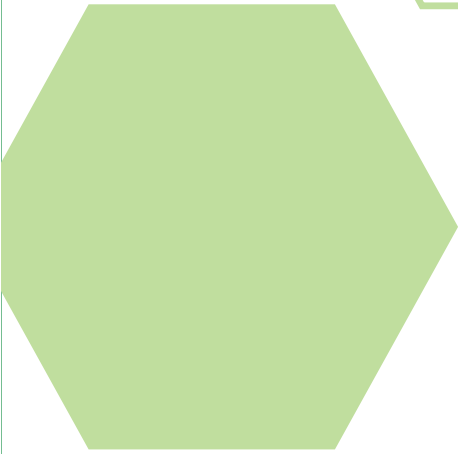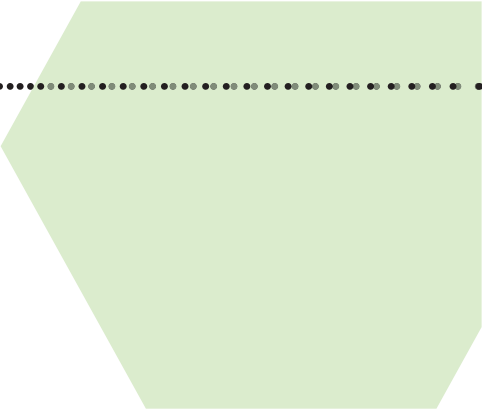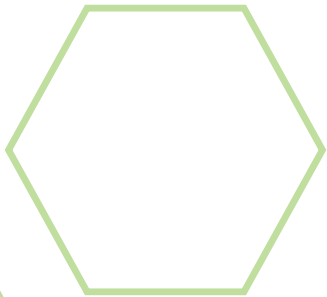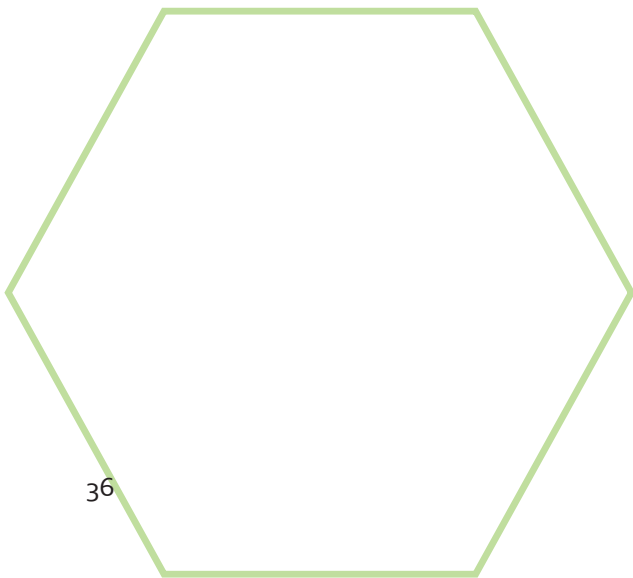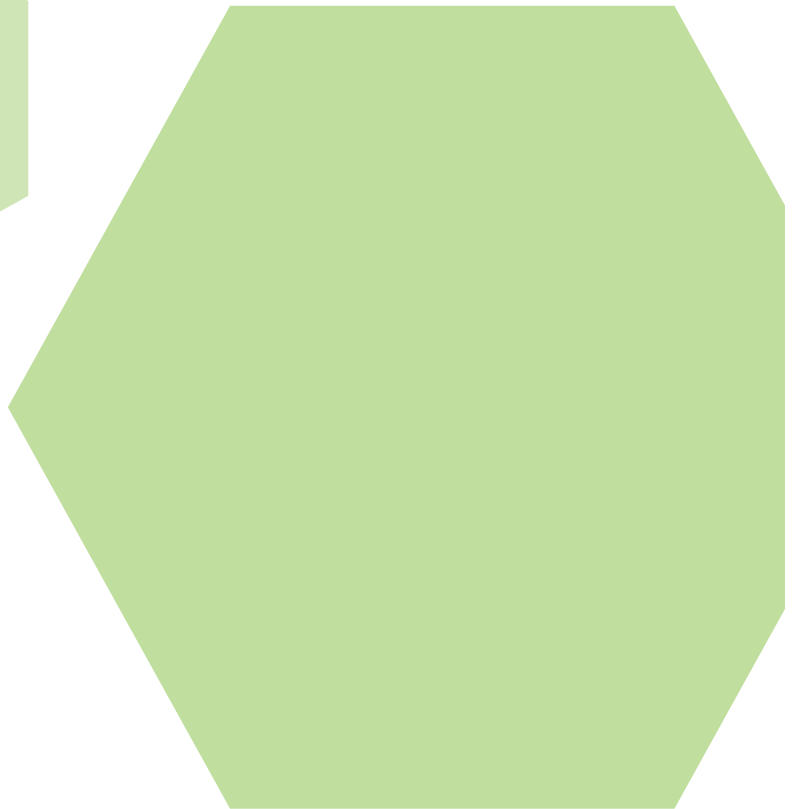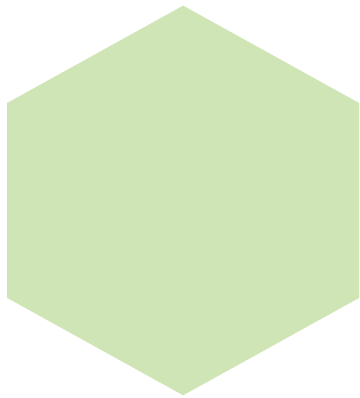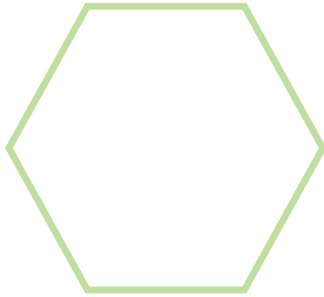
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CONCLUSIONS

During the research gathering and while interviewing, it became obvious that to create a design that fully meets the needs of the client, it is important to understand what the use of the space is. Though children view space as a playground, space should be designed to promote the holistic development of a child. As research has shown, specific prepared environments- spatial layout, warm and friendly environments, lighting, scale, perception, nature, color and textures all play a significant role in foster learning. In the future, breaking away from the typical "intuitional" day care center and pushing away from the standard will allow designers to create a healthy, nurturing and safe environment which facilities growth and development (Gur, 2014). With present emphasis on education within society and the vast amount of time children spend in day care centers, more than ever, it is time to consider the physical environment and the impacts it has on a child's developmental process.

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VISITOR DRIVEN EXHIBITIONS
CURATING MUSEUMS BASED ON VISITOR BEHAVIOR PATTERNS

BRADY LAURIN

VISITOR DRIVEN EXHIBITIONS

CURATING MUSEUMS BASED ON VISITOR BEHAVIOR PATTERNS

BRADY LAURIN

OBSERVATION.

INTERPRETATION.

SIMULATION.

Methodology

The methods chosen to execute this study were selected to be as easily accessible as possible. The lack of additional funding beyond personal investment by the researchers into this study was a driving factor in the methodology, though additional substitutes may be described within this section. The ability to replicate and apply this research was also an important factor in the methodology. When possible, low-cost, free, or open-source technologies were chosen to enable this research to be easily replicated and applied to various environments beyond educational museums.

Recorded data was collected through the use of the Brinno TLC200 Pro Time-Lapse Camera. The camera was positioned to view wide swaths of the exhibit space and programmed to record 1 still image every second. The recordings were then processed using MatLab to generate overlays illustrating areas with a large amount of movement, and visitor paths were tracked using Kinovea tracking software. Both softwares used were freely available to download as a student researcher.

Visitor tracks and the raw video files were studied to determine any potential behavior patterns among patrons of the museum. These included statistical tracking of the engagement rate among visitors for specific pieces or clusters in the exhibit space. This information was then further studied to reveal and deeper similarities not noticed through the initial observation.

Test simulations of the museum exhibits were created in AnyLogic, an agent based simulation program. The statistical information collected during analysis was applied to form the probability definition and the simulation was run for comparison.

Exhibit Zone A

Analysis of visitor paths in exhibit zone A point to a number of patterns in the way people view the display, particularly in the order and direction that they follow. The primary, and overwhelmingly standard path of travel through the exhibit flows through the exhibit in a linear fashion without any doubling back or looping around. The path is very densely defined through the majority of the exhibit, before splitting around a protected artifact case in the open floor area at the end of the exhibit. Prior to the fork and seen in one of the directions after, the path is very uniform among visitors, following the walls of the space. More erratic behavior and apparent indecision is visible in the open floor area of the zone.

The recognition of this phenomenon can be of great aid in planning exhibit spaces. If the goal of the exhibit relies on clear progression of information and an implied order of experiencing the information, the path analysis from zone A points towards the use of a more confined space with walls arranged to pass visitors from piece to piece. In exhibits where the experiences are not reliant on a set viewing order or the goal is free exploration, zone A analysis seems to suggest that open spaces can foster that type of behavior.

28%
43/151
Unprotected
Physical Artifact

11%
16/151
Unprotected
Physical Artifacts

27%
41/151
Protected
Physical Artifact

31%
47/151
Exhibit-Specific
Furniture

41%
62/151
Multi-Media
Digital Display

22%
33/151
Large Format Text
and Photographic
Artifacts

32%
49/151
Text, Photographic,
and Protected
Artifact Cluster

21%
32/151
Text and
Photographic
Artifact Cluster

17%
26/151
Unprotected
Physical Artifact

17%
26/151
Text and
Photographic
Artifact Cluster

15%
22/151
Museum
Furniture

27%
41/151
Did Not View Exhibit

4%
6/151
Protected Physical
Artifact

<u>Analysis</u>

Analysis confirms that the only digital display in the exhibit draws the most attention. The use of a multisensory digital display draws attention both as a visual connection to the video that is playing, and as an auditory feature with voice-over descriptions of what is being displayed on screen. The combination of the visual and audio features creates a high attraction rate to the object. The display receives the highest percentage of engagement with approximately 41% of visitors engaging with the display. It is also notable that visitors who engage with the display tend to devote significant time to this specific piece of the exhibit and often view the exhibit before engaging with other pieces on their path.

This zone also includes three protected and three unprotected physical artifacts. Two unprotected physical artifacts are placed under the tent structure and one along the exhibit wall, while one protected artifact is placed under the tent, one along the wall, and one in the open floor area. Combined, the unprotected artifacts average 18.66% engagement, while protected artifacts average 21%. On the surface, these numbers reveal that protected artifacts have just a slight edge over unprotected artifacts in terms of overall engagement. However, the margin widens significantly when compared based on the actual placement of the artifacts. Between physical artifacts located under

the tent, the protected artifact engages at a rate 1.38 times higher than unprotected artifacts, comparing at 27% versus an average of 19.5%. Along the wall, visitors are 1.88 times more likely to engage with the protected display, comparing at 32% versus 17%. Of note is the fact that just 4% of people engaged with the protected artifact in the open floor space, with its placement occurring after the path splits in direction and behavior. When looking at the comparable positions of protected and unprotected artifacts, people appear much more likely engage with the protected display than the unprotected one.

Other key figures of note from exhibit zone A relate to the furniture present in the space and the rate of pass-through visitors. Analysis of the video recordings shows that the third highest rate of engagement across the entire zone is with the exhibit-specific furniture in the tent structure, engage more than double the amount of visitors compared to the museum furniture. This may indicate that because the seating is not viewed as a piece of the actual display, there is little need to engage with it. The flexible museum furniture's placement in the open area may also have an effect the rate of engagement. Another notable figure is that for zone A, 27% of patrons do not view any exhibit pieces, however, this number may be skewed by inadvertently counting museum employees.
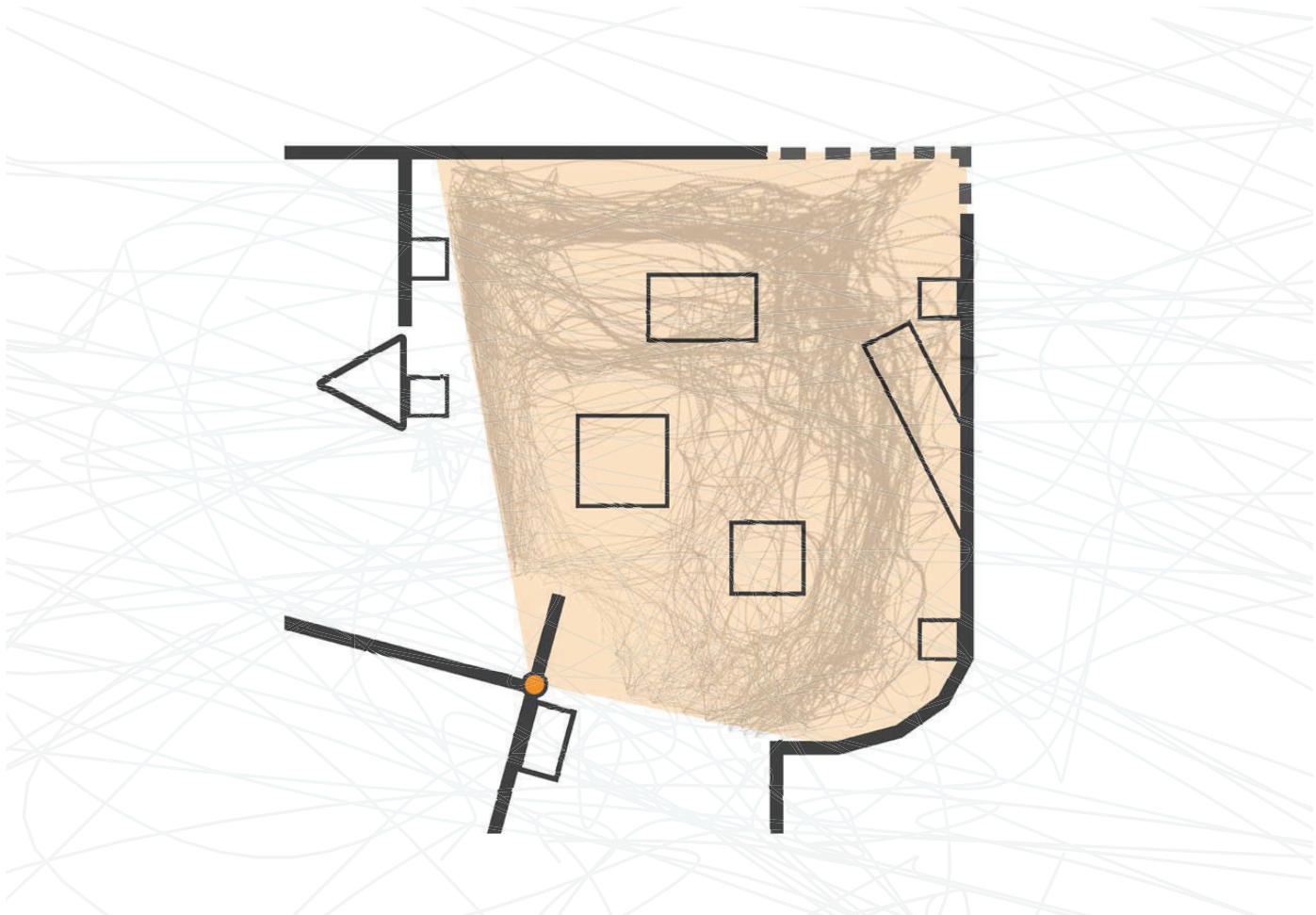
Exhibit Zone B

The path through the exhibit itself is very interesting. In Zone B, the path tends to flow through the exhibit in a right to left direction regardless of the visitor's point of entry. Like in zone A the path follows the bordering walls of the exhibit with various pieces displayed in sequence. The contrast from zone A is the way in which visitors handle exhibits in the open floor area. Because the zone appears set up like an enclosed room instead of a corridor, the open space is surrounded by exhibit pieces, with the protected artifacts like islands in the open floor area. Because there is no implied sequence to viewing the floating cases, visitor paths are much less densely defined, with decision making appearing erratic at times. The cases also perform at the low end of the spectrum of engagement rate for zone B, attracting an average of 25.66% of visitors. Like before it appears that people tend to prefer the comfort of following along the walls of an exhibit, rather than being in the open space.

Analysis

The rate of engagement for pieces and clusters in zone B was much higher by comparison than those of zone A. The first cluster in sequence from left to right along the exhibit walls features standard size prints and protected artifacts, this cluster attracts a staggering majority of visitors at a 65% engagement rate. The placement of this cluster immediately off the entry to the zone makes it incredibly visible and accessible to visitors. Other high performing pieces in the exhibit include the exhibit-specific furniture along the sole permanent wall. The piece is a re-creation of a historic bar featured in the banner-sized print behind it. The arrangement provides a forced perspective of the bar coming out of the photo and into the exhibit, complete with a dressed mannequin behind it to serve as the bartender. This piece performs extremely well compared to the furniture and unprotected artifacts in zone A, attracting 44% of visitors to engage with it in some way. A number of pieces perform near 40% attraction with visitors as well, these include two clusters of large-format printed materials (38% and 40%) and another standard size print cluster (38%). Across the board, artifacts in this layout perform better than the previous.

One surprise in the findings was that the interactive digital display in the exhibit did not meet the same rate of engagement as the multisensory display in zone A. As was described in the methodology, the rate of engagement for this specific piece was determine by the number of people who physically interacted with the display, or who engaged after interaction by someone else. The interactive display only engaged 23% of visitors to the exhibit, compared with 41% of visitor engagement with the multisensory display in zone A. This is likely due to the small size of the display, the lack of auditory attraction before initiating the display, and potentially fatigue based on its placement at the end of the exhibit sequence.
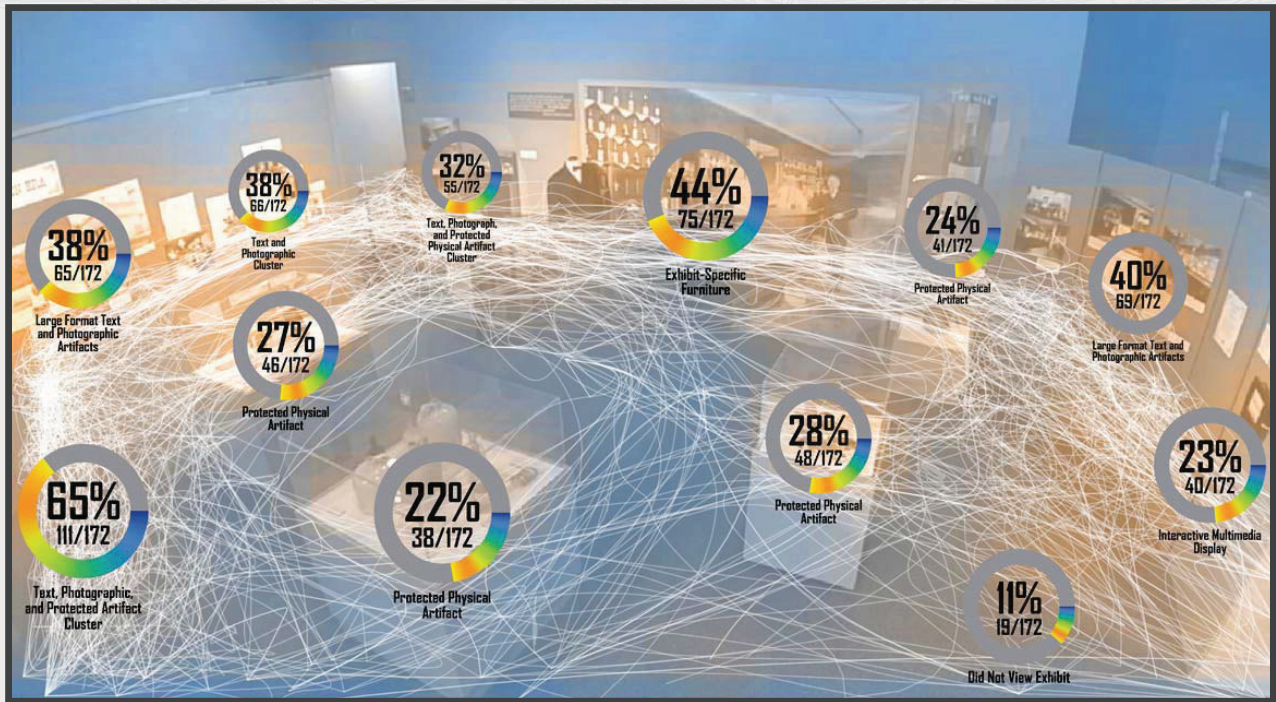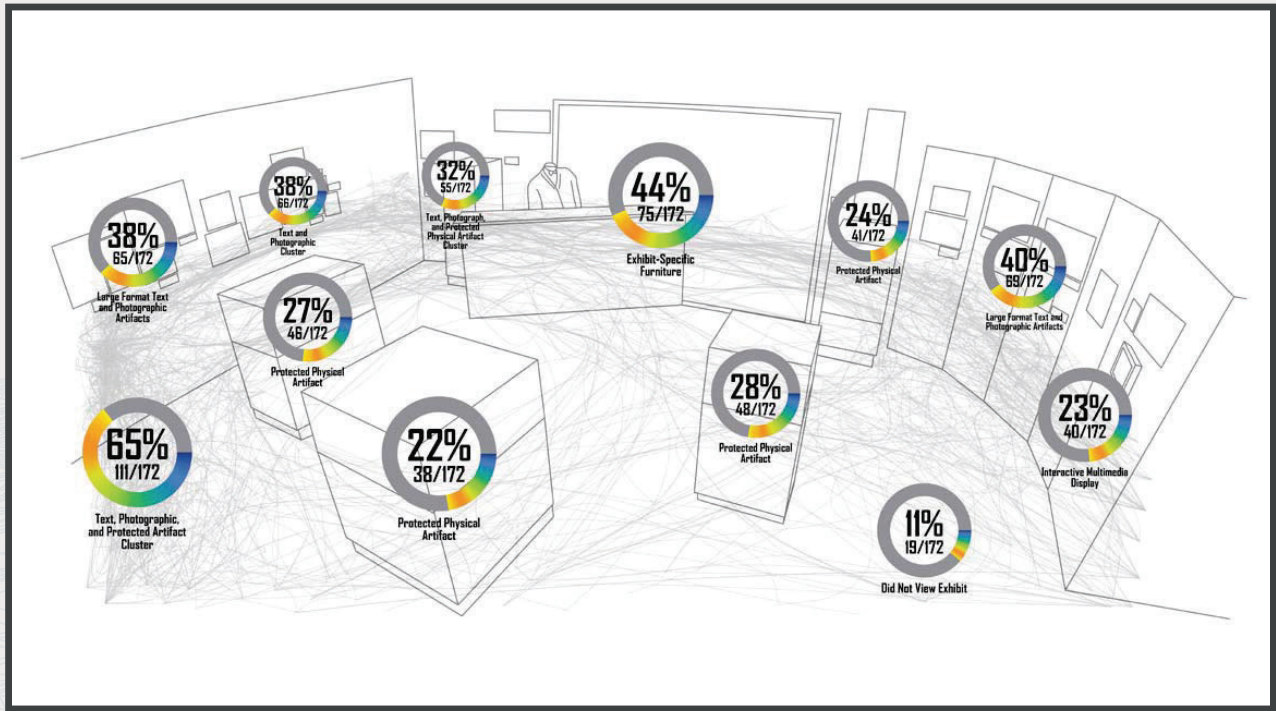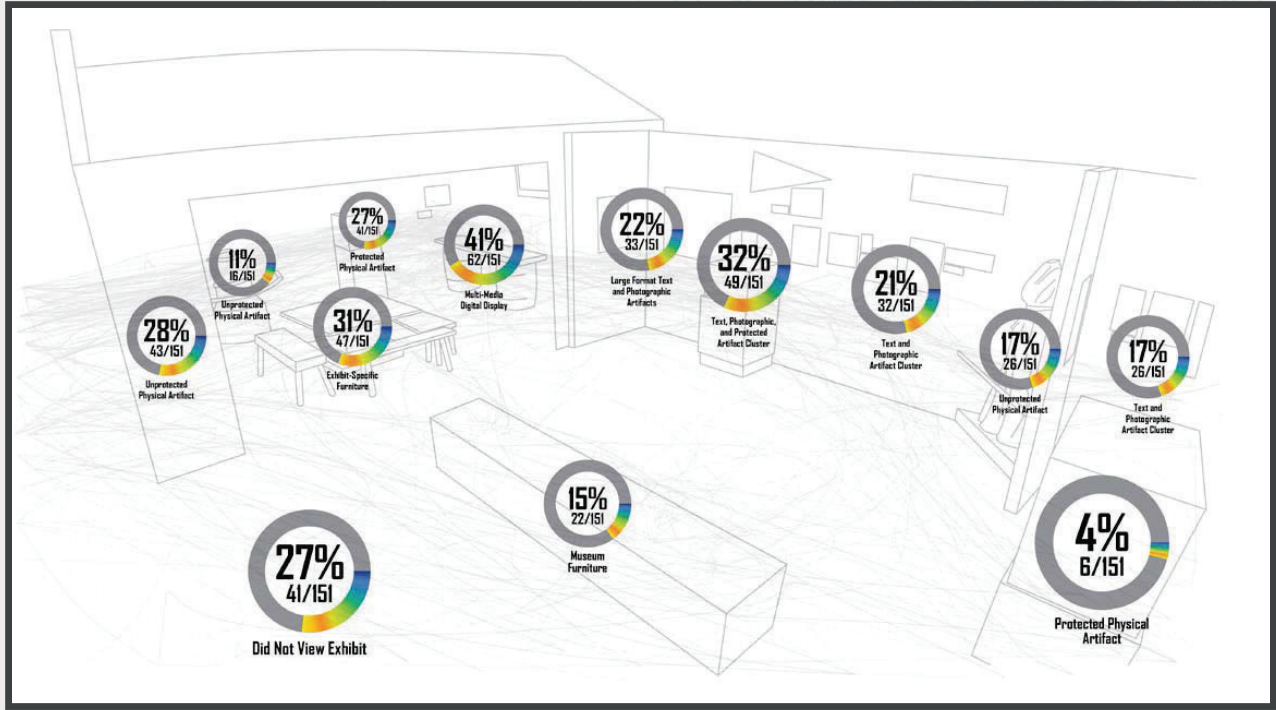
Universal Findings

Analysis of both zones yields similar path results despite the differences in layout and placement in the exhibit at large. The presence of these key similarities is reassuring for the potential of predicting visitor behavior in museum exhibit design.

The biggest takeaway from the analysis by far is the path similarities between the two zones. In each zone visitors overwhelmingly prefer to view exhibits from along the wall. In each zone, the path flows in a predominantly left to right direction through the space regardless of the point of entry. The density of the path varies slightly between the two zones but is generally the same. The most visible path differences between the two is visible by the apparent indecision in open space. In both zones visitors entering open space appear less predictable in direction, often wandering slightly as they determine their next destination. The location that this wavering occurs is the difference between the zones, while it occurs in both zones it is much more prevalent in zone B because of the placement of multiple artifacts in the open floor area, compared to just one at the end of the exhibit in zone A.

It also appears that given the choice, visitors appear more attracted to protected artifacts than unprotected artifacts. This is believed to be based on the implied value of placing artifacts behind protective glass. As described in the zone A analysis, this is true across varying placements of the artifacts in the exhibit space.

Finally, statistics point to digital displays providing high rate of attraction when properly sized and providing multisensory stimulation. Interactive digital displays out to be positioned in a manner that demonstrates their functionality and sized to communicate its information well with visitors. Once again, placement in the exhibit space remains an important determinant in the success of the display.

Simulation

Upon completion of the analysis, the statistics derived from the study were used to simulate visitors in the exhibit space to determine if the method had any validity. AnyLogic software was utilized to create a visitor flow definition in the exhibit and using the probability of attraction to determine visitor path. The definition was created in such a way that a sequence of exhibits was created but a specific path was to be determined only by the software, in which the simulated visitors travel by path of least resistance to their destinations. The simulation would be determined a successful indicator for potential design application if the path drawn by simulated visitors matches the real-world pathways.

In each case the results of simulated visitors follow closely the paths of their real-world counterparts. The density mapping created by the AnyLogic software illustrates the paths taken by agents in the simulation model. In each simulation, the lighter colors mark less frequently occupied space by visitors in the exhibit zone. These areas line up well with the open space not frequented by visitors in the actual exhibit. Likewise, the areas where visitors stop most often in the actual exhibit coincide with the colored markers of high density occupation in the simulation model.

The success of the simulation model in adequately reflecting the results of real-world analysis indicate the potential of simulation modeling in the design process to predict visitor behavior in a planned exhibit space. Using the combined averages for visitor engagement with respect to their locations and the exhibit layout type, simulation may be used to test new exhibit designs for pathway optimization. Given a designer's set goals for the project, a possible layout may be tested using simulation to determine if those goals may be successful, providing greater control and understanding of how visitors are actually experiencing the exhibit.
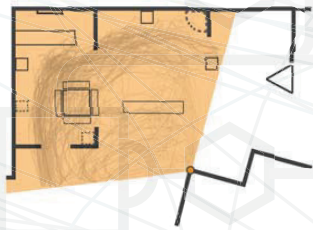
Exhibit Zone A
Visitor Paths
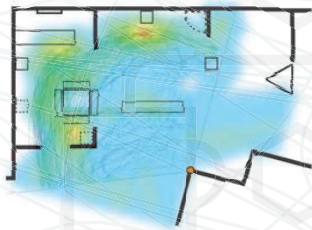
Exhibit Zone A
Visitor Paths & Simulation Map
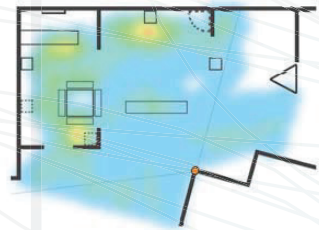
Exhibit Zone A
Simulation Map
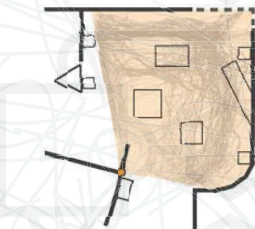
Exhibit Zone B
Visitor Paths
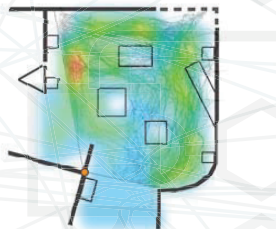
Exhibit Zone B
Visitor Paths & Simulation Map
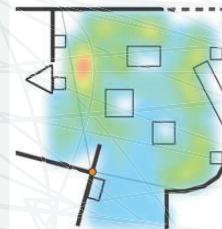
Exhibit Zone B
Simulation Map

Conclusion

The use of visitor behavior tracking and analysis can be of great use to museum professionals and designers alike. Using established technology commonly used in other applications and adapting process to fit the context, low cost options exist to aid in the design of new museum and exhibit spaces. As shown through this study, the implementation of inexpensive cameras and intensive study of visitor pathways, a number of common behavior patterns can be extrapolated. These patterns have been proven to successfully match simulated outcomes, signaling the potential for this process to be more widely applied in the field of museum design. Architects, planners, and museum staff alike could benefit from the implementation of the process utilized in this study to better understand their patrons and predict how future exhibitions will be experienced. Using standards established through greater study of this methodology, baseline engagement rates could provide a starting point for analysis, or individual study of existing museums can more specifically predict visitor behavior. Utilizing this process, museum designers may now have better control and a quantitative understanding of how visitors engage with exhibition spaces.

FLEXIBILITY WITHIN MODERN
OFFICE ENVIRONMENTS

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Graduate Architecture Student

in conjunction with
BWBR Architects
Stefnee Trzpuc, Firm liason

INTRODUCTION

The way people work, the way the want to work, the environments they work in, and the people working are changing every day. Historical trends have seen preemptive assumptions about the future of workplace design, leading to too-specialized environments that locked facilities into a certain mode of work and thought. Today's mainstream workplace philosophy favors preparedness for the unpredictable future. By exploring the means in which office designers and facility managers are preparing for the unknown, one can gain insight about the available technologies that promote flexible design and the issues that inspire flexible design techniques and elements.

CONTENTS

HISTORICAL PRECEDENTS

Change scenario Dissatisfaction with factory-like workspaces and offices
Design strategy Burolandschaft, office landscaping

The concept and terminology of an open office gained popularity in post-WWII America as emerging technologies allowed for buildings that were larger, deeper, and more open. Some innovative designers and their clients searched for ways to utilize this blank canvas to foster a sense of collaboration and increase productivity, which is where the true "open office" movement would be born. However, many office designs of the latter half of the 20th Century did not adhere to this humanistic philosophy, especially those built by developers. Clients and designers tended to rely upon economy and speculation of needs rather than actual needs. Further, the way professionals in the industry thought about organizational structures of their environments remained largely detached from current office demands, relying upon the Taylorism of the 1880s and 1890s ("History"). The Taylorist organizational method can be likened to Ford's model for an assembly line, where each task is broken down by function and arranged in the most efficient and economic way possible ("History"). Due to the stagnation of organizational schools of thought throughout the century, the office space norm was based in outdated stereotypes. The economic value of these offices with large interior spaces gave them an enduring presence in the industry, and when the concept of a true "open office" was introduced in 1967, people still pictured the overcrowded and monotonous sea of desks.

Amongst the many bleak "paper factories," some designers around the world still searched for ways to provide inspiring spaces, to foster collaboration by innovative space-planning techniques, and contain humanizing qualities that kept employees happy and focused. An iconic and influential office design from 1960 is believed to be the first true open office that rose from analyses of the company's work patterns. The concept is known as Burolandschaft and was first installed in the Bertelsmann Publishing Company in West Germany (Worthington 1997). An example of this floor plan (figure 2) shows clusters of working zones that are arranged based on employee workflow and the need for better inter-office communication. It was one that abandoned the Taylorist view and instead found priority in social connections and networks. It was a product of the post-war German context in that it was intended to be completely egalitarian, with all employees, regardless of status, seated in the open ("History").

Burolandschaft enjoyed popularity in Europe for some time and was eventually adopted in the United States as a more watered-down version known as office landscaping (Worthington 1997). Even in Germany, the purist version of Burolandschaft would not prevail, as it had many growing pains. Some were easy to fix due to the flexible nature of the spaces, however some would undermine the important tenants of the concept. The major complaints were privacy and noise.

4 | Flexibility in modern office environments

Figure 1 - Kremer - BBC.com
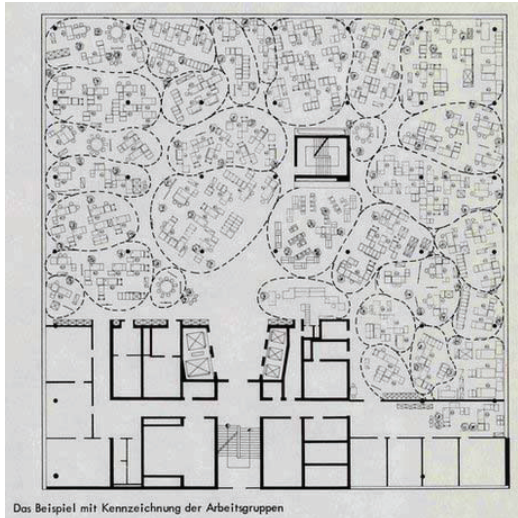
Das Beispiel mit Kennzeichnung der Arbeitsgruppen

Figure 2 - Kremer - BBC.com

Measure of effectiveness

To analyze the success of such a major organizational restructure, there are many factors that should be considered to understand the effectiveness. A survey of employees would provide information on their perceived efficiency and satisfaction with how the space performs. Sample questions include:
- Did you feel more productive before or after the change?
- Do you prefer the previous or current (lighting scheme/circulation/access to coworkers)?
- Do you think the restructure accomplishes what was intended?

These questionnaires could be supplemented with data about the company's actual employee performance, and wether there is more work being done before or after the restructure.

Flexibility in modern office environments | 5

HISTORICAL PRECEDENTS

Change scenario   Without barriers, workstation neighbors and noisy equipment like typewriters and time card punchers were especially unpleasant

Design strategy   Group users into bays and introduce screening systems

Noise control was a major issue into the 1970s and 80s due to the cumbersome and noisy technology that was found in many offices. Typewriters were found to be especially noisy, and were considered highly distracting when immediately adjacent to an employee that was not also using one (Ritche 1977). Implementing work zones typically solved this issue, and in this case came in the form of typewriter bays. When consolidating the machines into a single area, they essentially blended into a white background noise that was no longer distracting or an irritant. Creation of background noise proved to be beneficial, as it avoids the too-quiet condition that makes employees uncomfortable when making phone calls and doing other tasks that may draw attention (Kremer 2013). The use of screens was also found to be helpful in creating an acoustical barrier for employees on the phone or doing other loud tasks, and aided in visual privacy as well. These screens or movable walls were found to be most effective at 5'-0" to 5'-4" tall in creating a visual boundary that still maintained an airy atmosphere and prevented natural light from being blocked to different parts of the interior (Ritche). This solution prompted some furniture companies to start designing for open offices that were facing these issues, selling screening systems and demountable walls. This trend pulled the office landscaping or Burolandschaft further from its desired intention, and corrupting the idea of complete openness from which it was based ("History"). Other topics that furniture designers, especially the giant Herman Miller, found important during this era was the lack of employee autonomy. Especially in a Taylorist-designed office, there was a standardization and sameness across workspaces that provided no interaction. After some trial and error, the precursor to the modern-day cubicle was formed. By name of Action Office II, a line of office furniture was developed that allowed the employee to feel ownership over his or her space, a certain degree of privacy, and use it in the way they found most effective (Worthington 1997). The simplicity of installation made the units very popular over time and still a common sight in many offices today.

Measure of effectiveness

In this case, it would be important to keep a record of any complaints that are formally filed by employees regarding noise. A survey would also be helpful in ascertaining satisfaction or concerns, however minor, that may have resulted from this strategy.

6 | Flexibility in modern office environments

Change scenario   Shift from manufacturing-based to knowledge-based economy

Design strategy   Resconsider office design practices based on information technology

Amidst the changes in the office environment, managerial organization was still in need of an update, as the Taylorist view was losing more and more relevancy. The influence of Burolandschaft at least mainstreamed new ways of thinking in the office design industry as the American economy was becoming heavily influenced by technology (Worthington 1997). The 1980s marked the shift of a primarily manufacturing-based economy to a knowledge-based economy, laying ground for the technology boom of the 1990s. Still, with the rise of technology in this era and its profound and widespread effect on the way businesses were run and the way people worked, an industry restructure was necessary.

Old working methods couldn't support the new office characteristics even if they wanted to. These modern offices included employees that were highly mobile and may not stick to a typical 9-5. They might travel for business frequently or rely upon telecommuting and working from home. These employees may do a wider range of tasks and communicate with their coworkers differently than when work was paper-based. Many new considerations were necessary and the 1980s and 90s are largely considered a revolutionary time period of office design thinking.

As the personal computer became more common in business practices, radical ideas of what an office should be surfaced. An article published in 1985 maintained that with the prominence of knowledge-based work and reliance on information technology, offices need no longer be a dedicated physical space. Rather, the office is where you are as written by Stone and Lucceti in an article by the same name (Worthington 1997). These ideas are precursors to now-standard telecommuting, virtual offices, hot desking, and co-working facilities.

Measure of effectiveness

Attempting to quantify the success of these new office patterns would owe much to a survey of employees. Like the restructuring into office landscaping scenario, asking questions about perceived productivity paired with statistics about actual productivity and work output would be beneficial. It would also be useful to look into any change that the company is seeing after posting jobs advertising the use of hot desking, co-wo urvey, if they have seen a rise in applicants after advertising the non-traditional work method, employee retention

Flexibility in modern office environments | 7

MnDHS ELMER L. ANDERSEN BUILDING   CASE STUDY

Figure 3 - Elmer L. Andersen Building - BWBR Architects

Flexibility in modern office environments | 9

Change scenario   Consolidation of many departments and facilities into a single office building

Design strategy   Provide office amenities to allow for users to connect more freely and informally

A facility's physical space reflects, articulates, and reinforces their values (Vithayathawornwong 2003). For an organizational and physical restructure as large as the Minnesota Department of Human Services consolidation into the Elmer L. Andersen building, it is clear that a sense of community and connection between employees and departments is a key goal. Design elements contributing to this goal include the coffee bars, breakout spaces, conference rooms, and lounge seating. When analyzing the initial design and the current layout (see figures beginning on page 14), one will find that most of these accommodations and service spaces (shown in purple) remain intact around the other changes, or change shape but remain in the program. For the most part, these spaces are larger to accommodate groups and placed on the edges and inbetween different work areas. Across all the floor plans shown, to service areas that include a bar for seating, copiers, coffee and other appliances, are found at the north, south and east end of the main corridor. These areas remain largely unchanged throughout the lapse in time. Informal meeting spaces are also distributed throughout the floors, providing more space to have a quick chat or run into a coworker that one may not usually see when they stay near their desk. These spaces, shown in yellow, are on every other floor near the north staircase. This area also remains unchanged throughout time and is common throughout the floors shown. Other smaller spaces, usually including a table and chairs, are easier to place throughout the floor. Floor three, for example, shows the original layout with small spaces throughout the main corridor where many people can pass by.

Measure of effectiveness

To measure the effectiveness of the intended user connections, an occupant survey could be conducted, with questions comparing the office before and after the consolidation into the Andersen building.
- Do you feel more or less connected to coworkers within your department?
- Do you feel more or less connected to coworkers outside of your department?
- Do you feel that superiors are more or less approachable?

10 | Flexibility in modern office environments

Change scenario   Staff increases over a 10-year period

Design strategy   Integrated design strategies that allow for flexibility in spatial reconfigurations, including underfloor air distribution, universal lighting layouts, and grid planning

A large component of sustainable development lies within the building's ability to adapt to this rapidly-changing world in a manner that does not create extreme unnecessary waste. Preparedness for inevitable alterations, changes of use, and minor works eliminates building-related energy consumption and associated greenhouse gas emissions (Wilkinson 2012). Buildings and developments that are not prepared for such changes enter decline quicker which leads to faster need for demolition. Adaptability is crucial from the beginning of the process, especially within the attitudes of the owner of the property and their "strategic investment approach to built assets" as studied by Swallow in Structural Survey Journal (Wilkinson).

In the analysis of changes that have taken place in the Melbourne Central Business District's office buildings, it was found that the adaptable buildings tended to have deep plans, a curtain wall exterior envelope, and vertical circulation and services located in the center of the plan, which all contribute to flexibility. These buildings were also less likely to be sold, and in the buildings that were found to be more flexible, adaptations were prompted by tenant expiration and the goal of maintaining market position. In the buildings that were less flexible, the sale was "the catalyst for adaptation" (Wilkinson 2012).

Wilkinson insists that while buildings can be environmentally rated for decrease in operational energy and water consumption, they cannot be truly considered sustainable if the adaptations that are made continually send resources and construction materials to the landfill. In many cases, the adaptations of the buildings in Wilkinson's case study were result of changing compliance issues and refreshing tenant leases, rather than wear and tear, meaning the materials extruded from the building are likely in good condition and are recyclable. Her suggestion is to take these frequently-discarded items, like carpets, partitions, office furniture, framing, and suspended ceiling tiles, to lower-grade office buildings that use the materials for longer durations and typically do not buy the high-grade materials (Wilkinson 2012). With this broad perspective on the foundations of building adaptability, specific systems and design elements can be incorporated which commit to long-term flexibility in the goal of maintaining a building's usability and fitness.
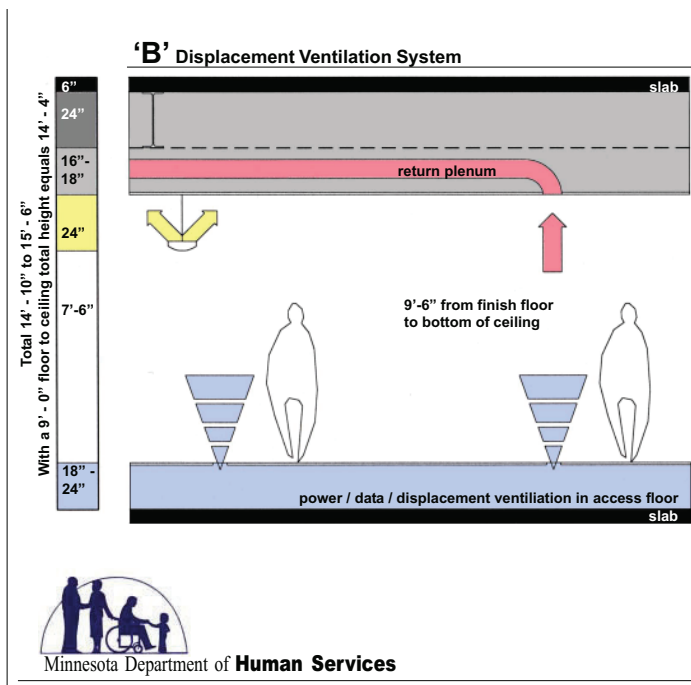
Underfloor air distribution systems provide more flexibility, is more energy efficient, user control, and thermal comfort than standard ceiling-based air distribution in deep open-plan offices. The UFAD system only cools the occupied zones of a space, which are typically from

the ground and up to six feet in height (Alajmi 2010). This means that the fresh air is not mixing with the warm air that has risen to the ceiling waiting to enter the return ducts, preserving the air freshness and indoor air quality, as well as reduces the volume and flow needed (Alajmi, Kwan). The air temperature when the system is cooling the space also does not need to be as low because it exits the ducts and is immediately within the occupied zone. Though the system has better occupant satisfaction than CBAD, one complaint that occupants have had with this system is air being too cold on their feet (Bos 2013, Alajmi). ASHRAE Standard 55 also notes the difference in temperature found in from the floor to head height while seated, and recommends a no more than 3° F temperature difference (Bos). Overall it is recommended to keep the air temperature no less than 65° F if the damper is less than three feet from the occupant's workspace (Alajmi). Conversely, occupants have found the system to be especially beneficial in the winter in keeping their feet warm. Further occupant comfort is found when the dampers, more easy to access than overhead vents, are able to be adjusted in their direction of airflow.

While the system has a higher up-front cost, savings can be found in the long-term energy costs and when reconfiguring spaces. A study of this system in various building heights in the warm climate of Kuwait found that savings of total energy loads and peak loads were better with UFAD compared to CBAD, and only increased as ceiling heights got bigger (Alajmi 2010). Because of this system's newness, controlled studies and case studies are the main outlet for performance information rather than long-term and large-scale field evaluations. In a study by Megan A. Bos and James A. Love, a study in the spring of 2012 was conducted to evaluate thermal and air quality and occupant satisfaction in the City of Calgary Water Centre Building in Alberta falling in ASHRAE climate zone 7. This study provides relevant information for the Midwest, as St. Paul is in an only slightly warmer climate zone 6. This building had a new UFAD system with swirl diffusers and quadruple glazing operable windows at the perimeter. By tracking thermal conditions within the building and surveying 33 occupants, the researchers were able to collect data about the effectiveness of the UFAD system and its consequence on user comfort. The system was able to maintain a median air temperature of 73° F with outdoor air temperature ranging from 38° - 64° F, though the high-performance glazing was able to assist in keeping the cold air out (Bos 2013). The users reported very little warm or cool discomfort on specific body areas, with 9% of respondents reporting cold discomfort on the foot and leg region, and 18% cold discomfort on hand and arm region (Bos). A large majority of the users also felt slight to high sense of environmental control. In general, 42% of the participants reported feeling cooler than neutral at their workstations, 21% reported feeling warmer than neutral; 30% wanted a warmer environment and 15% wanted a cooler environment. Overall, the system was deemed satisfactory (Bos). This system is therefore a logical choice when preparing for future spatial reconfigurations, as the plenum allows for cable management, diffuser, and terminal locations to accommodate

12 | Flexibility in modern office environments

'B' Displacement Ventilation System

Minnesota Department of **Human Services**

new furniture layout and support spaces. Additionally, it has been shown to perform on par with other HVAC systems in regards to user comfort and thermal air quality and is, when well designed and sealed, more energy efficient (Alajmi, Bos, Lee et al). The scheme proposed by BWBR is pictured above, showing the system geometry within the floor volumes. BWBR utilizes the underfloor plenums for air and data cable distribution as well. When the designers were proposing this system, it was compared to standard HVAC systems with overhead ductwork. The disadvantages of the displacement system include the necessary coordination with furniture, perimeter heating, and potentially complex fire ratings at partitions. The conventional system, while containing much more ductwork and having less individual control, was more familiar, could handle perimeter conditions better, and met the ventilation effectiveness guidelines.

This system allowed for various reconfigurations and spatial changes, along with grid layouts and lighting systems. The changes of spaces from the initial design to the current condition is found floor-by-floor on the following pages.

Measure of effectiveness

To evaluate the success of the underfloor air plenums in accommodating churn, allowing for simple reconfigurations, and providing user comfort, a study could be done to compare the interior remodel cost of the space with an above-floor HVAC system, and the actual cost that avoids rerouting ductwork and the consequential materials. Questionnaires inquiring about comfort would help understand how it performs for its users.

Flexibility in modern office environments | 13

Change scenario   Reduction of paper filing and related storage
Design strategy   Demountable walls allow for quick transition into workspace

When work shifted to knowledge-based in the late 20th Century, many speculated that workspaces would quickly become "paper-free". Studies have shown that computers have actually increased the amount of paper used in an office, as it is more supportive of knowledge-based work and was made more convenient by copiers (Humphry 2014). There are many predictions of the "perfect office space" that have proven to be false, but in an office that utilizes flexible design elements, there is little investment in adjusting for speculated or current needs. Demountable walls partitioning paper-related services and storage is a smart decision especially for topics that seem in flux.

Demountable walls, along with the strategies previously discussed, were implemented in the building in a way that allowed for new uses to take over for obsolete paper storage rooms. With increase of staffing, these unnecessary spaces could be transitioned into conference rooms, workrooms, or the walls could be detached to increase space for open-office cubicles.

Measure of effectiveness

The success of reconfigurable partition systems can be analyzed through the amount of workspaces initially and current day and the square footage gained or lost per person. The table on the next page show the original breakdown of workspaces, shown by number of cubicles and offices. The table shows that, at minimum, there was an increase of 120% and a total increase of 132% in the current office layout.

The next table shows the change of square footage per person in the original layout and the current layout. Overall, the amount of space each person is allocated has decreased, which is also obvious from the added cubicles when looking at the floor diagrams. Overall, each employee averaged a decraese of three-quarters of their space due to the staff increases over a decade.

Workspaces

Floor	Original	Current	Change	
3 & 4	150	185	123%	cubicles
	32	39	122%	offices
	182	224	123%	total
5 & 7	162	196	121%	cubicles
	27	34	126%	offices
	189	230	122%	total
6	163	213	131%	cubicles
	22	31	141%	offices
	185	244	132%	total
8	37	70	208%	cubicles
	33	49	148%	offices
	70	126	180%	total
Total	626	824	132%	

SF / person

Floor	Original	Current	Change
3	182 workspaces	224 workspaces	
44,600 sf	245.1 sf/person	199.1 sf/person	81%
4	182 worspaces	224 workspaces	
43,655 sf	239.9 sf/person	194.9 sf/person	81%
5 & 7	189 workspaces	230 workspaces	
44,600 sf	236.0 sf/person	193.9 sf/person	82%
6	185 workspaces	244 workspaces	
43,655 sf	236.0 sf/person	178.9 sf/person	76%
8	70 workspaces	126 workspaces	
37,076 sf	526.7 sf/person	294.3 sf/person	56%
			75.2%

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Interaction
- coffee bars
- conference rooms
- informal meeting areas

Services
- copiers/printers
- storage
- "Main Street" corridor

Floor 3
Current layout

Interaction
- coffee bars
- conference rooms
- informal meeting areas

Services
- copiers/printers
- storage
- "Main Street" corridor

Floor 3
Original layout

Interaction
- coffee bars
- conference rooms
- informal meeting areas

Services
- copiers/printers
- storage
- "Main Street" corridor

Floor 4
Current layout

Interaction
- coffee bars
- conference rooms
- informal meeting areas

Services
- copiers/printers
- storage
- "Main Street" corridor

Floor 4
Original layout

16 | Flexibility in modern office environments

Floor 5
Current layout

Interaction
- coffee bars
- conference rooms
- informal meeting areas

Services
- copiers/printers
- storage
- "Main Street" corridor

Floor 5
Original layout

Interaction
- coffee bars
- conference rooms
- informal meeting areas

Services
- copiers/printers
- storage
- "Main Street" corridor

Floor 6
Current layout

Interaction
- coffee bars
- conference rooms
- informal meeting areas

Services
- copiers/printers
- storage
- "Main Street" corridor

Floor 6
Original layout

Interaction
- coffee bars
- conference rooms
- informal meeting areas

Services
- copiers/printers
- storage
- "Main Street" corridor

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MnDHS ELMER L. ANDERSEN BUILDING   CASE STUDY

Interaction
- coffee bars
- conference rooms
- informal meeting areas

Services
- copiers/printers
- storage
- "Main Street" corridor

Floor 7
Current layout

Interaction
- coffee bars
- conference rooms
- informal meeting areas

Services
- copiers/printers
- storage
- "Main Street" corridor

Floor 7
Original layout

Interaction
- coffee bars
- conference rooms
- informal meeting areas

Services
- copiers/printers
- storage
- "Main Street" corridor

Floor 8
Current layout

Interaction
- coffee bars
- conference rooms
- informal meeting areas

Services
- copiers/printers
- storage
- "Main Street" corridor

Floor 8
Original layout

18 | Flexibility in modern office environments

These diagrams provide visual understanding of the increased density of the levels as staff continued to increase for a decade. Rooms that previously held printers, copiers, scanners, and filing were largely eliminated in the current plans, and instead distributed printers throughout the open office rows. Because of the concern about perimeter HVAC performance and to allow natural light throughout the whole office, cubicles were kept off the exterior wall in both iterations. The eigth floor, higher than the parking garage, was able to have fenestration along the major "Main Street" corridor.

CONTEMPORARY SCENARIOS

CONTEMPORARY SCENARIOS

Change scenario   Employees feel less territoriality and loyalty to their workspace

Design strategy   Provide control over immediate environment

      The innovations of office space design at the end of the 20th Century paved way for the multitude of innovative, creative, and even wacky office spaces in the world today. Still, relics of the old way of working hang on in many spaces. The cubicle, described the famous architect and office design critic Frank Duffy as "a disease, a pathology of the office" did not fulfill its intention of providing privacy or control over one's environment (Kremer 2013). The formulaic and standardized configuration is a throwback to exactly what designers of the Burolandschaft were trying to avoid. And, like the facility managers of 1930s through the 1970s clung to Taylorist notions of work methods, many organizations are still accepting this worn-out standard of office design without considering what could be possible when designing holistically for today's evolving needs and culture. What these facility managers are missing is the widespread and clear cry for spaces that foster creativity, allow for user control, and take advantage of the technological innovations that are continuously developing and enhancing lives. When considering employee comfort in an office environment, it can be broken down into three levels. Physical comfort, the most basic, addresses human needs of space in terms of hygiene, accessibility, and safety. Functional comfort includes immediate control over the environment, and psychological comfort includes feelings of territoriality and empowerment (Vischer 2008). Functional comfort in this case is the level that is most applicable, and is important for both employee morale and levels of stress. Employees dealing with adverse environmental conditions must expel energy to cope on unsupportive spaces instead of spending that energy on the task at hand. Some simple ways to make a workspace supportive include adjustability in chairs and worktables, movable furniture, and adjustable lighting (Vischer).

Measure of effectiveness

Occupant sureys would be beneficial in this case as well because the strategy revolves around employee comfort and satisfaction. Observations may also help discern if employees are taking ownership of space, by looking for things like photographs, moving furniture to fit their needs, or, conversely, looking for evidence that furniture is hindering workflow.

Change scenario

"Traditional" office facilities must compete with telecommuters, and the flexibility of virtual employment

Design strategy

Create an office that celebrates physical connection and creates a feeling of belonging

The working group's reliance and comfort with technology affords many opportunities to take advantage of a virtual office space, where all work-related resources are available anywhere by way of access to a network and a laptop. Because societal norms are changing in the United States, this arrangement is gaining popularity from families with both working parents as well as people who would rather stay mobile. This arrangement means that office spaces can be virtual environments as well as physical ones, as predicted by *The Office is Where You Are*. For many office facilities, this arrangement is not possible or desired, and the must compete with the attractive arrangements of the fluid and flexible system.

Hot desks, a current popular concept, is a non-assigned workspace (NBBJ 2006). They may be found within offices as temporary work places for employees who are infrequently in the office or for a regular employee who may bounce around different teams. The term is also used to refer to the many leasable spaces that are found around the world for travelling businesspeople. Those facilities provide internet services, sometimes a meeting space, video conferencing equipment, and other support features to allow employees to work from almost anywhere. The office-centered type, also called desk sharing, may be attractive to new or transitional organizations when staffing is in flux, but employees lack a sense of ownership of their space, which can lead to a feeling of under-recognition. As explained in *Other Office*, "everyone says they want to be equal, but nobody wants to be anonymous". Territoriality is an important consideration when creating spaces that employees want to be in, and is part of the psychological comfort that a worker will feel towards a space. It can be implemented on both team-level and individual scales, and includes the worker's participation in decisions, feeling of being heard, and feelings of empowerment (Vischer 2008). Employee participation beyond work-related matters is also crucial in company loyalty, and open, flexible offices provide the important opportunity for workers to be involved in the design of their environment. When consulted on design matters, employees are found to be try to learn more about their spaces and to solve environment-related problems more willingly (Vischer).

When designing a space that fosters face-to-face connections, it is also important to consider the way these different groups may interact. One of the emerging facilitators of change in the shape of workspaces is demographics. The new types of people working together means that not all working patterns can translate effectively between groups. Working styles of baby

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boomers are entirely different than those of the millennials, and with Generation Y working far past typical retirement age, spaces must be accessible by all groups together and separately despite different working patterns and requirements (Arup 2011). By providing flexibility of use, the ever-growing myriad of people and working methods can be accommodated. Accomplishing a feeling of belonging for all groups can provide stability in perceived social status, sense of privacy, and large-scale control (Vischer 2008).

Measure of effectiveness

A simple way to discern wether these spaces for connection are successful is simply if staff is using them, and how often. These spaces can take many forms, like the examples on the next page, and may be used throughout the day for planned meetings or for chance encounters. Some very hip companies even provide game rooms to help employees relax, team building, or unwind during breaks. Questionnaires reporting higher employee morale can likely be linked to these spaces that foster spontaneity and relaxation.

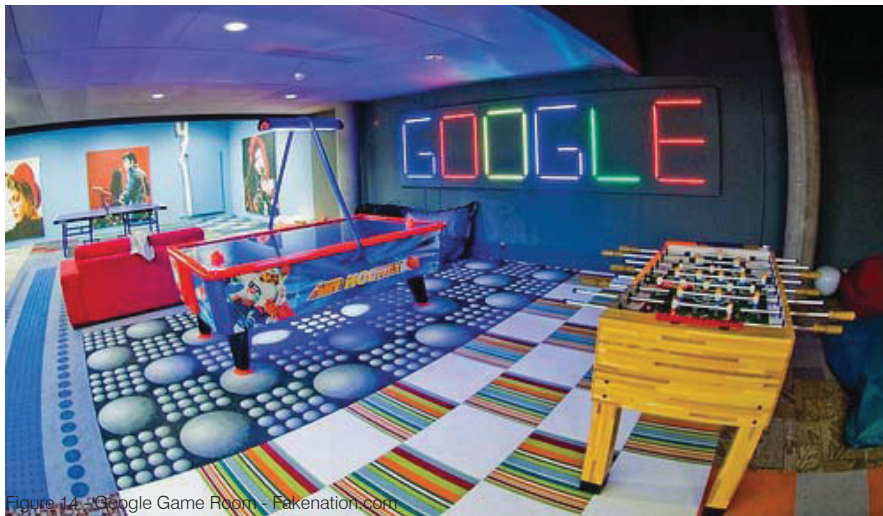Figure 13 - Office Design - OfficeDesign.blogspot.com

Figure 14 - Google Game Room - Fakenation.com

A P P E N D I X

Weekly report

Week 2   Establish communication with BWBR, begin literature review of historical precedents

Week 3   Continue literature review of historical precedents

Week 4   Establish design factors in which to study and diagram

Week 5   Create Revit model and run Lighting Analysis for Revit for Elmer A. Andersen building

Week 6   Submit literature review of historical precedents to Stefnee Trzpuc

Week 7   Generate list of change scenarios and design strategies, phone call with Eric West

Week 8   Complete lighting analysis of Elmer A. Andersen building;

Week 9   Compare before and after analytical diagrams for lighting and acoustics

Week 10   Begin inputting research findings and data into InDesign file for final report

Week 11   Develop and research design strategies including UFAD and demountable walls

Week 12   Continue research of design strategies including acoustics and lighting

Week 13   Compile research into draft journal article

Week 14   Continue develop measures of effectiveness for established design strategies

Week 15   Continue develop measures of effectiveness and spatial diagrams

Week 16   Package findings into research report and final journal article

Figures

A P P E N D I X

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Spatial Arrangemnts in Surgery Centers and Clinics

A simulation approach

North Dakota State University in partnership with HKS Architects

| Greg Bednar |

Architecture Studio 771, Fall 2014

Ganapathy Mahalingam

The goal of the research position was to use AnyLogic, a process modeling software, to model and simulate ambulatory care facilities. Using different metrics such as employee utilization, employee walking distances, room utilization, patient waking distances and wait times, the spatial arrangement of the ambulatory care facilities could be analyzed and adjusted accordingly to improve the characteristics of the room.

This GRA was funded through HKS Architects based in Dallas, Texas. The Liaisons for this Graduate Research Assistantship were Tom Harvey, a Principal and Academic Healthcare Practice Leader, and Upali Nanda, the Vice President and Director of Research at HKS.

Simulations in Healthcare

Simulations in healthcare have been extensively in the past years to improve efficiency and quality of care. There are many programs out there that can do this. MedModel, FlexSim, Simul8 Healthcare, AnyLogic. There are many options out there that can give a great idea on what to expect when running a healthcare service. Many of these simulation programs are not directly built to analyze the spaces or the built environment to help with the design of the healthcare building.

The history of computer simulations started in WWII through the development of the atomic bomb. Stanisław Ulam had been invited to join the Manhattan Project and worked on hydrodynamic calculations on the explosive lenses required for a workable bomb. Being unable to determine a closed-form expression or apply a deterministic algorithm, he explored the use of computer calculations to find his answers. This was the first recorded use of computer simulation to solve a problem. This method was then named the Monte Carlo method described as a broad class of computational algorithms that rely on repeated random sampling to determine numerical results.

The method has proven to give better results than human intuition in regards to predictions of failure or cost overruns. The Monte Carlo methods are used in three distinct problem classes: optimization, numerical integration, and probability distribution. This project will deal with the optimization side of simulation.

Objectives and Ideas to be Explored

· Model the entire process of an ambulatory care facility.
· Model the walking distances of employees and patients
· Minimize the walking distances of employees and patients
· Provide a logic map of a patient path when going into a clinic
· Compare different clinic arrangements with the different metrics.

How AnyLogic Works

AnyLogic is an agent based simulation software that is entirely Java based. This means it is fairly simple to make changes and create custom functions that use the software to its fullest potential.

Using simple logic flow diagrams one can visually program the simulation through what are called model blocks. They carry out functions to create entities, move entities, make them wait for a specified time, make them interact with other entities, and then make them exit the system.

Examples of these blocks are shown below. Getting + with them will help to understand the flow charts later in this report.

Source
Generates entities. Is usually a starting point of a process model.

Select Output
Routes the incoming entities to one of the two output ports depending on (probabilistic or deterministic) condition. The condition may depend on the entity as well as on any external factors.
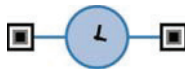
Delay
Delays entities for a given amount of time. The delay time is evaluated dynamically, may be stochastic and may depend on the entity as well as on any other conditions.

Move To
Moves the agent/entity to a new location in the network. If any resources are attached to the entity, they will move with it. The speed will be the entity speed regardless of the attached resources speed.
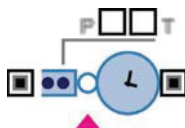
Service
Seizes a given number of resource units, delays the entity, and releases the seized units. Is equivalent to a sequence Seize, Delay, Release and should be used if the entity does not need to do anything but execute a delay between seize and release.

Pedestrian Modeling

The strengths of the pedestrian modeling library is that it tracks location data on every single pedestrian entity. This means there is collision detection with the other pedestrians meaning you can test to see how congested the hallways may get at peek usage.

You can also show the density of the pedestrian walking through the space. This is helpful for showing potential building wear spots that need to be monitored.
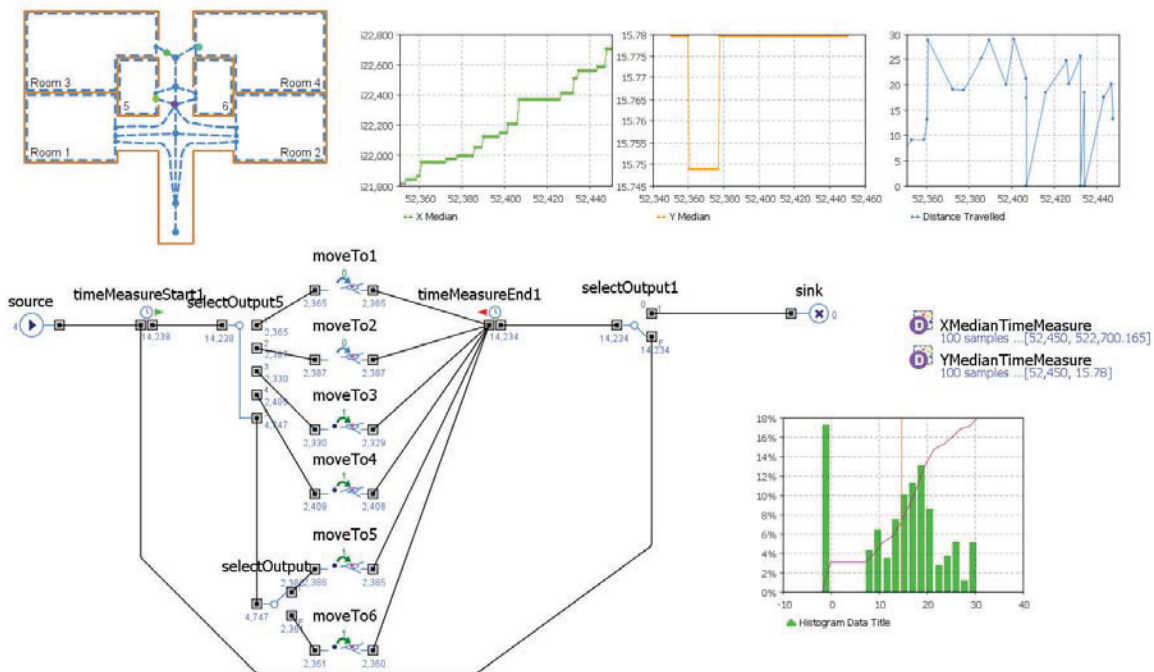
This model's purpose is to determine the function needed to plot the distance travelled by a single nurse. With this function we can apply it to a larger scale model system.

The system uses a start time and end time and by knowing the speed, we can easily find the distance as Velocity x Time = Distance. Unfortunately this method does not allow for measurement of the different entities that depend on this one. The only way to measure the distances for a role in the clinic model, is to have a completely different logic tree specifically for that role.

That is impossible to model because it's the patients that call for and determine the movement of the nurses.

This model shows what is needed to be done to model two different nurses having to visit multiple spaces. This is a double loaded clinic corridor design that HKS uses for its bed unit configurations. Ideally there would be wait times at each of the different spaces but the limitations of the software do not allow for this, so the effect is simulated by just traveling to one space and moving on to the next. The walking distances will be the same, the time however will not.
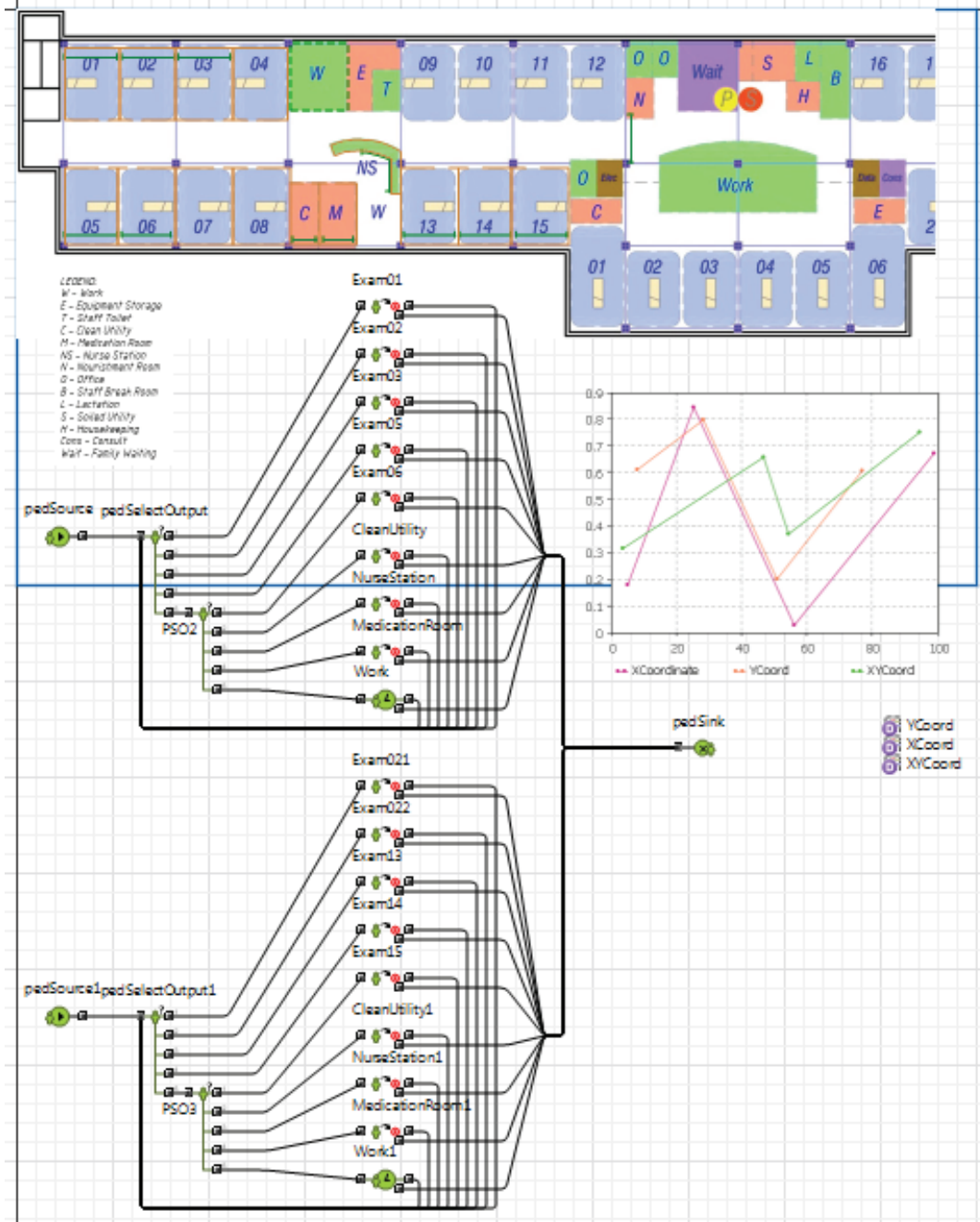
Process Modeling

The process modeling library is used to model systems. It takes each component of a complex system, and breaks it down into smaller processes. The main functinos used are [moveTo] [seize], [selectOutput], and [delay].
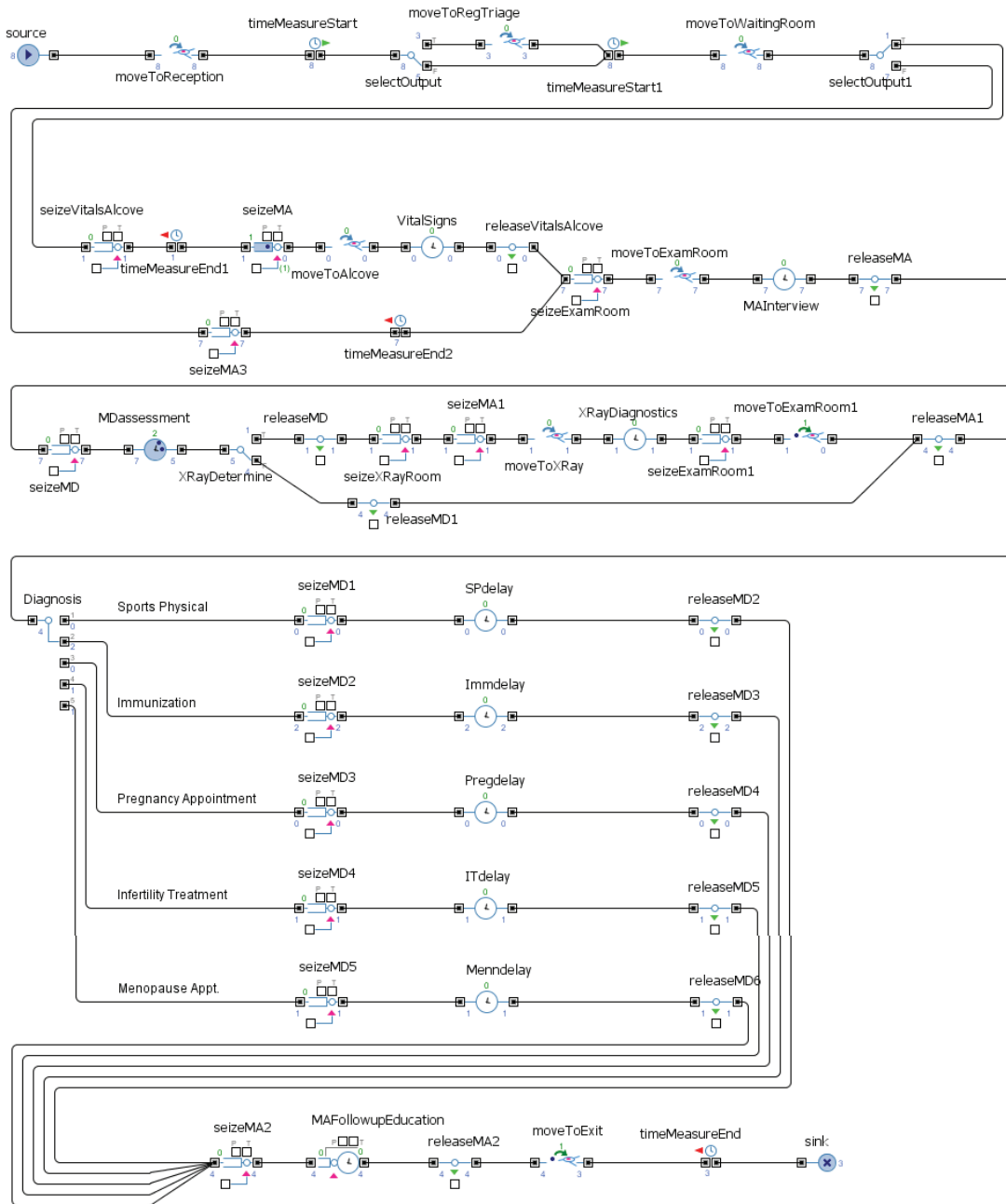
Kaysville Clinic

Below is the model that the previous logic map is linked to. Patients enter on the right, visit the reception counter, then depending on whether it is a drop in or a scheduled appointment, they will visit the registration/triage room then go to the waiting room.

After that the vitals alcove is reserved as well as a nurse is called. The nurse take the patient to the vitals alcove does the procedure then seizes an exam room and takes them to the room. The health interview is conducted the nurse is released and the doctor is called on. The doctor gives their assessment, determines if an X-ray is needed. If needed the doctor is released the x-ray technician is called, the patient is moved to the x-ray room, the x-ray procedure is conducted, and then the patient is returned back to the exam room.

The different procedure is then chosen whether it be a sports physical, immunization, pregnancy appointment, infertility treatment, or menopause appointment. After the appointment is completed, the patient is then dismissed and the nurses and doctors go back to their home locations.
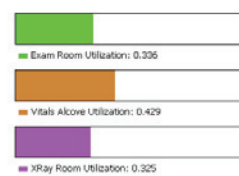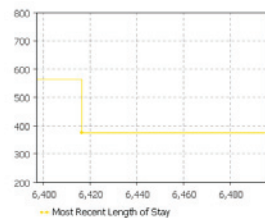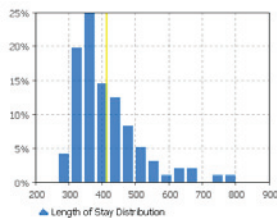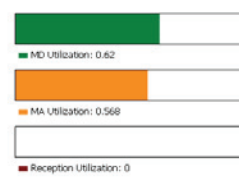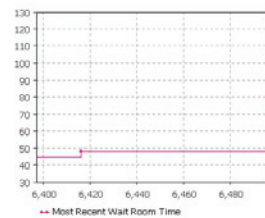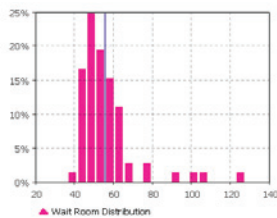
Riverton Clinic
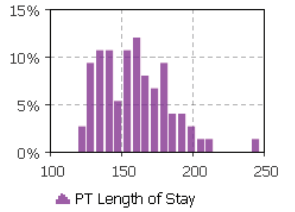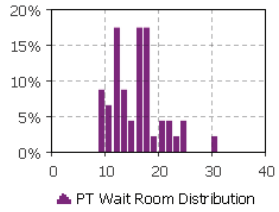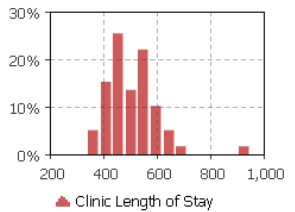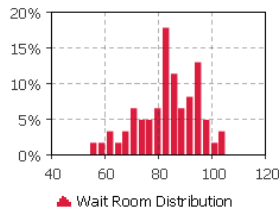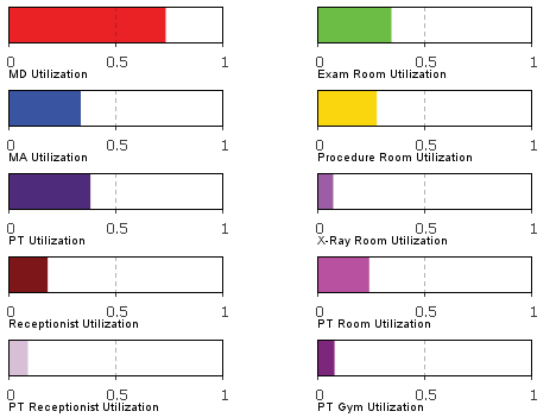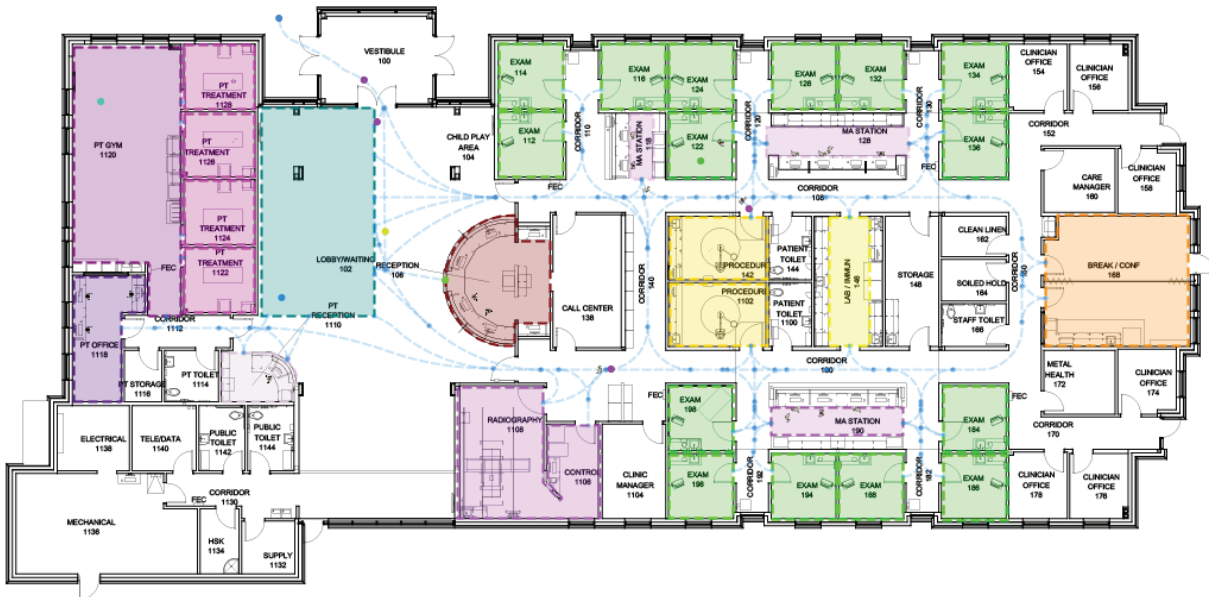
This is the second model that I created. Using the same process model as the Kaysville clinic, I just modified the model to add a Physical Therapy branch and removed the triage and vitals alcove sections. The model collects statistics on room utilization, staff utilization, wait times, and lengths of stay.

Below I will describe each step in detail explaining how anylogic deals with the different systems and how the branching into different processes work.

Understanding the Process Model

timeMeasureStartClinic

seizeReceptionist

release

selectOutput Clinic Branch **moveToReception** **timeMeasureStartClinicWait**

delayReception

moveToWaitingRoom1

source

Physical Therapy Branch

timeMeasureStartPT

seizePTReceptionist

release1

moveToPTReception **timeMeasureStartPTWait**

delayPTReception

# of patients that have arrived

# of patients that have gone through the Clinic or Physical Therapy branches

# of patients that have gone through Reception

1 patient is on its way to the receptionist

These blocks are used to collect data on wait times and total time spent at the clinic

These three blocks work in coordination of first seizing the receptionist to get service, then using a delay block to simulate the length of checking in, then releasing that receptionist so that it is available to serve other patients

The patients then continue on through the process model

After registration is complete, the exam is to be conducted. To do that both an MA and an exam room is needed. If available, both of them are seized through the seizeExamRoom block

seizeExamRoom

moveToExamRoom

releaseMA

timeMeasureEndClinicWait

MAInterview

This is the properties of the seizeExamRoom Block. The seize resoruce sets is selected to request both an exam room and MA before the seizure can be completed.

timeMeasureEndClinicWait is the block used to track the time each patient spent from checkin at the top of this page to now when the nurse and exam room are ready for the patient.

Once the patient and nurse reach the exam room, the interview takes place.

The patient then continues down the process model

Now that the resources (Exam Room and MA) have been seized, the MA "attaches" to the patient and brings them to the seized exam room.

After the interview takes place, the nurse is released from that patient, and is availble to be seized by another.

In the case that an X-ray is needed, the doctor is released, a nurse and the Radiography Room is seized

Once the resources are available and seized, the patient is taken to the Radiography Room

The x-ray is performed

The x-ray room is released and the patient goes back to its original exam room

Once the patient and nurse get back to the exam room, the nurse is released and the patient moves on to the procedure phase

MDassessment **releaseMD** **moveToXRay** **releaseXRayRoom** **releaseMA1**

seizeMD **XRayDetermine** **seizeXRayRoom** **XRayDiagnostics** **moveToExamRoom1**

releaseMD1

Once the MA interview has taken place, an assessment by the MD is to take place. With the room already seized by the patient, only seizure of an MD is needed.

After the assessment the doctor determines if an X-ray is needed. It is set to a ratio of 1:9 needing an X-Ray.

In the case that an X-ray is not needed, the docotr is released and the patient moves on to the procedure phase

Diagnosis Sports Physical — **seizeSportPhysical** — **SPdelay** — **releaseMD2**

Immunization — **seizeImmunization** — **Immdelay** — **releaseMD3**

Pregnancy Appointment — **seizePregnancyAppointment** — **Pregdelay** — **releaseMD4**
moveToProcedure1

Infertility Treatment — **seizeInfertilityTreatment** — **ITdelay** — **releaseMD5**
moveToProcedure

Menopause Appt. — **seizeMenopauseAppt** — **Menndelay** — **releaseMD6**

With diagnosis complete, the patient moves to the different procedures needed for treatment. The necessary resoruces are then seized.

Resources seized

Sports Physical: 1 MD
Immunization: 1 MD
Pregnancy Appointment: 1 MD, 1 Procedure Room
Infertility Treatment: 1 MD, 1 MA, 1 Procedure Room
Menopause Appt.: 1 MD

Since a procedure room is needed to complete the Pregnancy Appointment, and Infertility Treatment, moveTo commands are used to move the patient to the procedure rooms

The procedures are conducted

Once the procedures are completed, the unneeded resources are released and the patient returns to the exam room for the wrap up

seizeMA2

MAFollowupEducation

releaseMA2

moveToExit

timeMeasureEndClinic

sink

A nurse is seized for the final wrap up and education.

All resources seized by the patient are then released and they move to the exit

Once the patient leaves the building the timeMeasureEndClinic block notes the time the patient spent in the clinic and plots it on the histogram

The patient exits the process model

This is the Physical Training branch steming from the start of the process model.

If the patient has an appointment with a PT Specialist, they move to the waiting room while seizing a PT room and a Physical Training

Once the room and Physical Training Specialist is seized, the patient moves to the PT room and the appointment is conducted

Once the apointment is compleete, the room and PT Specialist is released

selectOutput1

timeMeasureEndPTWait

seizePTRoom

seizePT

moveToPTRoom

delay

releasePT

moveToExit1

timeMeasureEndPT

moveToWaitingRoom

PT Room

Gym

seize

moveToPTGym

delayPTGym

releasePTGym

The patient moves to the exit and timing statistics are collected for the Personal Training Branch

First the patients are split into two branches. One visiting the clinic for trainging at the Gym, and the other for an appointmnet in one of the physical training rooms

The gym is seized and the patient moves to the gym.

A session is performed in the gym and then the gym is released

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Conclusions

The pedestrian model does a great job of tracking individual players in the set up system. If the full version of AnyLogic was available it would be possible to model an entire clinic and collect distance statistics on all of the different roles in the environment. As it stands the educational version still does a good job of being able to model and produce useful statistics in small simulations. For example, deciding on room assignments for different staff. This part of the software could very effectively be used to determine room arrangement and spaces when time and distance from one space to the next is very important. Currently the software allows you to make a layout and test it. You can compare the results of the different tests and see what layout performs better. The software has no way to suggest the best potential arrangement however. A simulation software being able to suggest a potential layout would be a very big step from where we are now.

The process model does a much better at looking at things in the larger scale. It can deal with multiple types of resources being seized and released as well as using different rooms for multiple purposes. With the model that I built, we could see based on the arrival rate how many staff members are needed as well as how many rooms are needed. Depending on the location and expected patient numbers, we could confidently show how many rooms are needed of certain types. Accurate demographic data would be needed but with that data it would be easy to find the total number of rooms and staff needed for a new clinic.

Programming for clinic designs could become much more reliable and easy. It is no longer intuition, rules of thumb, and a little bit of luck. Using software to simulate building spaces and usage will become much more common. These software programs still have a substantial price tag but as costs go down I could see this being utilized in every substantial building. Stadiums, theaters, schools, community centers, convention centers, anywhere with significant traffic and space needs could use this program for figuring out a very accurate building program. Space, staff, and equipment needs can be very accurately determined.

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ALZHEIMER'S & DEMENTIA

A SPATIAL STUDY OF TREATMENT UNITS TO MAXIMIZE SENSOR COVERAGE

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ARCHITECTURE. STUDIO 771
DR. GANAPATHY MAHALINGAM | FALL 2014

RESEARCH REPORT

ABSTRACT

This is a research conducted to explore 1) the effectiveness of a camera sensor array for memory care treatment facilities, and 2) potentially innovative floor plan configurations for an overall better experience for patient, care taker, and guest. Revit in conjunction with the emerging Add-In Dynamo are the primary software programs utilized for the development and analysis of various design iterations and their effectiveness. Specifically, a single camera and sensor family has been developed inside of Revit that can be parametrically adapted to specification requirements to improve the coverage effectiveness while simultaneously gaging the economic impact depending on any given design decision. Dynamo is a visual programming interface tightly connected to Revit to introduce the possibility of creating complex and highly intuitive relationships not previously available from Revit. Essentially Dynamo has introduced a work flow comparable to that of Grasshopper to Rhino allowing for generative design. However, the primary difference being Dynamo's intimate connection to Revit over being a completely standalone application. In short, the following article covers the research methodology, design process, and design solution utilizing Dynamo as an integral tool for the research project and the future of B.I.M design everywhere.

RESEARCH METHODOLOGY

The research project used a concurrent approach to research and development. The first 4 weeks were devoted to establishing a base knowledge of Dynamo, developing a familiarity with the user interface, basic nodes, definitions, and terminology, and its connection to Revit. Simultaneously, a liaison was consulted to gain a base knowledge of the needs and limitations surrounding memory care centers as well as current cutting edge projects being conducted around the world specific to Alzheimer centers.

After the initial knowledge base was established, the project entered development starting with the creation of a fully parametric camera sensor family inside of Revit. An Alzheimer care unit floor plan was provided by the consultant for a basic design precedent which allowed an effective starting point to develop a Dynamo definition around with the integrated camera family.

As the project progressed, technical research for Dynamo was necessary to be able to effectively operate the desired project goal. Also, more research was needed to properly address the constraints surrounding memory care units in light of HIPAA regulations and patient needs.

WHY DYNAMO

Dynamo first emerged on the market in early December, 2012 with its primary goal to establish a visual programming language and interface fully integrated with Revit. The program it open source and direct communication is available with the developers. Besides the design benefits of Dynamo, the team has established an open process for development, encouraging users to feel free to contribute and take active participation to grow Dynamo. The API and code is available as well as current versions and development process on GitHub.

The project hosts a website to download latest versions, learn the program, and interact with users from around the world in their forum. Just like the open nature of the program, the community is very inviting to contribute and help its fellow members to help trouble shoot issues. The website can be found here.

The primary benefits of Dynamo include but not limited to:

1. INTERACTIVE PARAMETRIC DESIGN.
   With each change of a parameter, Dynamo can to 'Run Automatically' allowing for immediate processing of parametric changes to a design. Adding a slider node can allow for subjective tweaks and refinement in real time. See a brief demonstration here and here.

2. LOGIC TESTS.
   Conditions can be established to help filter down or select a given iteration based on how it meets the driving condition. Stringing sets of conditions together opens up possibilities for highly intelligent design.

3. DEFINITIONS.
   Dynamo definitions are not project specific and can be quickly reused many times after being developed. In light of conditional statements, it is now possible to automate design work that a designer may be running through internally already. The designer can focus their efforts on more important design considerations while staying within the established constraints.

4. COMPARATIVE ANALYSIS.
   Integration with Excel allows for adjusted parameters from Dynamo to be quickly exported and integrated to a spreadsheet for more effective comparative analysis. The power of Dynamo allows for the analysis of any parameter imaginable to be established and compared.

5. REVIT INTEGRATION.
   A hybrid approach to design with Revit is in the DNA of Dynamo and has been the primary concern since its outset. Therefore it is possible to use Dynamo as much or as little as desired to help automate design processes.

For the research project, Dynamo was integrated to build and gauge the effectiveness of the camera sensor array. Specifically, a 'cone of coverage' was established for the camera inside of Dynamo to represent the camera aperture and effective falloff distance. The intersection function inside of Dynamo allowed for the surface area on the floor plate to be articulated and quantified.

Revit was used to establish the floor plan configuration and room bounding units to inform limits inside of Dynamo. Also, the location of needed cameras and sensors are initially placed inside of Revit. The desire was to have location and orientation of a place component point in Revit to inform

Dynamo, but current limitations forced each camera instance to be properly oriented within Dynamo.

Finally, an Excel workbook is generated by Dynamo containing the following variables:
- Camera Type and Quantity
- Sensor Type and Quantity
- Coverage Quantity (in square feet)
- Coverage Percentage
- Cost per unit
- Total cost of system array

The primary variables determining the 'effectiveness' of the system array can be gauged from an economic perspective or a performance perspective. Preference is given to having higher coverage percentages in light of maintaining high quality care for patients in the center.

Refer to various sub-sections under 'The Solution' section for an in-depth explanation of each component part of the design process described above.

ESTABLISH PRECEDENT

As mentioned previously, establishing a baseline understanding of Alzheimer treatment facilities was necessary to create effective designs. For this, a liaison was brought in to consult and connect the designer to resources for design precedent as well as resources to cutting edge solutions currently being explored in firms and research institutions around the world.

A standard floor plan configuration for a memory care treatment facility was provided to help the designer understand the various programmatic demands and sizing requirements of the center. Upon bringing the plan into Revit, it was then used for reference in the development of a fully parametric adaptive camera and sensor family. It was also used for reference to develop the Dynamo definition and iteration pipeline prior to developing various floor plan configurations.

The first 4 weeks of the project were used to establish a solid understanding of the building typology prior to moving forward with research development. This also included reading articles to aid in understanding the user group specifically focusing on the patients, care takers, and visiting guests.

With the establishment of the design process and baseline understanding of Dynamo in conjunction with Revit, camera sensor system arrays, and the demands of memory care treatment facilities, the project moved into developing an effective solution.

ALZHEIMER'S: UNDERSTANDING THE USER

Beyond the software demands and capabilities needed to be effective in the project, it was essential to get inside the minds of the patients, caregivers, and families of those people using the facility.

It was found according to professionals in Neurology, Medicine, and Psychology, that there are certain

things that significantly improve responses from patients. The first is that a good environment is as good if not better than medicine for treating a degrading mind. Alzheimer and Dementia patients need to have as much familiarity as possible to integrate which can come down to the smallest of details such as an unfamiliar door knob or faucet operating differently.

For healthy environments, it was found to be highly beneficial to have free access to open outdoor spaces which gives a sense of autonomy.

For caregivers, they tend to be overstressed and overworked at the constant task of tending to their patients. As part of improving the overall program of the facility, loved ones should offer specific services to aid the caregiver such as offering to mow their lawn or do their laundry. This stress relief returns positive to the loved one with Alzheimer's being taken care of.

Patients are better off if they are constantly active. The inevitable wandering person often is patient pursuing some innate or conditioned end either as simple as the bathroom or something as ingrained as leaving work at 5pm as a trigger. By having a rich activity set, patients can stay engaged which minimizes wandering and stimulates mental activity.

Finally, privacy is paramount. The primary concern with these facilities is providing a sense of autonomy and so it is important to create facilities that allow the patient to feel a good sense of privacy that results in less often and less severe episodes.

THE SOLUTION
DESIGNING A SMART CAMERA

A single camera and sensor family has been developed inside of Revit that can be parametrically adapted to the specification requirements to improve the coverage effectiveness while simultaneously gaging the economic impact of making any given design decision. Having a single Revit family with multiple Types streamlines the design process and subsequent comparative analysis between design iterations.

Initially, a Revit Adaptive component was created. (See Figure 1.1) This included the camera's 'Cone of Coverage' which represented the aperture opening associated with a given camera type. This pa-
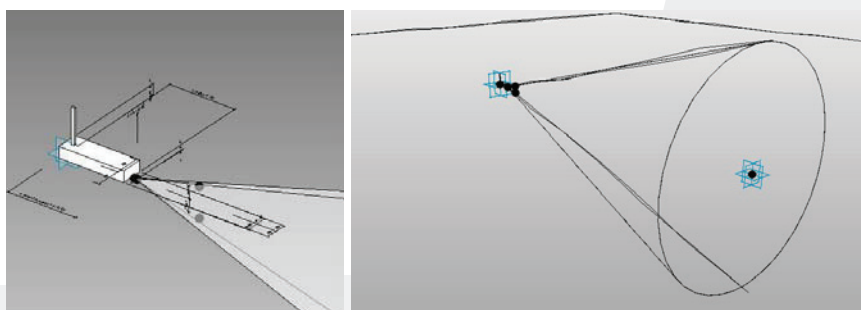

Figure 1.1: Revit Adaptive Camera Component.

rameter could be adjusted as needed depending on the camera specification and desired increased coverage.

The advantage to creating an adaptive component was the flexibility and freedom to place the component wherever desired. It would not be limited to being hosted to a ceiling or wall. This would avoid any potential issues when seeking custom orientations or slight tweaks in position.

However, this development went one step too far.

When using the 'Select Element' node inside of Dynamo and selecting the adaptive component, Dynamo was only able to map half of the cone geometry into it interface for reference. This gets back to how Revit generates geometry. With this solution, the designer would be forced to manually select 2 faces from Revit for each instance of the camera. Multiplying this across an entire camera sensor array system made is not a viable solution.

Here lies the first hybrid solution developed for the project between Revit and Dynamo. The adaptive component was maintained in Revit. The benefits to this include:

- Flexible placement and orientation of the camera or sensor. Having a familiarity with the Revit environment and transform tools in conjunction with the floor plan's walls, make it much easier to make good decisions for placement.
- Revit identity and meta data built directly into the family. Depending on the family type (or camera spec), the component price data could be gathered for gathering a final cost estimate for each design iteration.

Dynamo was then responsible for the following in relation to the camera component:

- Correctly syncing to the placement point of the Revit Adaptive component.
- Generating the 'Cone of Coverage' geometry and running an intersection to map the surface area of it's coverage.
- Parametric control over the camera's aperture opening, rotation vertically and horizontally, and it's offset from the ground or ceiling.

Unfortunately, Dynamo is currently only able to recognize the XYZ location of an Adaptive Component placement point but fails to read it's orientation. That means the designer is forced to transform and rotate geometry inside of Dynamo rather than having Revit act as the primary 'host' from which Dynamo gathers the base transformation information and then allows for further flexibility to sub-transformations within the overall hierarchy.

If changes in position and rotation were made inside of Revit, the parent relationship would peculate into the Dynamo definition and all child nodes developed and derived from the original Revit geometry would follow along.

Once the camera family was effectively created, it was a simple process of saving out a sensor copy

and tweaking its setting to match the specifications of a sensor. The only change that had to take place for the sensor was utilizing a hemispherical geometry for coverage compared to a cone.

The entire project revolves around this component to work effectively in relation to the floor plan. Next, an in-depth explanation of the dynamo definition will be explored.

DESIGNING THE DYNAMO DEFINITION

The majority of the research project was focused on the development and effective execution of the Dynamo definition. Dynamo operates like a stream flowing from one node to another moving from left to right until it reaches the end. Any break in the chain of nodes along the way has a ripple effect to any associated nodes downstream. With the ultimate piece of the definition gathering quantitative data and generating an Excel spreadsheet, there was no room for broken links in the definition stream.

Take a look at the finished definition here.

Figure 1.2 – The Dynamo interface gathering walls from Revit and testing operations with the camera component.

Creating the definition from start to finish includes the following component steps:

1. Map Adaptive Component point from Revit Dynamo.

2. Generate the camera cone of coverage and associated parametric sliders to control camera aperture, orientation, and offset distance from ceiling.

3. Map Revit Room boundaries into Dynamo using the LunchBox package 'Room Collector'.

4. Map Revit Floors into Dynamo using the LunchBox package 'Floor collector.'

5. Run intersection function to generate surface representation of every camera instance coverage amount.

6. Gather the surface areas sum total of all camera instances and export a variety of data functions to Excel.

7. Update parameters as needed for design decisions and run definition operation again to export another iteration for comparative analysis.

The camera sliders controlling its parameters utilizes a Dynamo custom node which is essentially a grouping of multiple nodes into a single package with associated inputs and outputs. This way the definition was consolidated into a single custom node for each camera instance in the model ready for precise control. By using a single node, with only the inputs visible, a single slider node can be used to control the parameters of multiple camera instances simultaneously. (See Figure 1.3)
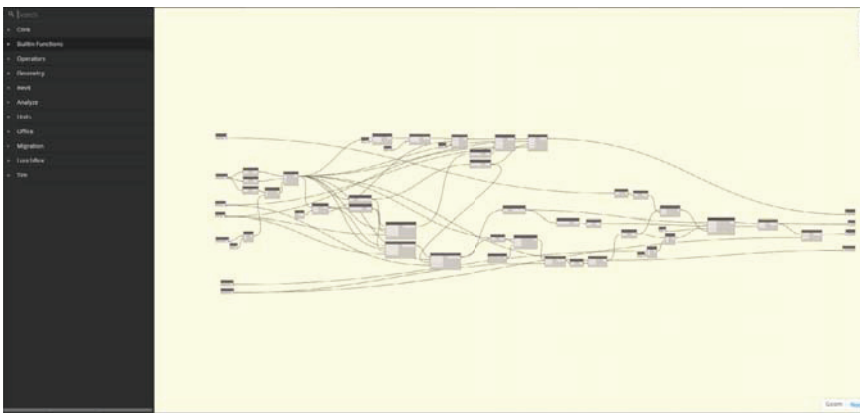
Figure 1.3 – Custom node of 56 nodes pulled together making 1 camera instance.

DESIGNING THE FLOOR PLANS

Once the Dynamo definition was established and operating properly, the next phase in the research project focused on developing a set of innovative spatial configurations for Alzheimer treatment facilities.

The primary design considerations focused on a streamlined plan to optimize care takers to have efficient lines of access to patients in case of an emergency. Designs aimed to incorporate closed loop circuits for patients to be able to wander and stay active with node points along the path for potential social interaction or activities. Points of entry and exit other than the main entry were designed increase the distance of travel before being able to exit giving the care takers and opportunity to intercept the patient before they are able to get out and into worse trouble.

The most interesting design challenge with this type of facility is walking the silver lining between effective control and maintaining a sense of independence for the patient. To an extent, designs have to respond to protecting patients from themselves.

A SHOCKING DISCOVERY

After extensive development of a tailored definition inside of Dynamo that is able to generate a camera array system for each iteration of a floor plan, it has been found to not be effective for the task of

analyzing the data in question. In short, it was only able to yield sub-par results because of its current limitations in geometric modeling.

As previously stated, a primary premise of the project was to be able to accurately simulate real-world scenarios inside the computer by developing a computer model that matched real-world sizes. However, after a painstaking development process, it has been found that Dynamo currently is too limited in its abilities to handle this specific project.

Specifically, it does not handle developing an accurate representation of a cone well in correlation with the necessary parameters to be manipulated for the full development of a camera system array throughout an entire building floor plan.

Also, the user interface of Dynamo is difficult to work with, causing a lot of added leg work that has already been established and packaged into a tool as in other software. The limitless possibilities have made it too difficult and too open ended to work with. Though a potentially viable solution was developed, it was not able to successfully handle an entire camera array system effectively.

Each instance of a camera had to have its own set of wires to then be custom oriented the proper direction after placement. This orientation was not able to be derived from the data provided by Revit whose model manipulation tools are far superior. This quickly became a labor-intensive task not only wiring up each camera instance but also positioning it properly after a series of trial and error tests.
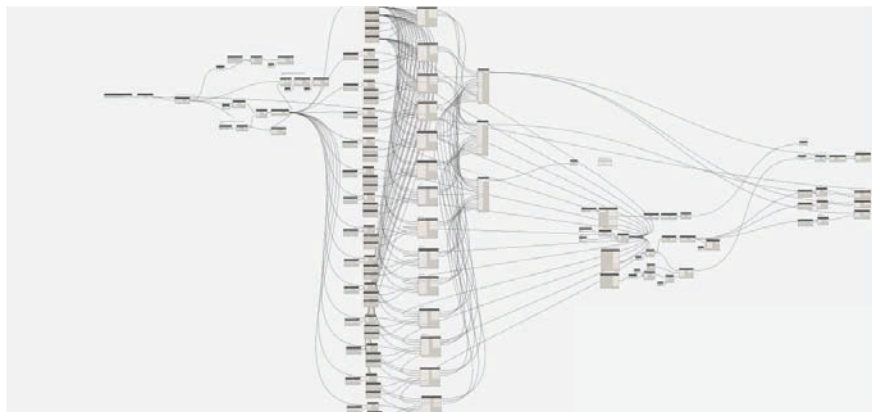

Figure 1.4 – Overall view of Dynamo with each camera instance needing its own massive wire set.
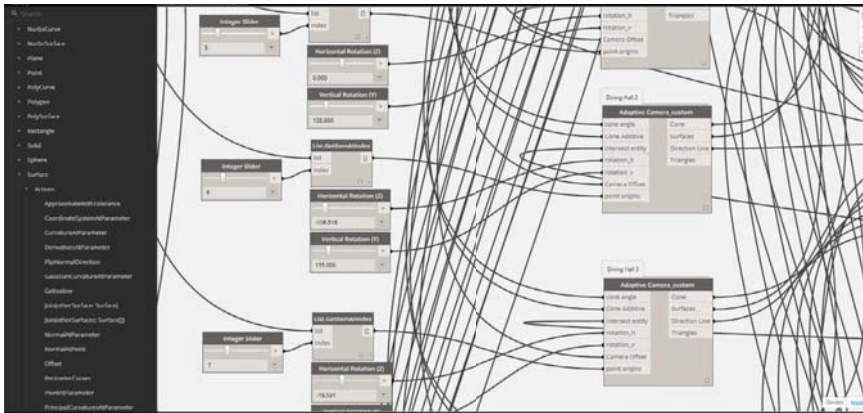
RESEARCH REPORT

Figure 1.5 – Close up view of wire set. Each custom node is comprised of an additional 56 nodes to build the camera.
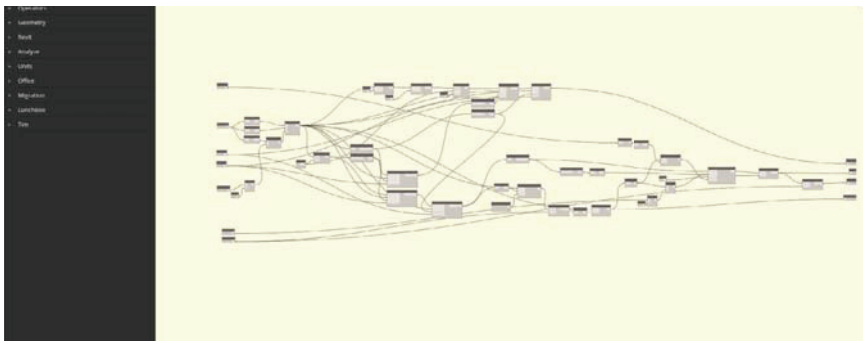

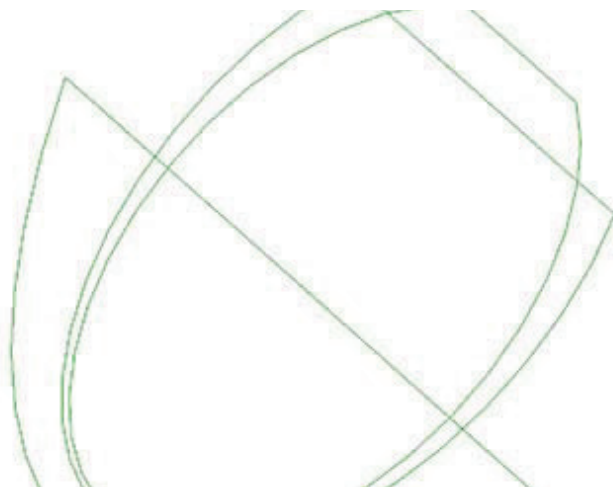Figure 1.6 – Custom node of 56 nodes pulled together making 1 camera instance.

Figure 1.7- Interpolation patterns from Dynamo camera intersection.

Not all was lost.

The cone representation was able to give the closest depiction possible of the footprint that the camera's cone of coverage would produce when implemented in the field. Again, because of the limitations of Dynamo, the best possible solution was to interpolate between 3 ellipses that, when combined, would form the most accurate depiction of the camera's coverage.

For CCTV camera selection, the primary features that were of concern were having sharp enough image quality and the aperture's overall opening. This model was selected because of its impressive 90° aperture opening. It will hardly miss a thing right below it as well as capture nearly the entire room when placed in an upper corner.

Because of the unexpected technical and operational issues that arose nearing the end, another method for achieving good results was pursued. The alternative method involves utilizing a combination of analysis tools that come standard inside of Revit.

First, an overall Area floor plan conveys a color-coordinated floor plan of the design iteration that can then be used in comparison to further iterations with the same color scheme. Matching scale and color allows for a very quick visual comparison to the overall floor plan layout as well as if there were different spaces prioritize in any particular iteration.

The second part utilizes a similar feature by creating a "Space Plan." The difference here is that a "Space Plan" is more general and open to the development of the user. Boundaries were specifically derived from the camera footprint established in the Dynamo definition. Two-dimensional line work was then placed subjectively throughout the floor plan to cover all the key areas specific to Alzheimer care units. For cameras, this includes public spaces such as:

1. Points of Entry,
2. Dining Hall,
3. Garden, and
4. All Corridors.

For sensor systems, they were specifically integrated into the following key areas:

1. Residence Thresholds (Corridor and Garden access)
2. Residence Water Closet
3. Residence Bed
4. Points of Entry & Exit (distanced far enough to give adequate time for caregiver intervention)
5. Perimeter Fencing

Figure 1.8 – Floor Plan analysis of Foyer La Grange | Couëron, France

THE FLOOR PLAN + DESIGN PRECEDENT

Because of the complexity of the development with the Dynamo definition and due to time constraints, one fully functional floor plan was able to be designed, integrated with the camera & sensor array system, and processed through analysis of the array's effectiveness compared to the whole. In addition, in-depth typological research was conducted and those floor plans are also included for comparison.

The process was taking a specific Area style establish inside of Revit, and assigning the correct category based on its function. After properly scaling, it was just a matter of placing walls and conducting take-off studies and area analysis.

It is important to note the difference in priority between the two designs. Both maintain a ratio of 1 caretaker to 6 or 7 patients but the location of services and amenities differs quite considerably. The Las Vegas Memory Care center shows itself put together almost piece-meal, showing little sense of contextual awareness and minimal spacing for residence.

However, at Foyer La Grange, there is a deliberate design move to separate residence to their own wing and have their own wandering loop. Each resident room has a connection either to the interior
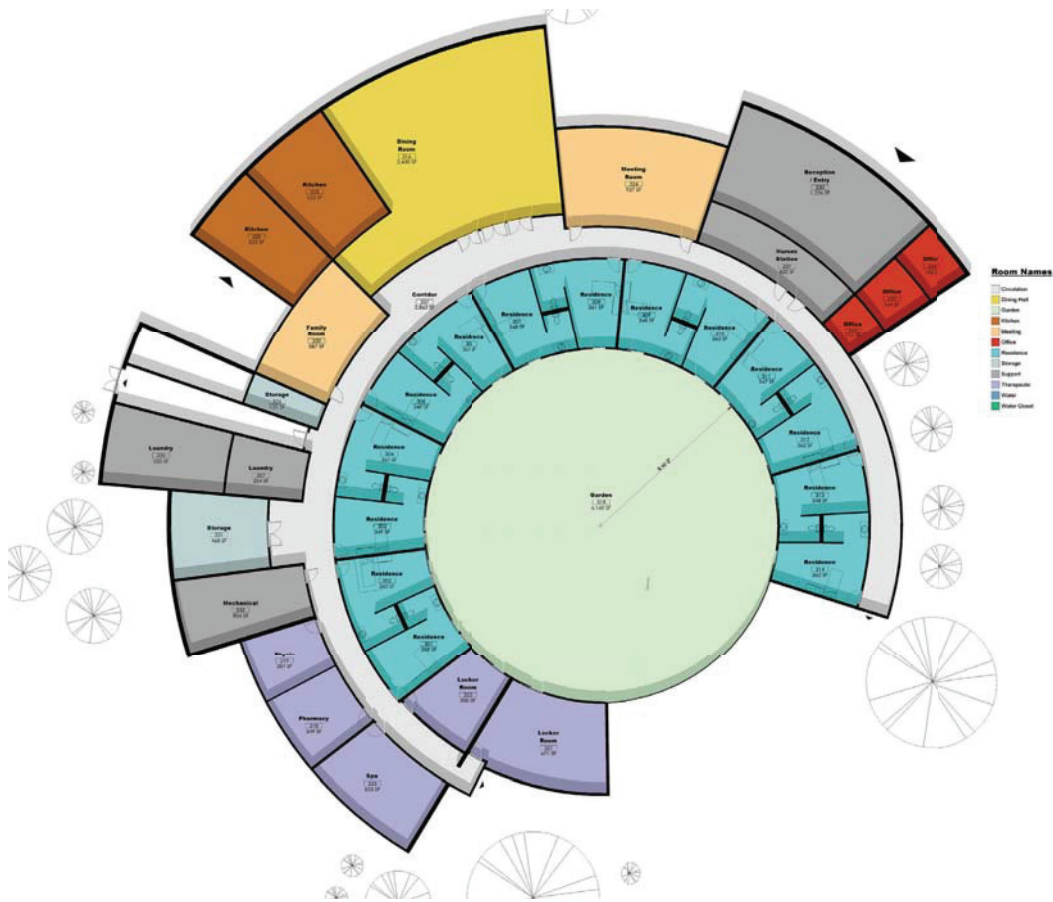
Figure 1.9 – Floor Plan analysis of Nevada Memory Care | Las Vegas, Nevada

garden or to an exterior view of nature and the city. There is sufficient nursing equipment discreetly placed in the central island. Priority is placed on views to nature and also the activity of the center. As a transition point, there is a series of therapy or activity stations including: hairdresser, physio room, spa, activity room, pharmacy, and locker rooms.

On the other side exists the nursing station, kitchen and dining, front meeting hall and reception for visiting family and support services. In my studies, I found this configuration to be highly effective and a strong design point.

John Zeisel, president and co-founder of Hearthstone Alzheimer Care, stated recently in an article on APlaceForMom.com, that gardens "are crucial in helping dementia care residents feel less trapped and more attuned to the natural rhythms of day and night."

This was the primary design focus I took away for the project design. Maintaining views to nature and not completely enclosing the garden, but leaving a segment open to a key vista or view to the city is primary. Everything else would be ideally situated around that bearing in mind to keep therapy and activity for residents to one wing and staff assistance and service on the other while still maintaining appropriate response proximity for caretakers.

Figure 2.0 – Final design solution. Alzheimer Care Center

 A single corridor connected the entire building with special indents made for larger sized objects or higher traffic but acts as a wandering circuit for residents. The destination on one end is the activity wing complete with spa, physio room, pharmacy, and locker rooms.

The clear focus revolves around residents having a secure garden and direct access to it from their living quarters. This gives views to nature and a sense of autonomy away from the rest of the facility. It also acts as an activity foyer and a place that can be a healthy distraction if residents our found wandering for something that doesn't exist. The wedge opening to the south promotes an additional sense of autonomy and potentially views to city or nature depending on the site location.

DESIGN OF THE CAMERA + SENSOR SYSTEM ARRAY

Now that the core design has been established, the next step integrates the camera/sensor system array into the floor plan. Primary design consideration were mentioned previously in the article. Again, the primary consideration focused on promoting a strong sense of autonomy of the patient while providing quick and effective information to the caretaker for intervention as needed.

Working with a consulting specialist in this facility type, cameras were constrained to outside patient care rooms covering the corridors, entry and exit points, nursing station, and outdoor recreation area.
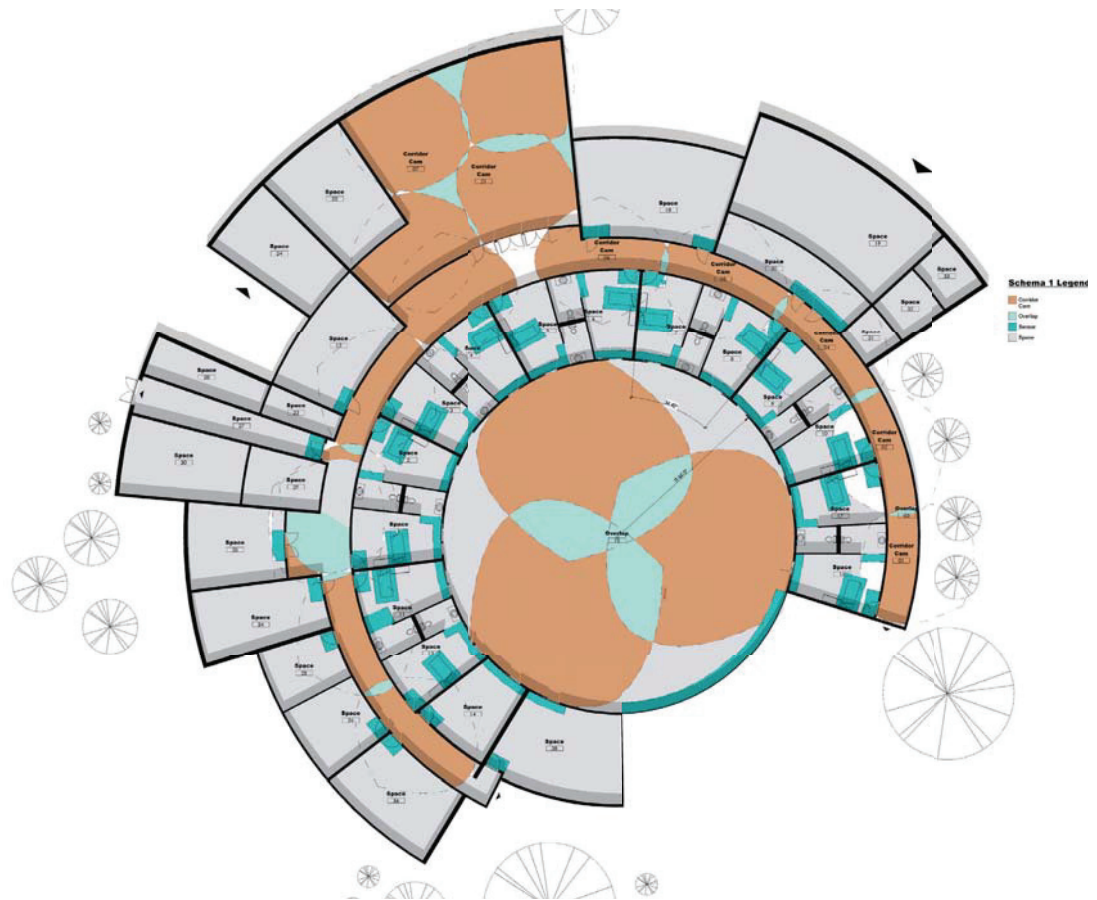
Figure 2.1 – Camera Coverage (Orange), Sensor Coverage (Turquoise), and Overlapping (Green)

Sensors in conjunction with RFID tags were utilized throughout the patient rooms at critical points. This method of monitoring is approved under HIPAA regulations and is currently mainstream for this type of treatment facility. Specifically, sensors were placed on the patient bed, entry door, bathroom door, in the ceiling overhead the kitchen area, and at the window. The primary concern is the safety and welfare of the patient while allowing for effective operations for care takers to focus their efforts where needed. According to Tony Farmanali, a design specialist in the field, 90% of injuries to residents occur while they are getting out of bed. As a result, sensors and RFID tags are placed for the protection and welfare of the patient.

The design of the array system dealt with the specific placement of each camera and sensor but did not deal with care taking operations or any sort of security camera user interface development. This is reserved for the company supplying the security equipment.

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ANALYSIS

Some key statistics were developed in relation to the solution above. The first shows an overall pie chart depicting the amount of square feet used in the building and where priority was given. It's no surprise that circulation is higher than a typical 15% found in most buildings because a primary activity for residents is wandering through hallways.

The second graph shows the total area per section highlighting the Garden in green, Dining in yellow, Circulation in gray, and finally the camera coverage area in blue. Areas where camera coverage are less would be in the Garden zone because it is securely guarded with plenty of additional eye-on site minimizing need for every square inch to be covered by a camera.

The third graph shows the sensor coverage in relation to the resident's quarters area. This is the primary area of placement for sensors but have been reserved only to key trigger points specifically at either point of entry, the bed, and the bathroom. Additional sensors have been placed at room doors and the front end of corridors to maximize time for caretaker response.

CONCLUSION

This project has explored Dynamo as a strong possibility for developing and conducting highly intuitive and highly customized analysis solutions for almost any project imaginable. Through the process of learning the program and developing a working definition that would satisfy the project goals and intent, it was found that a streamlined approach through Revit was a much more effective solution.

Revit cannot conduct intersection operations among other things which was essential to this project success. However, priority was misplaced on the total extent to which Dynamo would contribute. Dynamo was ultimately best to use the intersection function with a cone shape, extract that surface shape geometry, and then translate back into Revit for floor plan analysis.

Unfortunately, this conclusion was arrived at too late in the process to develop substantial comparative analysis for Alzheimer Care Centers as would have been preferred.

The results of the this project primarily point to production possibilities and work flow pipelines for professional practice but has not yet gathered enough quantitative data to draw significant design conclusions at this time.
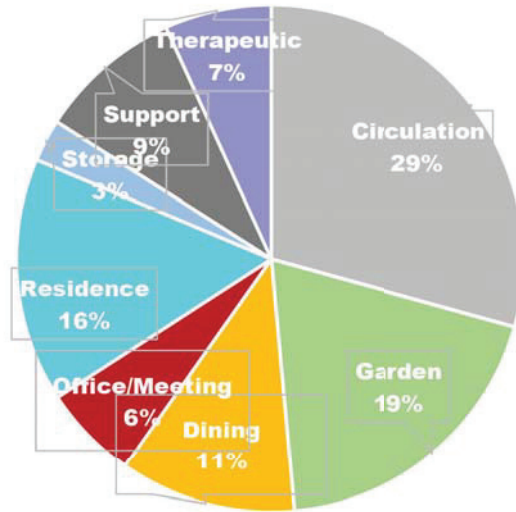
ABOUT THE AUTHOR

Timothy Halvorson is currently pursuing his Masters of Architecture as North Dakota State University in Fargo, North Dakota. He has a passion for building and design automation, seeking opportunities to explore new and innovative solutions with each project.
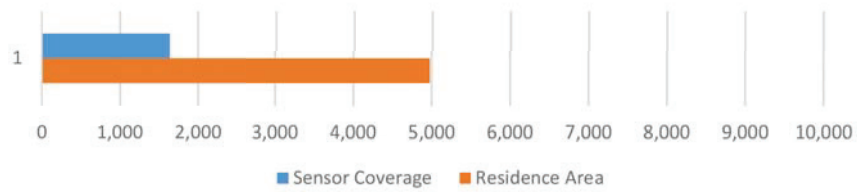
Area Breakdown

Therapeutic 7%
Support 9%
Storage 3%
Circulation 29%
Residence 16%
Office/Meeting 6%
Dining 11%
Garden 19%

Camera Coverage

Garden | Dining | Area Covered | Circulation Area

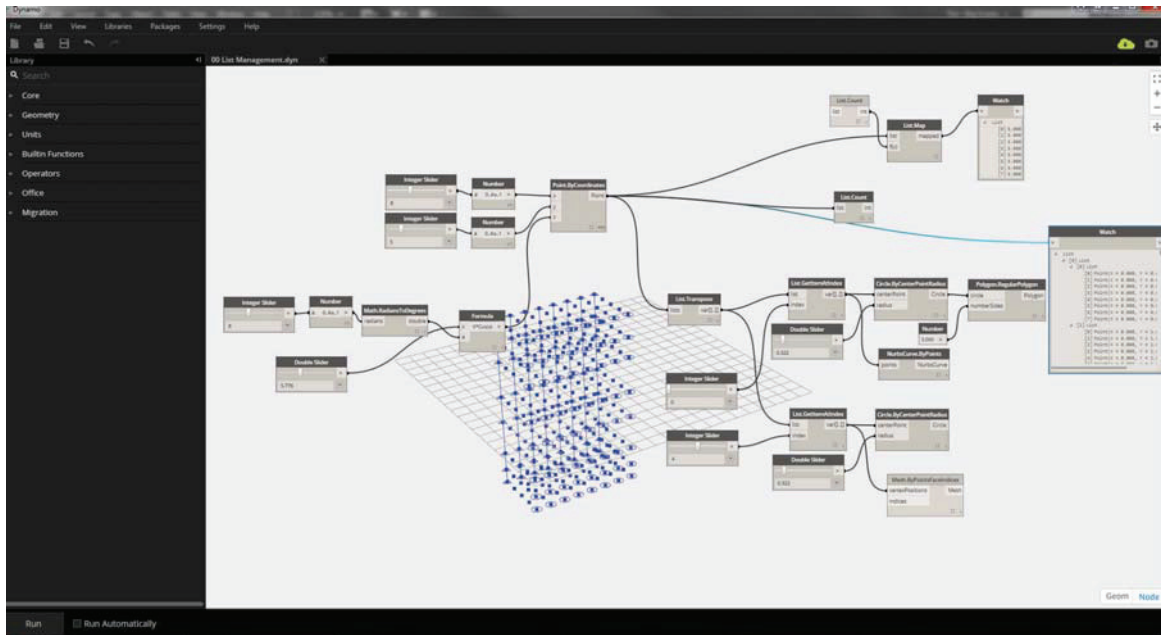## Sensor Coverage

Sensor Coverage | Residence Area

Image 1.1 Dynamo User Interface. Uses a network of interconnected nodes to compute algorithms visually controlling key parameters with sliders
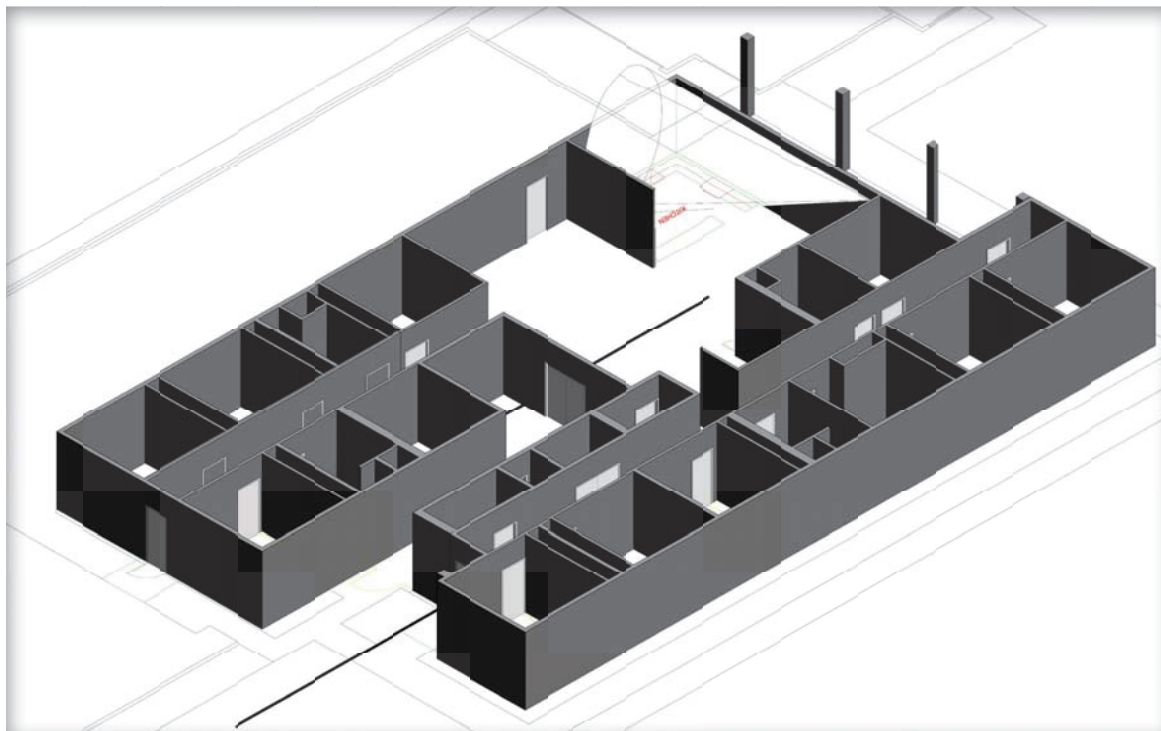

Image 1.2 Revit Interface with 1 adaptive camera placed into the model. Model shown is the reference floor plan from Nevada Memory Care

RESEARCH REPORT

October 3rd, 2014

The following reports on the actions, research, and methodology practices that have been or are currently being utilized for the development of more effective Alzheimer and Dementia patient care from . The research is conducted by Timothy J Halvorson with North Dakota State University supervised by Dr. Ganapathy Mahalingam and sponsored by Klai Juba Wald Architects®.

For the past month I have been gaining a deeper understanding of Alzheimer's as a disease and how preventative measures can be taken to stimulate the mind and slow down the degradation process. The other major aspect of my time has been building a technical knowledge base of Dynamo which is a powerful parametric software that plugs into Revit and runs computational functions coordinated through a visual programming interface. (See Image 1.1) To get an idea of the capabilities of Dynamo, check out this 1 minute highlight video produced by Autodesk: https://www.youtube.com/watch?v=8U15Q4FqCgw.

The research project will utilize the advanced parametric capabilities afforded by Dynamo to quickly iterate between multiple design options at varying scales. The plan is to create an iterative "scorecard" that can rank each iteration produced down to a quantifiable amount to aid in making the best possible design decision. Specifically, a dynamic camera and sensor Family developed in Revit will incorporate parameters such as 'Cone of Coverage', Tilt Angles in X, Y, Z directions, Camera Cost, and other key parameters that will aid in creating the most effective coverage system possible. Each of these key parameters can be scheduled in Revit and exported to Excel for final reporting and representation.

Using Dynamo, the effectiveness of camera coverage will be gauged to determine intersection points at the floor plate and walls with the goal aiming to generate a 3D form from the data to immediately highlight gaps in the coverage.

To this point, the primary focus has been building a technical working knowledge of Dynamo in conjunction with Revit and Excel and establishing the base Camera Family in Revit. Simultaneously I have been looking into the various projects mentioned in the "Smart Condo" article originally sent by Tony to study the coverage systems used in each. The next steps will be to develop an effective iteration pipeline to intelligently process designs and innovative spatial configurations.

END RESEARCH REPORT #1

Image 1.1 Revit Interface with 1 adaptive camera placed into the model. Model shown is the reference floor plan from Nevada Memory Care

Image 1.2 Dynamo User Interface. Uses a network of interconnected nodes to compute algorithms visually controlling key parameters with sliders

RE-THINK SPACE + COVERAGE

A Spatial Study of Alzheimer Care Centers & Effective Camera and Sensor Coverage

Patients with Alzheimer's disease or dementia, have special needs for their care. An important aspect of this care is a constant monitoring of the patient's activities during the day and night, so that they do not harm themselves. These patients are often challenged in their wayfinding in spaces. Architects who design care centers for patients with Alzheimer's disease or dementia, often make the spatial arrangement of the care centers follow a rigid pattern in order to facilitate the required monitoring. This can reduce the quality of the life experience of the patients, and the architectural quality of the design of the care centers.

Klai Juba Architects, through the generosity of John Klai II, has funded a research project at North Dakota State University in the fall semester of 2014, where graduate Architecture student Timothy Halvorson, will investigate various spatial arrangements of care centers for patients with Alzheimer's disease or dementia, for their effectiveness in being able to be covered by various sensor based systems for monitoring the patients. Halvorson will create computer-based 3D models of various spatial arrangements of care centers, insert parametric computational models of various sensor systems into these spatial arrangements, and analyze, using graphics, how effectively these sensor systems serve to monitor the patients. By discovering innovative spatial arrangements that have excellent sensor coverage, Halvorson hopes to uncover life-enhancing design options for care centers for patients with Alzheimer's disease or dementia.
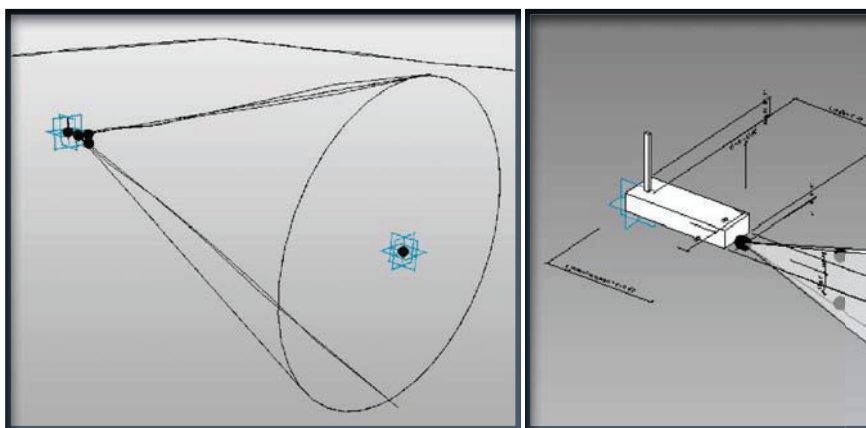
Image 1.3 Adaptive Placement Camera. Key parameters are built into this Family to effectively schedule and compare design iterations.

RESEARCH REPORT

The following reports on the actions, research, and methodology practices that have been or are currently being utilized for the development of more effective Alzheimer and Dementia patient care from . The research is conducted by Timothy J Halvorson with North Dakota State University supervised by Dr. Ganapathy Mahalingam and sponsored by Klai Juba Wald Architects®.

For the past week I have found the breaking point of Dynamo. The LunchBox package for Dynamo is a popular add-in that is able to do a variety of useful tasks including collecting walls, floors, rooms, and many other things from Revit and transferring their data into Dynamo for manipulation. Given a particular wall type, it is able to grab every instance placed in the Revit project and return the unique wall ID, solid geometric representation, bounding line, height, level, and a couple other ID tags.

The intention was to be able to map the walls into Dynamo, extract just the outer faces that bound the corridor and rooms, then have those boundaries slice down the coverage of the camera for an accurate representation and measurement of the camera's coverage. If this step were to be skipped, the ellipse formed on the floor plate would permeate into rooms adjacent to the corridor as if the camera could see through walls. This is an unacceptable solution.

While running the python script to gather the wall data from the Revit API, it became common for Dynamo to overload in the transfer process and cause Dynamo or Revit or both to crash. The more geometry to process of a particular wall type, the more chance of causing a crash. Also the more wall types being queried, the more chance of a crash.

After a week of trying to get the intersections to work properly resorting to simple "sandbox" type projects to test various hypotheses for a solution, I found it is very difficult to add functionality. There is a long list of processes to breakdown and regroup lists of geometry to create the right mix in order to get everything funneled to one final process. The final process of finding a particular intersection relationship has then become the product of a vast set of simple relationships added up together.
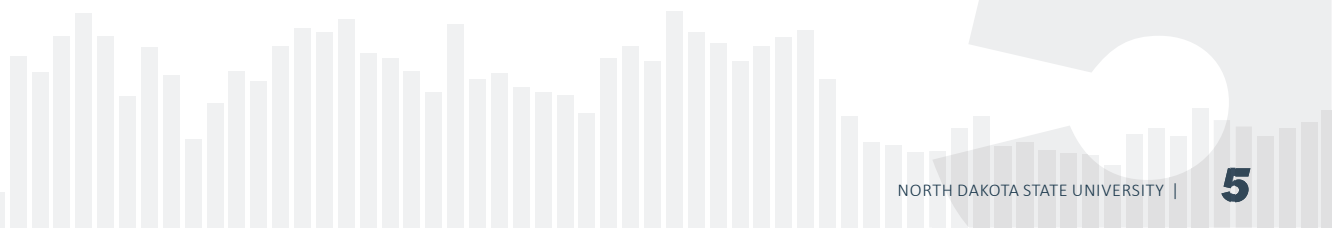
I found that there is quite a lot of redundancy down the pipeline. Every time even the simplest of transformations occurs on say, rotating a piece of geometry for example, Dynamo then recreates a copy of the geometry in the newly desired position. You now have 2 pieces of geometry with only 1 where you actually want it. As a result, to visualize the desired final product, I am constantly unchecking the 'Preview' option on multiple links in the Dynamo food chain.

The following page gives a breakdown of the various components that generate a given iteration, exported to Excel for comparative analysis.
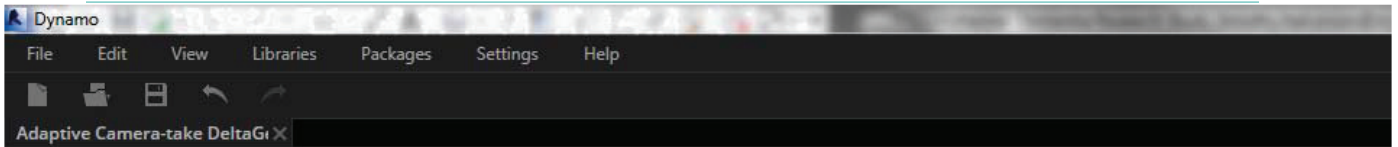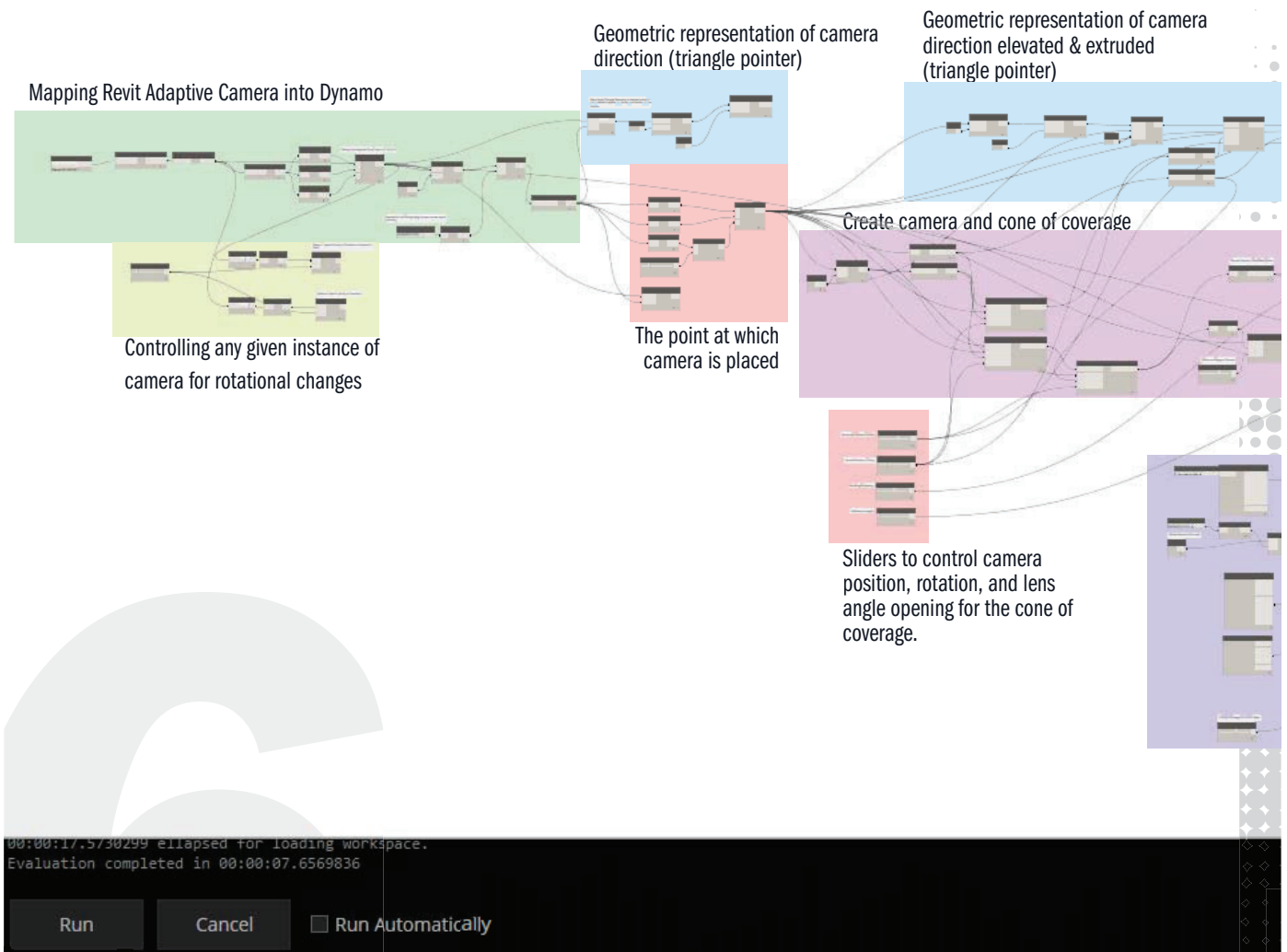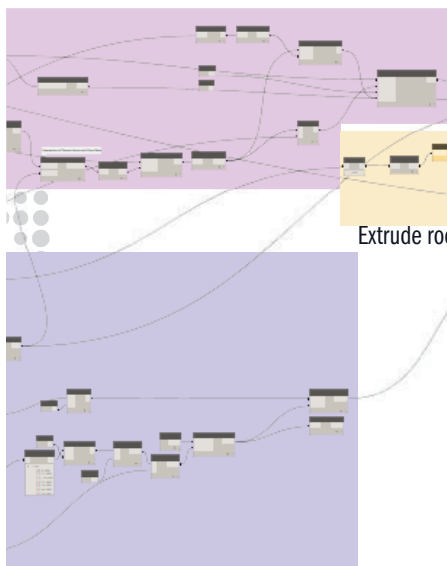

END RESEARCH REPORT

BREAKING IT DOWN

Dynamo

File Edit View Libraries Packages Settings Help

Adaptive Camera-take DeltaG ✕
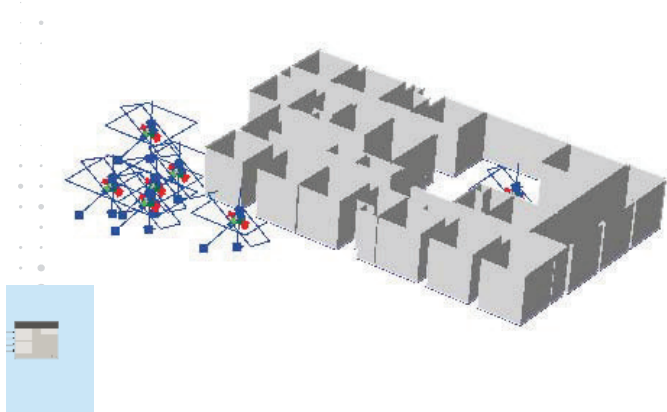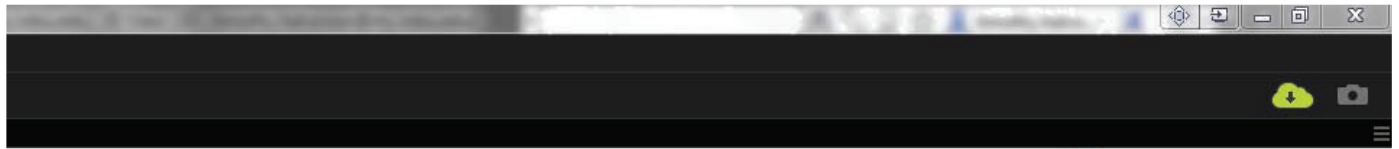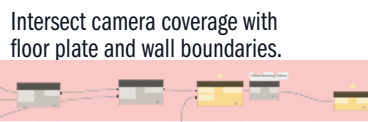
This is the Dynamo user interface. It is essentially an open canvas to place as many nodes as desired to process a given definition. Working left to right and thinking of nodes as 'downstream' and 'upstream' in the generative process. This diagram breaks down the different components of my definition. The primary areas driving the definition and being extracted are highlighted in RED.

Geometric representation of camera direction (triangle pointer)

Geometric representation of camera direction elevated & extruded (triangle pointer)

Mapping Revit Adaptive Camera into Dynamo

Create camera and cone of coverage

Controlling any given instance of camera for rotational changes

The point at which camera is placed

Sliders to control camera position, rotation, and lens angle opening for the cone of coverage.

00:00:17.5730299 ellapsed for loading workspace.
Evaluation completed in 00:00:07.6569836

Run   Cancel   ☐ Run Automatically

Extract area information and export to excel spreadsheet

Intersect camera coverage with floor plate and wall boundaries.

Extrude room geometry

Map rooms borders and floor plate geometry from Revit

Geom | Node

RESEARCH REPORT

As the project comes to its end there are some key important discoveries that have been made which, found earlier, would have drastically altered the final outcome and quantity of deliverables produced.

After extensive development of a tailored definition inside of Dynamo that is able to generate a camera array system for each iteration of a floor plan, it has been found to not be completely effective for the task of analyzing the data in question. In short, it was only able to yield sub-par results because of its currently limitations in geometric modeling. As previously stated, a primary premise of the project was to be able to accurately simulate real-world scenarios inside the computer by developing a computer model that matched real-world sizings. However, after a painstaking development process, it has been found that Dynamo currently is too limited in its abilities to handle this specific project.

Specifically, it does not handle developing an accurate representation of a cone well in correlation with the necessary parameters to be manipulated for the full development of a camera system array throughout an entire building floor plan.

Also, the user interface of Dynamo was difficult to work with and get any sort of real traction toward a positive end. The limitless possibilities almost made it too difficult and too open-ended to work with. Though a potentially viable solution was developed, it was not able to successfully handle an entire camera array system effectively. Each instance of a camera had to have its own set of wires to then be custom oriented the proper direction after placement. This orientation was not able to be derived from the data provided by Revit whose model manipulation tools are far superior. This quickly became a labor-intensive task not only wiring up each camera instance but also positioning it properly after a series of trial and error testings.

Not all was lost.

The cone representation was able to give the closest depiction possible of the footprint that the camera's cone of coverage would produce when implemented in the field. Again, because of the limitations of Dynamo, the best possible solution was to interpolate between 3 ellipses that, when combined, would form the most accurate depiction of the camera's coverage.

The primary camera specifications have been included to the right. The primary features of that were of concern were having sharp enough image quality and the aperture overall opening. This model was selected because of it's impressive 90° aperture opening. It will hardly miss a thing right below it as well as capture nearly the entire room when placed in an upper corner.

The methodology for the project has been forced to change due to unforeseen circumstances.

The alternative method involves utilizing a combination of analysis tools that come standard inside of Revit. First, an overall Area floor plan conveys a color-coordinated floor plan of the design iteration

CCTV Camera Pros
Video Surveillance Systems for Home, Business & Government

DPRO-92311 Dome Security Camera
650TVL Resolution / 3.6mm Fixed Lens

The DPRO-92311 is an indoor dome CCTV camera that supports **650 TV lines of resolution**. This dome camera provides a clear color picture in day mode and clear back and white in low light surveillance mode. The DPRO-92311 comes with a **Fixed 3.6mm Lens**, which provides the user with an viewing angle of 92° degrees.

DPRO-92311 Mini-Dome Features & Specifications

Camera Lens: Fixed 3.6mm Effio Lens, with a viewing angle of approx. 92 Degrees.

High Resolution	**650 TVL Resolution**
Image Sensor	1/3" Sony Super HAD CCD II
Scanning System	2:1 Interlace
Number of Pixels	1020 Horizontal x 508 Vertical 520K Pixels
Effective Pixels	976 Horizontal x 494 Vertical 780 Pixels
Scanning Frequency	15.734KHz(H), 59.94Hz(V)
S/N (*Signal to Noise*) Ratio	>52dB (AGC Off)
Minimum Illumination	0.1 Lux at F1.2
Electronic Shutter Speed	Auto / Manual / 1/60 sec ~ 1/100,000 sec
Video Output	CVBS: 1.0 p-p 75Ω
O.S.D. (On Screen Display)	Lens, Shutter/AGC, Day/Night, Backlight, and more.
White Balance	AWS / PUSH / Customizable sets 1 & 2
Back Light Compensation / BLC	Off, BLC, HLC, Selectable
2DNR (2D Digital Noise Reduction)	On / Off (Level adjustable)
ATR	On / Off (Level adjustable)
Day & Night	Auto (Day to Night time Change), Color, B&W
Privacy	Off, On (8 Zones) (Motion on 4 Zones)
Motion Detection	Off, On (4 Zones)
Image Conversion	On, Off
Language	English, Japanese, German, French, Portuguese, Spanish

Environmental	
Operating Temperature	**14°F~122°F** (-10°C~+50°C)
Storage Temperature	-4°F~140°F (-20°C~+60°C)
Power	**DC 12V**
For more information on this indoor dome camera, *click here to visit the DPRO-92311 product page*	

that can then be used in comparison to further iterations with the same color scheme. Matching scale and color allows for a very quick visual comparison to the overall floor plan layout as well as if there were different spaces prioritize in any particular iteration.

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3. 3) Garden, and
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For sensor systems, they were specifically placed in the following key areas:

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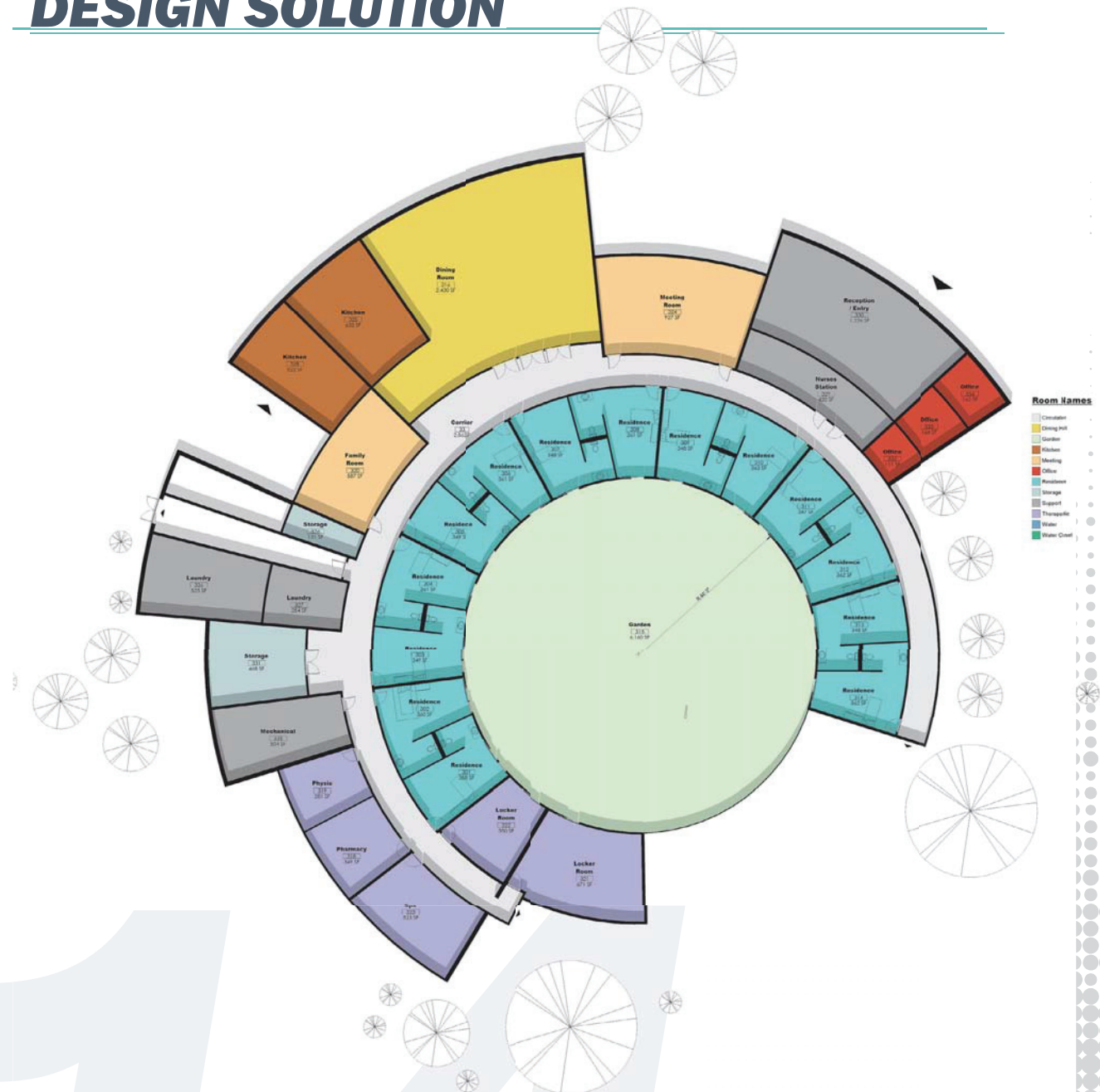5. Perimeter Fencing
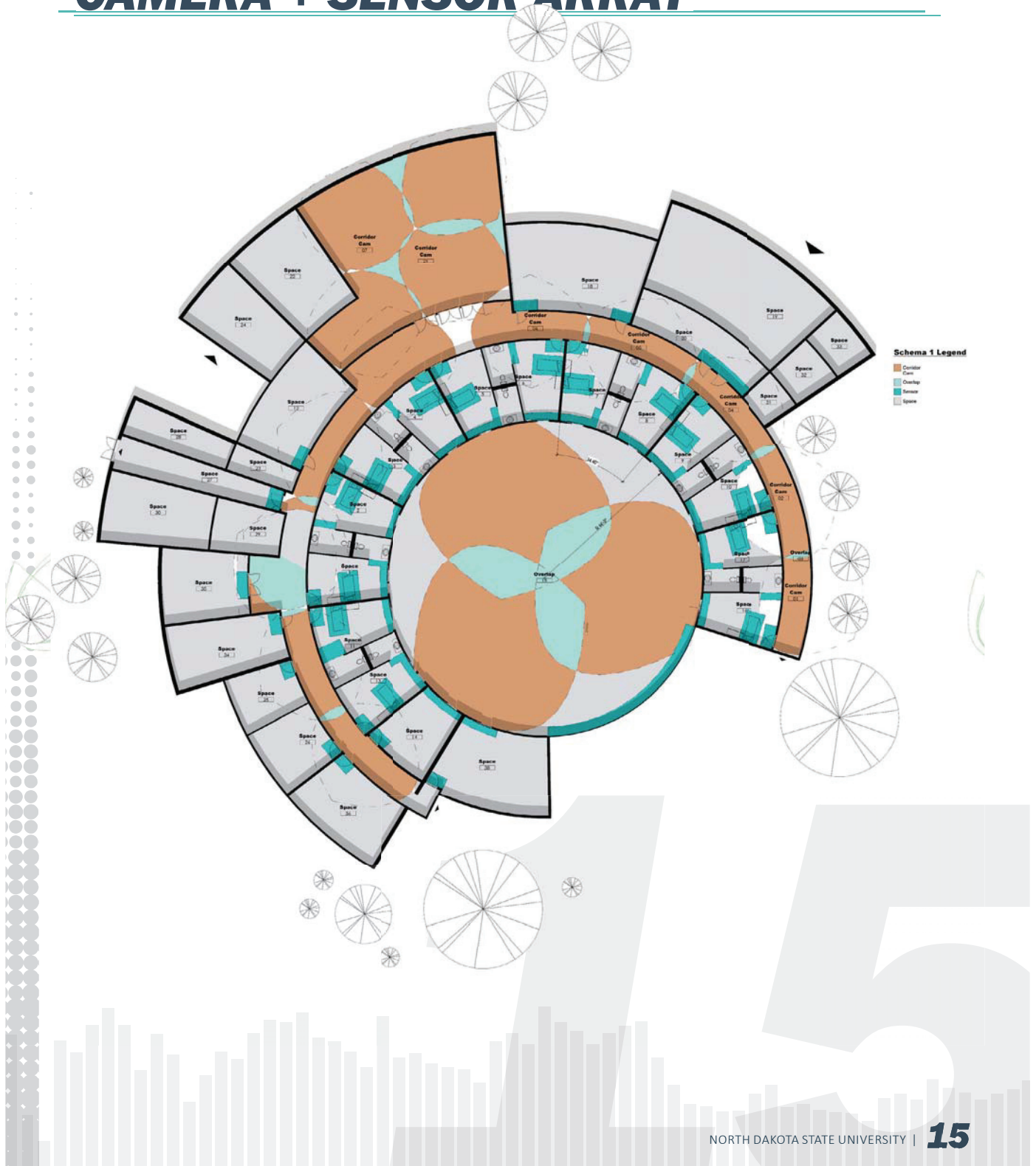

END RESEARCH REPORT
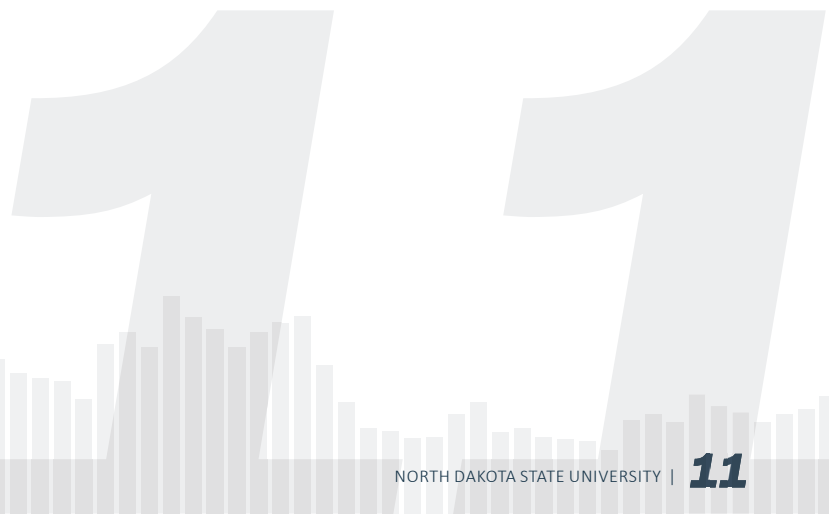
TYPOGRAPHICAL RESEARCH

ENTREE
PRINCIPALE ◀

F.NORD ▼

EXISTANT
F.NORD ▼

Page 155
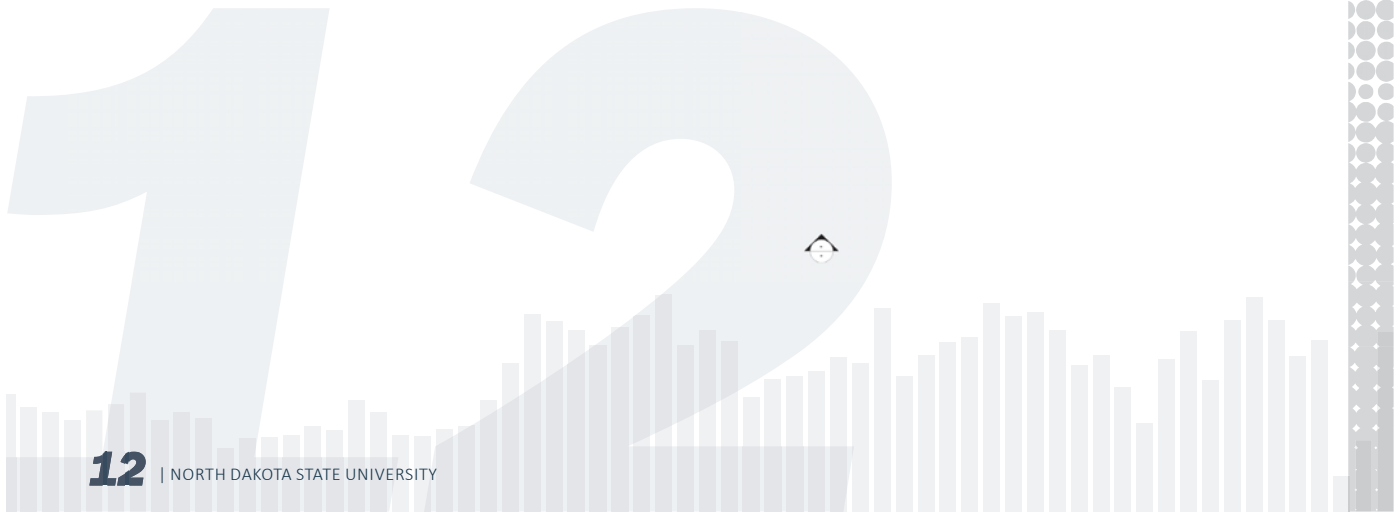
DESIGN SOLUTION

CAMERA + SENSOR ARRAY

Schema 1 Legend
- Corridor Cam
- Overlap
- Sensor
- Space

Space Schedule

Name	Area		%
Corridor Cam	1,374	sf	5%
Corridor Cam	1,373	sf	5%
Corridor Cam	1,350	sf	5%
Corridor Cam	614	sf	2%
Corridor Cam	570	sf	2%
Corridor Cam	567	sf	2%
Corridor Cam	315	sf	1%
Corridor Cam	312	sf	1%
Corridor Cam	259	sf	1%
Corridor Cam	258	sf	1%
Corridor Cam	238	sf	1%
Corridor Cam	232	sf	1%
Corridor Cam	227	sf	1%
Corridor Cam	220	sf	1%
Corridor Cam	219	sf	1%
Corridor Cam	218	sf	1%
Corridor Cam	201	sf	1%
Corridor Cam	142	sf	1%
Corridor Cam	140	sf	1%
Corridor Cam	29	sf	0%
Corridor Cam	24	sf	0%
Corridor Cam	19	sf	0%
Corridor Cam: 2	**8,901**	**SF**	**32.45%**
Overlap	258	sf	2%
Overlap	254	sf	1%
Overlap	57	sf	0%
Overlap	49	sf	0%
Overlap	45	sf	0%
Overlap	29	sf	0%
Overlap	24	sf	0%
Overlap	17	sf	0%
Overlap	15	sf	0%
Overlap	12	sf	0%
Overlap	11	sf	0%
Overlap	10	sf	0%
Overlap	9	sf	0%
Overlap	6	sf	0%
Overlap	4	sf	0%
Overlap: 18	**800**	**SF**	**2.92%**
Sensor	121	sf	0%
Sensor	48	sf	0%
Sensor	47	sf	0%
Sensor	45	sf	0%
Sensor	43	sf	0%
Sensor	42	sf	0%
Sensor	38	sf	0%
Sensor	36	sf	0%
Sensor: 94	**838**	**SF**	**3.06%**
Space: 117	**12,902**	**SF**	**47.04%**
Total Area	**27,430**	**SF**	
Grand total: 251			

Room Schedule

Occupancy	Name	Area	SF	%
Circulation		**9,385**		**36.29%**
Circulation	Corridor	2,862	sf	11%
Circulation	Corridor	363	sf	1%
Garden	**Garden**	**6,160**	**sf**	**23.82%**
Dining		**3,585**	**SF**	**13.86%**
Dining Hall	Dining Room	2,430	sf	9%
Kitchen	Kitchen	633	sf	2%
Kitchen	Kitchen	522	sf	2%
Office/Meeting		**1,951**		**7.54%**
Meeting	Meeting Room	927	sf	4%
Meeting	Family Room	587	sf	2%
Office	Office	164	sf	1%
Office	Office	162	sf	1%
Office	Office	111	sf	0%
Residence		**4,977**		**19.24%**
Residence	Residence	363	sf	1%
Residence	Residence	362	sf	1%
Residence	Residence	362	sf	1%
Residence	Residence	361	sf	1%
Residence	Residence	361	sf	1%
Residence	Residence	361	sf	1%
Residence	Residence	360	sf	1%
Residence	Residence	358	sf	1%
Residence	Residence	349	sf	1%
Residence	Residence	349	sf	1%
Residence	Residence	348	sf	1%
Residence	Residence	348	sf	1%
Residence	Residence	348	sf	1%
Residence	Residence	347	sf	1%
Storage		**862**		**3.33%**
Storage	Storage	468	sf	2%
Storage	Storage	263	sf	1%
Storage	Storage	131	sf	1%
Support		**2,929**		**11.33%**
Support	Reception / Entry	1,226	sf	5%
Support	Laundry	525	sf	2%
Support	Mechanical	504	sf	2%
Support	Nurses Station	420	sf	2%
Support	Laundry	254	sf	1%
Therapeutic		**2,174**		**8.41%**
Therapeutic	Locker Room	671	sf	3%
Therapeutic	Spa	523	sf	2%
Therapeutic	Locker Room	350	sf	1%
Therapeutic	Pharmacy	349	sf	1%
Therapeutic	Physio	281	sf	1%
Water Closet	**< see residence >**			
Grand total: 162		**25,863**		
Area Lost to Walls		1,567	sf	6%
Total Area		**27,430**	**SF**	

CAMERA + SENSOR AREA ANALYSIS

Area Breakdown

- Therapeutic 7%
- Circulation 29%
- Support 9%
- Storage 3%
- Residence 16%
- Office/Meeting 6%
- Dining 11%
- Garden 19%

Camera Coverage

Legend: Garden, Dining, Area Covered, Circulation Area

Sensor Coverage

Legend: Sensor Coverage, Residence Area
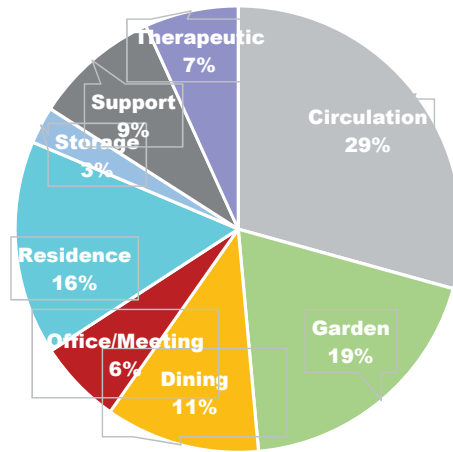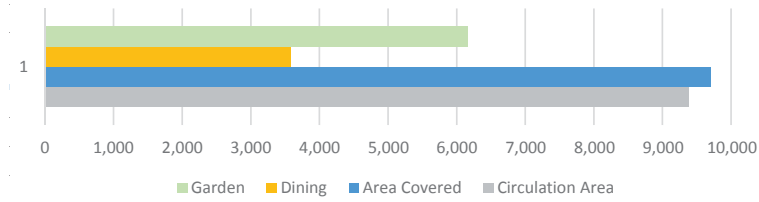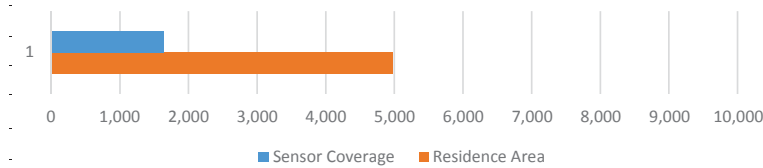
RESOURCES

1. http://ovidsp.tx.ovid.com.proxy.library.ndsu.edu/sp-3.13.0b/ovidweb.cgi?&S=EDMEFPG-PNFDDMOHINCLKPEIBLKHMAA00&WebLinkReturn=Full+Text%3dL|S.sh.22.23.25.33|0|0 1300407-201010000-00002&Complete+Reference=S.sh.22.23.25|2|1

2. http://www.archdaily.com/450249/day-center-for-alzheimer-s-patients-luis-navarro-jo-ver-carlos-sanchez-garcia-angel-martinez-garcia/

3. http://www.archdaily.com/532737/alzheimer-residence-for-the-foyer-la-grange-mabire-re-ich/

4. http://www.archdaily.com/339308/new-accommodation-facility-for-alzheimers-philip-pon-kalt/

5. http://www.archdaily.com/295469/urban-day-care-center-for-alzheimer-patients-cid-san-tos/

6. The Smart Condo Project: https://www.dropbox.com/s/23ohb6h74e3zspp/The%20 Smart%20Condo%20-%20Visualizing%20Independent%20Living%20Environments%20 in%20a%20Virtual%20World.pdf?dl=0

7. http://www.aplaceformom.com/senior-care-resources/articles/alzheimers-care-facilities

8. http://msdh.ms.gov/msdhsite/_static/resources/118.pdf

9. http://www.mayoclinic.org/healthy-living/caregivers/in-depth/alzheimers/art-20046222

10. http://www.alz.org/advocacy/state-priorities.asp

The Potentials of BIM

Communication, Collaboration, Coordination

By: Josh Muckenhirn, Ganapathy Mahalingam, and R.L. Engebretson Architecture, Interiors, and Construction

Table of Contents

List of Tables and Figures

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Research Abstract

The goal of this Graduate Research Assistantship is ultimately to discover and document various methodologies for integrating and linking numerous documents to one 3D Model. Through this investigation, I hope to successfully document, step-by-step, how such integrations can be implemented and utilized to increase the efficiency of BIM modeling. Virtual 3D modeling is no longer sufficient for the Architecture and Construction industries. Project members and owners are demanding a more cohesive methodology for communicating throughout the design and construction processes, and even into post-project occupancy. Throughout the design and construction of a project, there are numerous models each illustrating a different system within the building such as an Architectural model, a Mechanical model, a Structural model, and so on. Having separate models can hinder the construction process by slowing down communication between offices. With holistic BIM modeling, the communication process can be revitalized and revolutionized by merging all models into one cohesive and integrated model with access to all necessary documents and information used both during the construction process, and after the building has been completed.

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Research Methods

A. Literature Based Information
- i. Physical Books and Text
- ii. Web-based Articles
- iii. Web-based Journals
- iv. Web-based Blogs
- v. Web-based Tutorials

B. Videos
- i. Web-based Software Tutorials
- ii. Webinars
- iii. Web-based free lectures

C. Personal Communication
- i. Contact and communicate with RLE liaison
- ii. Discuss research questions and problems with Dr. Ganapathy.
- iii. Discuss research with classmates to gain differing perspectives.

D. Software Analysis
- i. Download various software
- ii. Test, experiment, and get familiar with various software.
- iii. Discover how each software integrates with one another.

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BIM: Changing the Game

BIM Overview

BIM Modeling is still in its infancy - largely unknown and under utilized by many professionals. Some do not fully understand its true capabilities, and misinterpret BIM modeling as "just another 3D modeler". BIM modeling takes the B+M (building modeling) to a whole new level by inserting the I (information) within the process. It allows for improved communication, constructablility, and simply eases the entire design and construction processes by increasing collaboration between all stakeholders. It evolves the 3D modeling to 5D modeling by adding cost estimating, construction scheduling, clash detection, and facility maintenance capabilities to a single model. It gives the design teams the opportunity to literally "build" the project before it is physically constructed. True BIM modeling is revolutionizing the AEC industry by increasing communication and collaboration, reducing potential conflicts in construction processes, and increasing facility maintenance capabilities.

Benefits of BIM

BIM improves efficiencies of communication and collaboration within a project team by including all pertinent information within a single virtual environment. Product information such as Operations and Maintenance Manuals, object specific specifications, assembly code and costs, and so on can all be provided so all team members have instant access to the information. The ability for clash detection in the cloud reduces construction conflicts late in the process because they can be realized and resolved immediately - greatly reducing potential time and money costs. A project that stays on budget and schedule makes for a satisfied client.
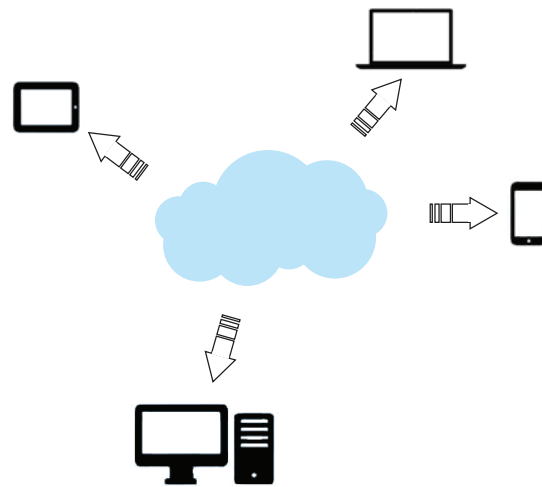
Figure 2 - Cloud Computing
Cloud computing gives business owners the ability to free up storage and computing space. Rendering and computing on a computer can completely tie it up because rendering takes up so much processing power. Cloud computing also allows instant access from virtually anywhere with an internet connection - revolutionizing communication and collaboration.

Project Factor	Traditional Delivery	Integrated Delivery
Team	Fragmented, assembled on "as-needed" or "minimum necessary" basis, very hierarchical, controlled	Integrated entity of key stakeholders, assembled early in the process, open, collaborative
Process	Linear, distinct, segregated, knowledge gathered "as-needed", information hoarded, silos of knowledge and expertise	Concurrent and multi-level, early contributions of knowledge and expertise, information openly shared, trust and respect
Risk	Individually managed, transferred to the greatest extent possible	Collectively managed, appropriately shared
Reward/ Compensation	Individually pursued, minimum effort for maximum return, often first cost-based	Team success tied to project success, value-based
Communication/ Technology	Paper-based, two dimensional, analog	Digital, virtual, Building Information Modeling, 5+ dimensional
Agreements	Encourage unilateral effort, allocate and transfer risk, no sharing	Encourage, foster, promote and support multilateral open sharing and collaboration, risk sharing

Figure 3 - Project Delivery Differences
infoComm International, Building Information Modeling

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BIM modeling is however better suited for different business models. For example, because of the collaboration innate in the Design-Build business model, DB is well suited to benefit from BIM. Even more than the traditional DB model, an Integrated DB model has the potential to work fluently with BIM modeling. With the DB model, the owner chooses the designer and constructor at the same time, allowing for increased communication and collaboration earlier on in the process. This decreases constructability issues later on by realizing them sooner in the process - reducing costly change orders. In order for BIM to realize its full potential, collaboration must be present throughout the entire process, and not just in the construction phases. BIM will provide all teams with project information, allowing all stakeholders to make more accurate decisions in a timely manner. However, as with many other business models, the owner plays an integral role through the design process, but then backs off during the construction phases. BIM allows the owner easy access to all progress on the project - from design to completion. Involving the owner throughout the entire process will offer the opportunity of continuous innovation and improvement.

The traditional Design - Bid - Build model however is not necessarily as well suited for BIM modeling.

With the DBB model, the owner initially hires a designer who creates the program and initial design for the owner. The designer then sends the drawings out for bid **AFTER** the design has been set. This inherently decreases collaboration opportunities within the process. As a result of the DBB model, many constructability and coordination issues are not discovered until the project is in the construction phases - creating costly change orders and alterations.
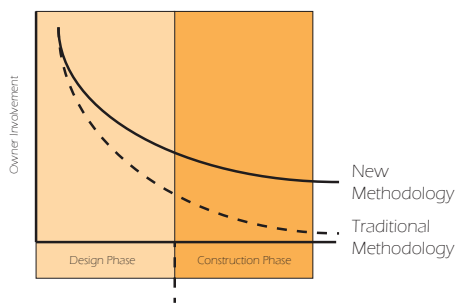
Figure 6 - Owner Involvement through project phases

In the traditional model, owners have high involvement at the beginning as their program and design are being worked out. Once construction begins, the owner pretty much loses all track of the project until it opens. In an Integrated Project Delivery that uses BIM modeling, owners are not only encouraged, but requested to stay involved right until the end. This will allow innovation and improvement of the project throughout the construction process.
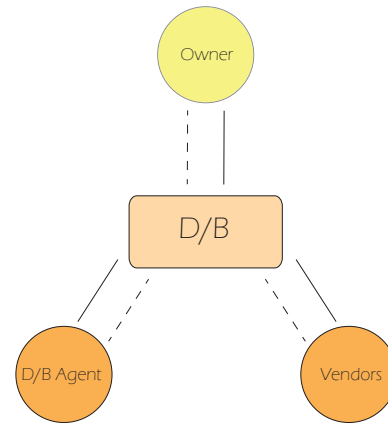
Figure 4 - Traditional Design-Build Model
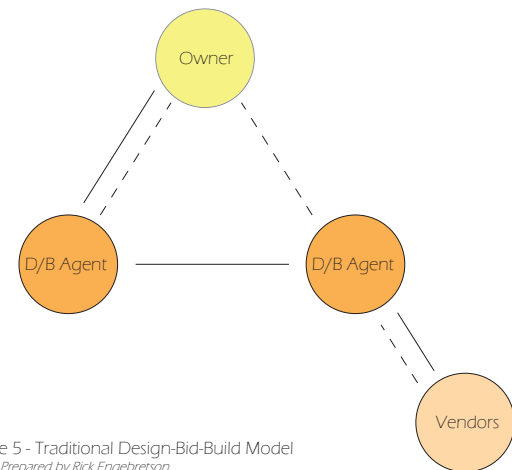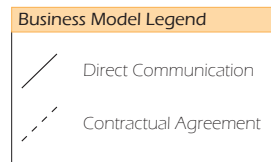*Prepared by Rick Engebretston*

Business Model Legend

Direct Communication

Contractual Agreement

Figure 5 - Traditional Design-Bid-Build Model
Prepared by Rick Engebretson

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Integrated Project Delivery

Currently, all of the major business models used today outdate BIM modeling, and fail to take advantage of its full potential. Because of this, a new project delivery method must be created, adopted, and implemented in the AEC industries. BIM modeling offers a rich database of information that can be shared with many project stakeholders at once. Working in conjunction with BIM modeling, a relatively new project delivery method has begun to make itself known. The Integrated Project Delivery method has the ability to permanently alter the AEC industries for the better, and to actually work with and build on BIM's strengths.

In order for this to take place, all project stakeholders (architects, owners, engineers, contractors, construction managers, et cetera) need to be involved from the very beginning. This will allow everybody to make informed decisions rather than "best estimates" and "educated guesses". By increasing involvement from the beginning, construction issues, for example, can be discovered sooner and fixed before construction begins. This will reduce costly change orders and save time later in the construction process.

IPD will require more time spent on the front end of the project - which may require rethinking the project's fee structure. Because more hours will be spent sooner in the process, fees may need to be increased at the beginning, and later decreased due to a streamlined finish to the project. The typical Construction Documentation phase will be drastically reduced, if not eliminated all together, because the "construction documents" will be worked out throughout the entire process. Constructability issues will be brought up immediately which will ineviatbly make more accurate drawings sooner in the process.

Principles of IPD:

1. Mutual Respect and Trust
2. Mutual Benefit and Reward
3. Collaborative Innovation and Decision Making
4. Early Involvement of Key Participants
5. Early Goal Definition
6. Intensified Planning
7. Open Communication
8. Appropriate Technology
9. Organization and Leadership

(American Institute of Architects, 2009)

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Challenges to BIM

One of the single greatest challenges within the industry is the interoperability of various software.

>As of now, there are numerous BIM software available (Revit, AutoCAD, ArchiCAD, Navisworks, etc.) and they do not always "communicate" with one another. This greatly hinders the collaboration process if team members do not use the same software.

Not only do different software create integration problems, but different versions of the same software can be a headache.

>As every software is upgraded annually, this can potentially create collaboration issues if one team member chooses to upgrade and another does not. For BIM modeling to realize its true potential, and for it to really gain fire, software interoperability issues must be resolved.

Legal issues may be one of the greatest barriers to the future of BIM.

>Because numerous project members and teams have the ability to alter the model, it is difficult to decipher who has copyright to the model itself. Ownership of the model raises further questions regarding liability. If an error occurs in the design or construction processes and numerous project teams make alterations to the model, it is difficult to decide who is responsible for the error. Did the architecture office make the mistake? Did the contractor make the mistake? Did the engineers? Or was it simply an error on the construction site? Many new legal issues will have to be resolved before BIM modeling is adopted by the entire industry.

>Assemble and BIM Glue give administrators the ability to control who has access to a file. This will help avoid certain unintended legal issues by limiting who can actually alter the model and who can simply view it. The software also keeps a record of who makes alterations to the model and when.

BIM models can become too bulky and unmanageable.

>One of the bottlenecks in the advancement of BIM modeling is computer hardware. This is because once all necessary parameters and information is included within a model, the file size can become massive. In order to simply view a model such as this require top of the line computer hardware that many firms cannot afford.

>*This is where cloud computing really shines. Storing and viewing models on the Cloud saves immense amounts of computing power, allowing for larger file sizes to be handled by lesser hardware.

>The limiting factor within Cloud computing is your internet speed. The faster and more reliable the internet connection, the better models will run in the Cloud. Another pitfall related to Cloud computing is the possibility of an internet outage. Without a connection, you may not have access to files that are stored online.

BIM modeling offers a completely new methodology for delivering design and construction services.

>Because of this, the entire design and construction process must be redefined to fit the new model of project delivery. This will include altering the design phases to reflect how BIM modeling can improve the process as a whole.

In order for BIM to truly take off, all industries need to begin to utilize its capabilities.

>BIM's full potential will be realized when all AEC industries begin to use it for integration purposes. BIM will not be much use if only one industry (i.e. Architecture) uses it because BIM is about information sharing and exchange.

General Implementation

Level of Development Tracking

Keeping a record of the LOD can add an extremely useful dimension to the BIM model. The LOD lets users know what the model elements and information can be relied on for. The higher the level of development, the more accurate and reliable the model information.

There is a distinct difference between **Level of Development** and **Level of Detail** however.

Level of Detail - describes how much detail is put into the model, and can be thought of as an INPUT to the Level of Development.

Level of Development - degree to which geometries and attached information has been thought through, or the degree to which users can RELY on the model and associated information. The Level of Development can be thought of as the overall OUTPUT.

LOD 100
The Model Element may be graphically represented in the Model with a symbol or other generic representation, but does not satisfy the requirements for LOD 200. Information related to the Model Element (i.e. cost per square foot, tonnage of HVAC, etc.) can be derived from other Model Elements.

LOD 200
The Model Element is graphically represented within the Model as a generic system, object, or assembly with approximate quantities, size, shape, location, and orientation. Non-graphic information may also be attached to the Model Element.

LOD 300
The Model Element is graphically represented within the Model as a specific system, object or assembly in terms of quantity, size, shape, location, and orientation. Non-graphic information may also be attached to the Model Element.

LOD 350
The Model Element is graphically represented within the Model as a specific system, object, or assembly in terms of quantity, size, shape, orientation, and interfaces with other building systems. Non-graphic information may also be attached to the Model Element.

LOD 400
The Model Element is graphically represented within the Model as a specific system, object or assembly in terms of size, shape, location, quantity, and orientation with detailing, fabrication, assembly, and installation information. Non-graphic information may also be attached to the Model Element.

LOD 500
 The Model Element is a field verified representation in terms of size, shape, location, quantity, and orientation. Non-graphic information may also be attached to the Model Elements.

Example – light fixture:

100 - cost/sf attached to floor slabs

200 - light fixture, generic/approximate size/shape/location

300 - Design specified 2x4 troffer, specific size/shape/location

350 - Actual model, Lightolier DPA2G12LS232, specific size/ shape/location

400 - As 350, plus special mounting details, as in a decorative soffit

Information retrieved from:
BIMForum LOD Specification

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General Implementation

Creating the BIM Model

1. Determine if the project will utilize a Federated or an Integrated model.

2. Create an overall schedule for design decisions and construction milestones.

3. Manage design changes and prevent unlimited scenario analysis.

4. Determine whether third parties will be included.
   i.e. End users, government agencies, consultants, etc.

5. Create a schedule for when models will be updated and released for downstream use.

6. Determine to what extent and when 2D drawings will be needed.

7. Determine other important documentation needed to be included with the model.
   i.e. Operations Manuals, Maintenance Forms, etc.

8. Determine is the project will be handed over to the client or end user. Decide to what level of detail the end user desires in the model once it is exchanged.

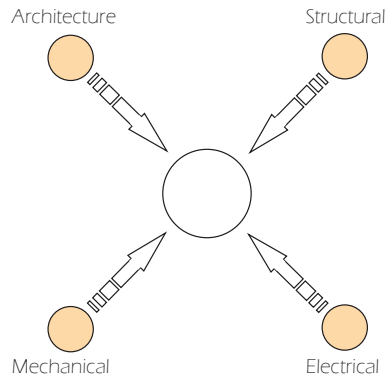Delivering an Integrated Project - American Institute of Architects

Figure 7 - Federated Model
"The "Federated Model" concept requires that all component models be combined for coordination only; each model creator retains responsibility and ownership for their model and work. Component models are updated by their respective creators and combined for coordination as the project moves forward". (Construction Users Round Table, 2010)
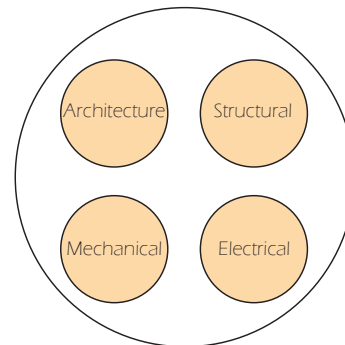

Figure 8 - Integrated Model
"The "Integrated Model" concept requires that all component models exist in one model, with one entity responsible for maintaining the integrated model. The integrated model becomes better and better defined as the project moves forward. A designated party will be responsible for the integrated model" (Construction Users Round Table, 2010).

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General Implementation

A few tips for implementing BIM and IPD:

1. Identify a BIM Manager

   This will be a full time job. The BIM Manager will be responsible for keeping track of and organizing all the information needed for the project. They will coordinate all the information gathered from within the architectural office, the contractors, the engineers, and so on. The BIM Manager should create a schedule and plan to determine and set when important events will occur - such as clash detections and model updating.

2. Develop an estimated cost and time for implementation

   This should include the cost of any new and additional hardware, software, training, subscriptions, and the full time salary of the BIM Manager(s). Remember, this will be a full time job, so it will require either hiring internally or externally.

3. One-on-One

   DO NOT attempt to acquire and train employees on multiple new software simultaneously! Instead, work on fully understanding and implementing a single piece of software at a time. This will alleviate a lot of stress (yes, it may be a stressful endeavor!)

4. Aim small, miss small.

   To begin the implementation process, do not over do it! Begin wth a relatively small-scale project and work with a few employees instead of a large team. This will help ease into the transition, and if a mistake is made, it will be relatively less costly.

5. Stay up to date.

   The BIM Manager should always be versed in the latest technology being used by the industry. This does not necessarily mean they need to have a full-version copy of every software released to the market, but simply, that they are aware of it and can at least discuss and understand it. This may require educational seminar/webinars and research on the BIM Manager's part. Along with this, funding for software updates and subscriptions should be kept available so everything works properly.

6. Create your own resources

   As the firm implements the BIM and IPD methodologies, they should simultaneously keep a record of all the "do's" and "don'ts". When something new is discovered, record it for future use! As employees become more familiar with the software, have them create tutorials, walk-throughs, and a resource database for future reference. This may require a full time employee at the beginning of the implementation process.

Information adapted from Brad Hardin's book,
BIM and Construction Management: Proven Tools, Methods, and Workflows

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Important Note

Through the research, numerous software were explored in an attempt to discover their usefulness and integration capabilities. The software highlighted in this article include:

Assemble Systems
Autodesk BIM 360 Glue
SimpleBim
3DA Systems
Blue Beam Revu

For each software, an overview is provided along with a few helpful tips and items to note. The monetary cost of the software is also provided. The goal of these overviews is to inform the firm of the different software available for use in the implementation of BIM modeling - the final decision on which to actually utilize must be done internally. This paper offers an unbiased, objective review of the software.

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Assemble Systems

Assemble Systems is an online model viewer that has the ability to import all project information and parameters - not just the "important" ones. It offers a streamlined, integrated method for instantly sharing and viewing project information. Every model produced within the process of designing and constructing a building can be placed into a single project and viewed by the entire team. The Assemble Systems model viewer is free to everybody (to an extent), but in order to publish a model from the native program (such as Revit or AutoCAD) one must purchase a license. This allows a firm to give instant access to a project's information to anybody who may want or need it - such as the client or building owner.

Assemble Systems does import all project parameters - even custom, shared parameters. The server also imports attached hyper links as active links within the viewer, giving instant access to important information and documentation. However, only online web-URL's come in as active links. Local file locations cannot be opened. Because of this capability, items such as Operations and Maintenance Manuals, object specifications, maintenance forms, and so on can be directly linked to the viewer as long as they are hosted online. This greatly increases the power of BIM modeling because the 3D model becomes more than a static visualization tool - it becomes dynamic. It does however lack the ability to hand the model and information over to the building owner because a license must be owned to have permanent access to the project information. Assemble Systems does allow exporting project information to a Microsoft Excel file that can be saved and shared..

Dashboard Option	Assemble Systems
Pricing	$3,600/ year
Quantity Takeoff	✓
Active Links	✓
Excel Export	✓
Markups/Comments	✗
Bi-directional Communicaion	✓
Import Revit Linked Models	✗
Merge Models	✗
Full Parameter Import	✓
Interactive 3D Model	✓
Clash Detection	✗
Model Variance Comparison	✓
Accessibility Control	✓
As Built Drawings	✗

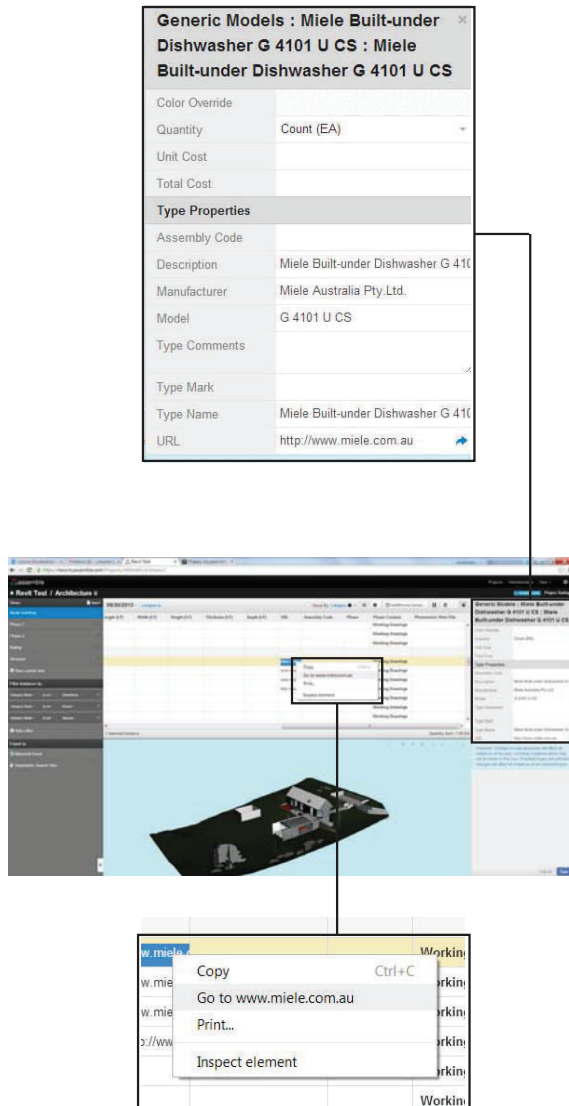Figure 9 - Assemble Systems Overview

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Assemble Systems

Important Items to Note:

Assemble Systems is less than two years old!
> The support staff are continuously updating the software to meet the needs of the industry. The future of Assemble Systems could potentially change the AEC industry.

When using Assemble Systems, make sure to use Google Chrome or Firefox web browsers to ensure proper functionality.

Assemble does NOT include the ability to alter model geometries and quantities natively.
> These must be done within Revit and re-published to Assemble. Assemble only allows alterations made to properties of objects and families.

Assemble allows members to view the model and information for free.
> Purchasing the license is only necessary to publish and sync to and from Revit.

As of now, Assemble only allows altering information for Type Properties, and not Instance Properties.
> However, we have been informed that the Assemble Systems team is planning on a late November/early December update which will include this functionality.

There is no automatic notification when an Assemble model version is updated.
> In order to be alerted to the update, the publisher must manually alert you through e-mail, phone call, text, etc.

As of now, Assemble is useful for 3D model viewing and not 2D graphic or sheet viewing.
> However, in the November/December update, Assemble will be adding the ability to publish 2D graphics such as sheet views and schedules - greatly increasing its functionality as a dashboard option.

Assemble does NOT import models that are linked within Revit.
> It will however import models that are previously BOUND in Revit.

Figure 10 - Assemble Systems 1
Hyper links do import in as active links within Assemble. In order to access hyper links associated with Instance Parameters, users must right-click the hyper link and click "Go to [URL address]". This does not work with file destinations however - only web addresses.

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Assemble Systems

Oza Bouchard (Video Testimonial)
- *VP and Managing Principal of Leo A Daly Architects*

"Assemble augmented the project team's ability to analyze design model changes dynamically (through the Compare feature), as compared to conventional methods of days or weeks.

Design Cost Trending in Real Time.
Although cost estimating may seem like a daunting task which many offices simply do not have the time to do on their own, Assemble Systems makes keeping track of baseline estimates quick and easy.
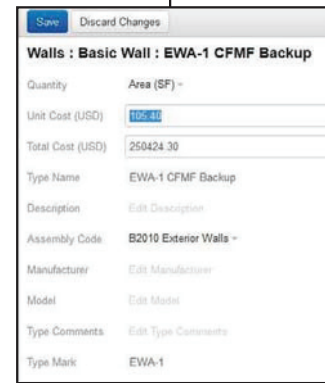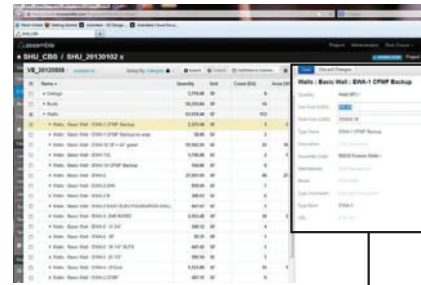
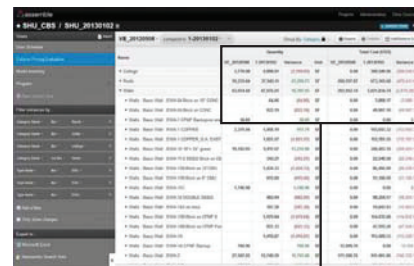### Automated Estimating

Comparing Models

1 – Enter assembly cost data into the properties window for major project assemblies.

2 – Use the compare feature to compare and track how alterations made to the model potentially affect the overall cost of the project.

Figure 11 (top right) - Assemble Systems Cost Data

Figure 12 (bottom right) - Assemble Systems Comparison

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Autodesk BIM 360 Glue

Autodesk BIM 360 Glue is an online based model viewing and editing software with clash detection capabilities. It allows a user to merge numerous models into one cohesive model to view various clashes between different models. For example, a user can "Glue" (upload) an architectural model showing wall locations and layout, and merge that model with a structural model showing beams, columns, floors, and so on. If a column were to be clashing (intersecting) a wall or floor where it was not supposed to, BIM Glue notifies the user of the clash. This capability can save immense amounts of time and money by immediately recognizing clashing elements so they can be fixed as soon as possible - before construction begins.

As soon as a model owner updates and re-Glues a model to the cloud account, all team members viewing the model at the time of the upload are simultaneously alerted that the model has changed. BIM Glue then gives you the option to reload the current model so it is congruent with the newest version.

Another benefit of BIM Glue is that all information is stored in the cloud. This frees up valuable space on the native computer system, allowing for increased processing power. All information is also backed up within the cloud, eliminating the need to worry about computer crashes.

| Dashboard Option	Autodesk 360 Glue
Pricing	$150/seat/month
Quantity Takeoff	✘
Active Links	✓
Excel Export	✘
Markups/Comments	✓
Bi-directional Communicaion	✓
Import Revit Linked Models	✘
Merge Models	✓
Full Parameter Import	✘
Interactive 3D Model	✓
Clash Detection	✓
Model Variance Comparison	✘
Accessibility Control	✓
As Built Drawings	✓

Figure 13 - Autodesk BIM 360 Glue Overview
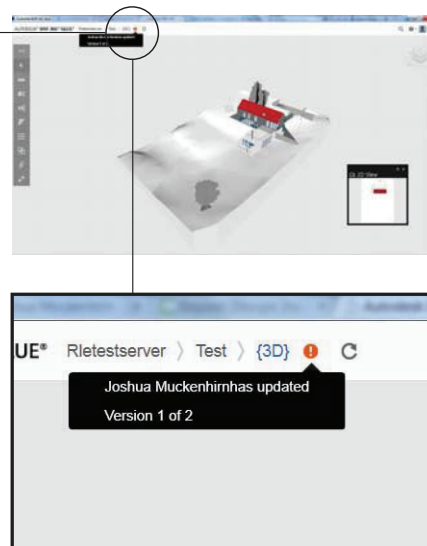
Figure 14 - BIM Glue Model Update Notification
When an updated model version is Glued to the account, anybody who is viewing the older version on the Glue account will be automatically alerted of the update. The viewer will then be asked if they want to update to the current model version or stay on the older version.

BIM 360 Glue Tutorials

Autodesk BIM 360 Glue

Figure 15 - BIM Glue Mobile App

The Glue mobile app gives viewers the ability to view all elements associated with a model. It has all the functionalities of the desktop version, but gives the added ability to take the model virtually anywhere. It allows users to view and update model information - even in the field.
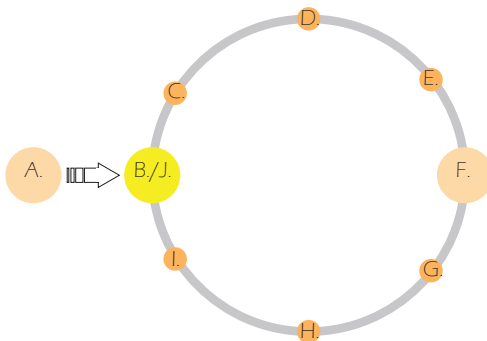

Figure 16 - General 360 Glue Process

A. Publishing software (i.e. Revit)
B. Glue it
C. Merge models into a single model
D. Run a clash detection/markup
E. Notify necessary personnel
F. Return to the original model within the publishing software(i.e. Revit)
G. Run a Clash Pinpoint
H. Resolve clashes/make necessary changes
I. Notify team members that changes have been made
J. Re-Glue the model to cloud to alter the merged model.
Continue the steps to alter/maintain the model throughout the process.

ONLY SUPPORTS WINDOWS OS CURRENTLY

Autodesk BIM 360 Glue is not included in other Autodesk subscription plans
It is a stand alone program requiring its own subscription plan.

BIM Glue can upload and read virtually any 3D file type.
This gives you the ability to upload and view models created in various programs - which may be the case when working with new consultants.

There is an Ipad mobile App that allows users to view and markup the model as well as take measurements, view hyper links, and run their own clash report.

It allows for advanced project security and access by giving the project manager the ability to set permissions and security settings.
This allows different users varying levels of access which will insure that the alteration of the model is limited to qualified individuals.

All previous versions of a model are automatically saved, allowing users to view the project history and progress.
If an alteration to the model is unwanted, users can simply revert back to a previous version and continue to work on and update that model.

The viewer is NOT free for all users.
Unfortunately, a user account is necessary to view models and files within 360 Glue. Autodesk is currently working on creating a free online viewer.

Marked up 2D views (such as sheets) do not import back into Revit as do clash detections.
You can mark up a 2D view and then notify a user of the comment, but then that user must manually change the view in Revit themselves.

BIM 360 Glue has the ability to read and view IFC files as well.
This gives Glue the ability to truly act as an overall dashboard for project teams to use because it can view virtually all 3D models.

It does not import Type parameters - only Instance parameters.
However, I have contacted Autodesk support and I was informed that it should import all custom and shared parameters. This issue is currently being investigated.

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Autodesk BIM 360 Glue

Nichols, Melburg & Rossetto Architects and Turner Construction Company

Case Study Success Stories

"Now, decisions are made more quickly and potential problems solved earlier in the construction process. In the old days, **it would have taken a week for us to generate an RFI**, reference the appropriate documents for the architects, and wait for the response. Autodesk BIM 360 Glue helps speed up our coordination process by having the most current model available all the time, **reducing the amount of time** it takes to get questions answered from the design team."

-Adam Della Monica (Virtual Design and Construction (VDC) Engineer at Turner Construction Company)

Figure 17 - Turner Construction Company

M Moser Associates

"Autodesk BIM 360 Glue has allowed us to bring 3D modeling to members of the team who are a bit removed from the design process. **You don't need much training to navigate the 3D model like a pro**."

-Chris Swartout (Senior Associate with M Moser Associates)

The Walsh Group

"**Since it's in the cloud, they don't need a powerful computer**. Autodesk BIM 360 Glue makes it easy for our subcontractors to go into the model and look at it, spin it around, save a view of a problem area, and easily send that view back and forth with Internet links."

-Weston Tanner, (Virtual Construction Manager at Archer Western)

Figure 18 - M Moser Associates

"If subcontractors don't have ownership, if they don't feel like they're responsible for the BIM model, then it doesn't get used. We can sit here and do coordination all day long, but **if those guys aren't involved in the process**—actually making design decisions based on the BIM coordination—**then it's worthless**."

-Weston Tanner, (Virtual Construction Manager at Archer Western)

*The Walsh Group is a Chicago based general contracting, construction management, and design-build firm.
Archer Western is a member of The Walsh Group.

Consigli Construction Co.

"At handover, the owner can get a model with all the associated equipment information. **Linking equipment information** to the model makes maintenance over the entire lifecycle of the building easier."

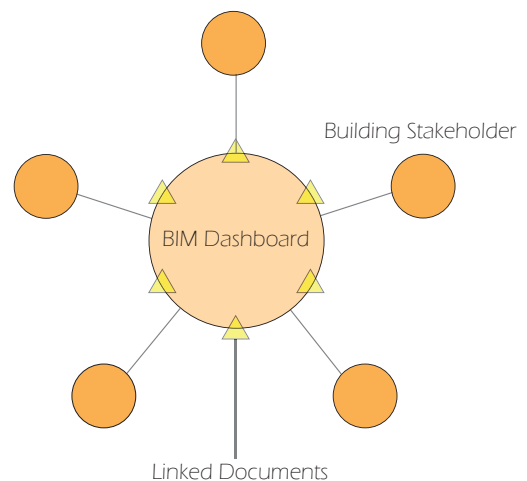*-Andy Deschennes (BIM Manager for Consigli)*

Figure 19 - BIM Glue Conceptual Model
Project stakeholders are given access to the selected BIM dashboard which allows them to view all important and linked documents and information. The dashboard is the piece of software that the model is hosted on and gives access to the model information.

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SimpleBIM

SimpleBIM is a powerful tool to help reduce file size by choosing what parameters and objects will be exported from the Revit model. The model exports as an IFC 3D model which is readable by numerous software including Adobe PDF. This is useful in a few scenarios. If a model is being tested for energy efficiency, the model owner can specify to export only the parameters and object that would affect the energy usage of the building. This greatly reduces the file size and the time it takes to run the test because there are fewer pieces to the model. If the model is one cohesive model - already incorporating architectural, structural, mechanical, and plumbing systems - SimpleBIM gives the ability to specify only certain aspects of the project. If the structure of the building is being examined, then the owner of the model need only choose to export the structural elements of the model. Once again, this greatly reduces the file size; saving much needed time.

SimpleBIM is not an all-encompassing dashboard option. It does not give the ability to create an initial Quantity Takeoff or estimation within the software itself. SimpleBIM, as it stands, does not allow applying markups and comments to the model because it is used to prepare a model for data exchange. Once the model is in IFC form, it can be loaded and viewed with an outside program such as Adobe Acrobat which allows markups and comments. SimpleBIM also does not offer a method of communicating with Revit itself. For example, you cannot change an object property within SimpleBIM and have that information automatically be uploaded back to Revit.

Dashboard Option	SimpleBIM
Pricing	800 Euro/seat (1-4)*
Quantity Takeoff	✖
Active Links	✖
Excel Export	✓
Markups/Comments	✖
Bi-directional Communicaion	✖
Import Revit Linked Models	✓
Merge Models	✖
Full Parameter Import	✓
Interactive 3D Model	✓
Clash Detection	✖
Model Variance Comparison	✖
Accessibility Control	✖
As Built Drawings	✖

Figure 20 - SimpleBIM Overview

*For full product pricing, click here.

**SimpleBIM does allow quantity takeoff by exporting information to Excel first. It does not run a full quantity takeoff on its own.

Figure 21 - SimpleBIM File Trimming Graph
SimpleBIM is a powerful exchange tool that gives the ability to include only desired parameters and model information. This greatly reduces file size which decreases processing time. If users want to run an energy analysis with a 3rd party software, SimpleBIM can selectively include only parameters pertinent to the analysis.

SimpleBIM Tutorials

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SimpleBIM

SimpleBIM and IFC's - AEC Magazine (2012)   Important Items to Note:
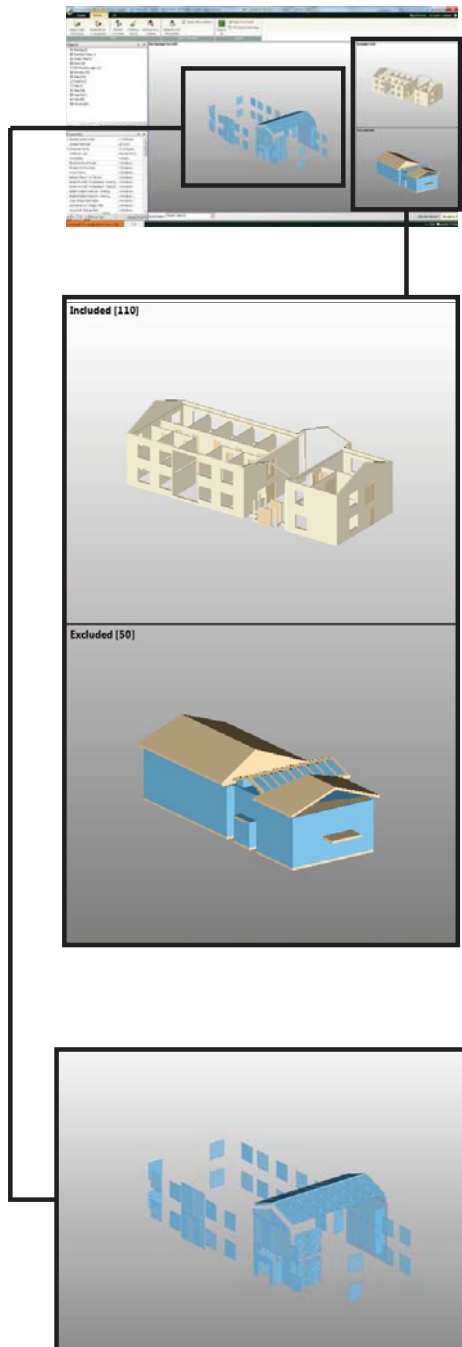
SimpleBIM is most useful when utilized as a data exchange model.
   It optimizes 3D models for export and sharing with other individuals and other programs by reducing the file size. This is done by chopping up the model and including only information pertinent to the task at hand.

SimpleBIM allows you to customize a "template" for exporting the model
   This will automatically chop the model to include only the items included in the template - saving time by eliminating the need to edit numerous models..

As of now, SimpleBIM only allows to upload and view one model at a time.
   However, an update is currently in its Beta test version, and once it goes live, it will allow numerous IFC models to be merged and viewed within one window. This will bring clash detection capability to SimpleBIM.

SimpleBIM is very useful when running various building analysis.
   Because of its capability to selectively export model geometries, SimpleBIM can save time when running simulations such as energy simulations. By cutting the amount of information in the model to include only properties and geometries pertinent to the analysis, processing time and file size will be reduced.

Figure 22 (Left column) - SimpleBIM: Choosing Objects
   SimpleBIM makes it easy to visualize and understand what model geometries are included and excluded by creating separately labeled windows corresponding to each.

SimpleBIM

There are a few easy methods to manually choose what objects will be included in the model export.

1. Select, drag, and drop objects from the "Not Decided Yet" window into the "Included" and "Excluded" model viewers.

2. Select whole categories or individual instances from the "Objects" tree, drag and drop them into the "Included" and "Excluded" model viewers.

3. Create and choose a template which will automatically trim the model for you.
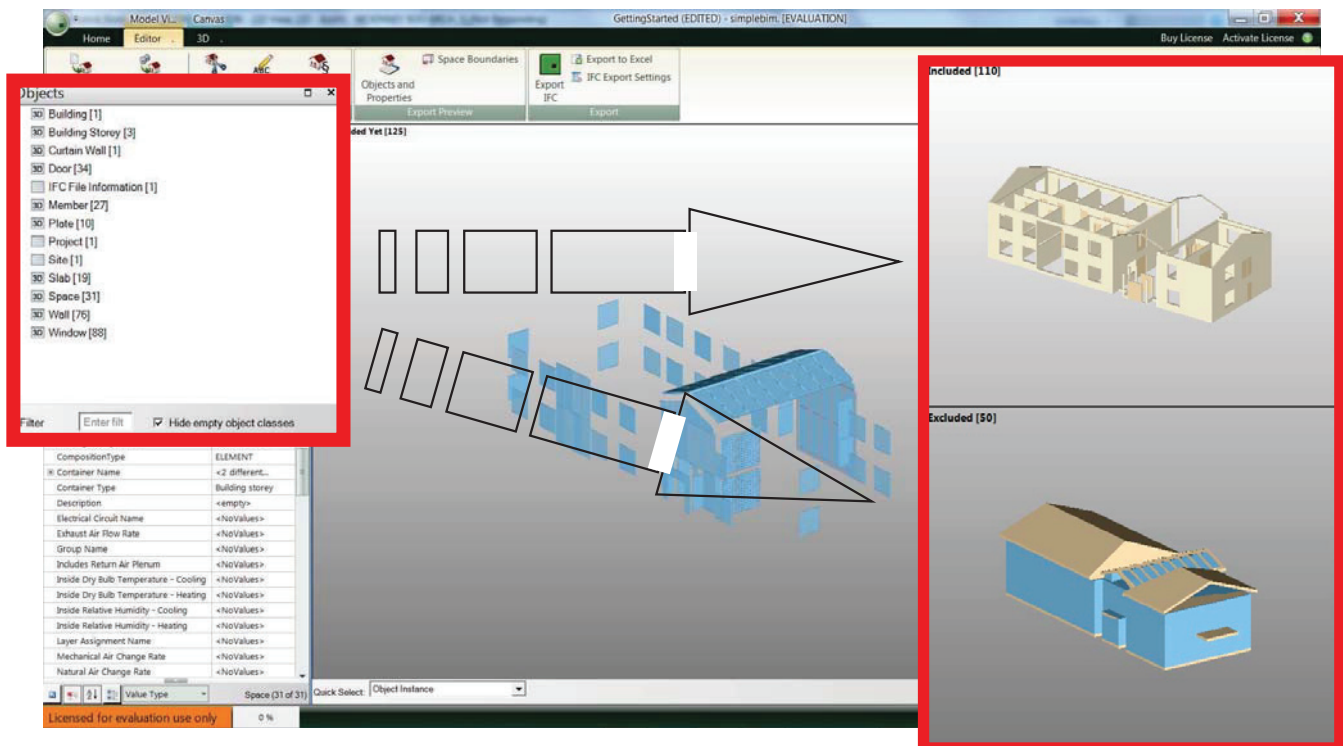

Figure 23 - SimpleBIM: Choosing Objects Methodologies
In order to choose what objects to include in the trimmed model, just drag and drop the objects into the "Included" window from the "Objects" window or the "Not Decided Yet" window.

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3DA Systems

3DA Systems offers a one-click PDF converter that plugs into Revit architecture. The exporter has the capability to reduce file sizes by up to 97%, which greatly increases its exchangeability by allowing uploading it to a cloud based server or even through e-mail. The software offers the ability to easily view, markup, and comment directly on the PDF itself. However, the problem with 3D PDFs is that they do not export any hyper links as active links. This is a major flaw in the software because it does not directly link online documents, manuals, and websites into one cohesive document. This limits 3D PDF's capability to be used as a universal dashboard for BIM modeling.

3D PDF's would be the most useful if an office simply wanted to share the design with a client or outside stakeholder for viewing purposes.

If the receiver of the PDF does not require the specifications, manuals, and other documents, then the 3D PDF would work perfectly as a simple, universal viewing platform.

In order to export to Excel from the 3D PDF file itself, you must first export the information in a CSV file format.

In order to export the model data directly from Revit to Excel, the 3DA Systems Metadata Exporter must also be purchased. This will allow a one-click to Excel functionality within Revit itself.

NOTE: The mobile app for iOS systems does not include the capability to view model and object properties. '

It is simply a 3D model viewer with very limited functionality. This severely limits 3DA System's capability for use as a dashboard - even if it had active links.

NOTE: The next release of the software will include the ability to import hyper links as active links.

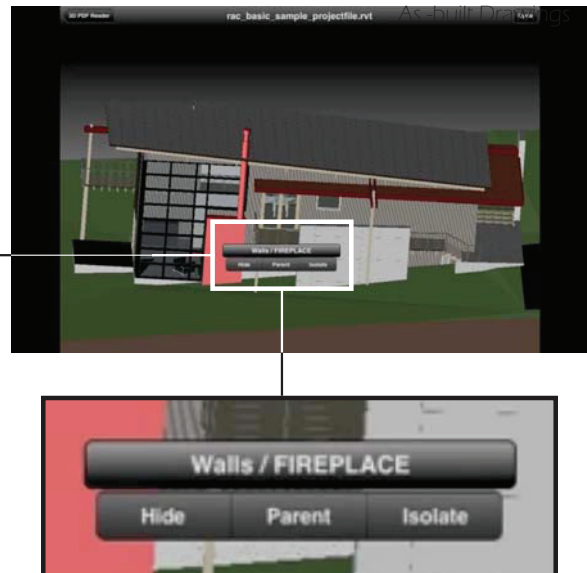| Dashboard Option	3DA Systems
Pricing	$189/seat
Quantity Takeoff	✖
Active Links	✖
Excel Export	✓
Markups/Comments	✓
Bi-directional Communicaion	✖
Import Revit Linked Models	✓
Merge Models	✖
Full Parameter Import	✓
Interactive 3D Model	✓
Clash Detection	✖
Model Variance Comparison	✖
Accessibility Control	✓
As Built Drawings	✓

Figure 24 - 3DA Systems Overview

Figure 25 - 3DA Systems Mobile Viewer
The mobile app for viewing 3D PDF's is severely limited in its capabilities. It does not allow viewing the model tree and properties. All the app does is visualize the 3D model and objects.

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Revu Blue Beam

Revu Blue Beam is essentially an alternative PDF viewer to Adobe Acrobat with a few added perks. Blue Beam offers the creation of online Studio Projects and Sessions which are essentially private servers that allow posting various documents/ PDFs for other members to view and markup. It is a central location for all files associated with a single project.

Blue Beam also gives the capability to manually measure on a document.

> For example, Blue Beam allows taking a construction document and measuring how much space is between two different elements to check clearances.

Blue Beam does import project parameters as active links.

> When viewing model properties in the 3D Model Tree, URL addresses are active if clicked on twice. It then opens the web page or document within the Blue Beam interface.

Blue Beam can eliminate wrestling over large piles of paper.

> This is especially useful when red-lining drawings because markups and comments can all be done on the Blue Beam server. Who doesn't like a clean desk?

Great for visualization purposes with the client.

> Instead of handing them static images, you can hand over a fully populated 3D model that they can explore on their own. It will keep them updated and excited about the project.

The eXtreme edition of Blue Beam includes Optical Character Recognition (OCR) and Redaction capabilities.

Dashboard Option	Blue Beam
Pricing	Standard: $179/seat* CAD: $249/seat* eXtreme: $299/seat*
Quantity Takeoff	✓
Active Links	✓
Excel Export	✓
Markups/Comments	✓
Bi-directional Communicaion	✗
Import Revit Linked Models	✓
Merge Models	✗
Full Parameter Import	✓
Interactive 3D Model	✓
Clash Detection	✗
Model Variance Comparison	✗
Accessibility Control	✓
As Built Drawings	✓

Figure 26 - Blue Beam Revu Overview

*For full product pricing click here.
**For full product version comparison click here.

To see the differences between Blue Beam and Adobe Acrobat, click here.

Optical Character Recognition (OCR): allows scanned files to become text searchable and selectable documents.

Redaction: allows users to permanently delete confidential information from the file for security purposes.

Revu Blue Beam

Unlimited storage space

At Revu's most basic level, it can be used as Cloud storage for users to store and access files in the cloud.

Can markup and compare documents.

Once a file has been altered or marked up, users can compare the two documents side-by-side, and Revu highlights what has been changed. This will help avoid missing certain markups and changes made to documents.

Comparing Documents Overview

Imports 3D PDF's directly from Revit (or other publishing software)

These include ACTIVE HYPERLINKS.

Can set security protocols such as password protection, signature, etc.

You can create custom columns within the PDF file which can include FORMULAS.

Cost Estimation Workflow

i.e. You can create a "Material" column and associate a price with this. You can then create a "Total Cost" column that uses a custom formula to compute the cost of a material.

Creating Custom Columns/Formulas

This is essentially a Quantity Takeoff within Revu itself.

For example, let's say a floor finish within the project costs $12 per SF. You can create a formula to calculate the total cost of the material (for every room that the material is used) by automatically multiplying the Material Cost by the measured SF of the space.

Important Items to Note

There will be a major version upgrade coming early 2014 – Revu 12.0

This will only be compatible with Windows 7/8 Operating Systems because Microsoft is ending support for XP in 2014.

AutoCAD (2004-2009) and Solidworks (2004-2009) will NOT be supported.

MS Office XP 2002/2003 will NOT be supported.

NOTE: the Quantity Takeoff capabilities are highlighted simply to showcase one functionality of Revu. In my opinion, Assemble makes the process even easier.

Apple iOS is NOT supported by any Revu software at the moment, only Windows.

However, Apple iPad IS supported for mobile access.

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Revu Blue Beam

Blue Beam Vu

This is a FREE viewer provided by BlueBeam.
You can view all markups, comments, annotations, etc.

Can digitally sign PDF's

Can connect and access Revu Studio Projects* that are set up by licensed users.
> This allows you to access all files shared on the Studio Project.
> You can also markup/comment on the files.

Can connect to Revu Studio Sessions* that are set up by licensed users.
> Allows you to collaborate in real-time with other users and team members.

CANNOT create Studio Projects and Sessions, just join ones that are already created.

Can take measurements on a PDF document, but these measurements cannot be saved as annotations. They are simply used for personal reference.

CANNOT alter/edit PDF files – you CAN comment and markup PDF's however.

Revu CAD

$239 per seat (price per seat decreases when bought in bulk)
> i.e. For 10-24 licenses - $179 per seat ($212 with the annual Maintenance)

$59 per seat annual maintenance support (optional)
> Includes "premium" technical support through email and telephone

All licenses include email support for free, but with the annual maintenance program, you get direct telephone support as well.

Includes free Major upgrades for new versions that may become available
> i.e. version 11.0 to 12.0
> Minor upgrades (11.0 to 11.5) are free to all licenses

$119 software upgrade per seat (without Maintenance program)
> 10-24 License upgrades - $89 per license

*The costs are a **one-time payment**. The only recurring payments would be for the optional Maintenance Program.*

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Revu Blue Beam

Revu eXtreme

$299 per seat (price per seat decreases when bought in bulk)
> i.e. For 10-24 licenses - $219 per seat ($268 with the annual Maintenance)

$69 per seat annual maintenance support (optional)
> Included Maintenance offerings same as Revu CAD.

$149 software upgrade per seat (without Maintenance program)
> 10-24 License upgrades - $109 per license

Includes Optical Character Recognition (OCR), Redaction capabilities, PDF form creation, scripting, and structures.
> OCR – This allows scanned files to become text searchable and selectable files.
> > *Without this, files scanned to the computer cannot be searched using functionalities such as "CTRL+F". The files are simply a viewable PDF. You can also "Copy" information from the scanned PDF and "Paste" it into another open document.*

> Redaction – This allows users to permanently delete/remove confidential information from a file for security purposes.

> PDF Form Creation – Allows the creation of PDF forms and form fields. (I am looking into this further)

> Scripting – Can add custom script functions to PDF's to streamline processes.
> > *i.e. You can set a script that – when chosen – will automatically add a Submittal Cover Sheet, flatten the images and documents, attach the PDF to an email and email the file to another person. (This is just one, simple, example)*
> > *I am looking into Scripting further, but so far, it does not seem too difficult to at least understand how to use its basic functions.*

> Structures – I am not entirely sure about this one, but I will find out more.

*The costs are a one-time payment. The only recurring payments would be for the optional Maintenance Program.

Optical Character Recognition Overview

Redaction Overview

PDF Form Creation Overview

Scripting Overivew
Script Reference Guide

Structures Overview

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Revu Blue Beam

Revu Studio Project

This allows files to be uploaded to the cloud so users on other computers can access, markup, or download the files to their local computer.
Allows for online collaboration.

There is a 100GB storage capacity PER Studio Project.
But you can create as many Studio Projects as you like.

Revu Studio Project Overview

Revu Studio Session

This allows online collaboration in REAL-TIME.
When a session is set up, the host invites users through email notification so only those users can have access to the Session.

All members of the Session can markup and collaborate on the SAME document at the same time. Sessions also include a "Chat Room" where users can instantly communicate with one another to ask questions, answer questions, etc.

The Studio Session allows users to "follow-along" with another users' screen.
i.e. "John" needs to physically show or explain something to "Sue". Sue chooses to screen-follow John, which allows her to see what John is seeing/doing. She no longer controls her screen, but is watching John's screen through her monitor. It is essentially a screen-capture.

There is also a 100GB storage capacity per Studio Session. You can create as many Sessions as needed.

At the end of the session, you can save and print off a summary of the studio session. This highlights and organizes everything that was done during the session.
i.e. It lays out who made what comment/markup, the date and time it was done, on what file it was done, and on what page of that file (if the file has numerous pages) it was done.

Revu Studio Session Guide [PDF]

Revu Studio Session Overview

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Revu Blue Beam

HKS Leverages Revu and Bluebeam Studio for IPD

"On previous projects that didn't use Revu or Bluebeam Studio, we would have to send multiple versions of drawings from each person and filter through repetitive comments. Studio let everyone view and respond to each other's comments so it was easy to see who needed to complete a task."

-Deva Powell, AIA, LEED AP, Project Architect at HKS

Bristol Compressors

"Bluebeam Revu has helped me revise and check drawings. **If there is a revision on the same sheet size, the "Sync" feature works great at zooming in and helping me locate that change.** When using pen and paper to check an old revision to a new revision, I would highlight or mark off what I had checked. I am now able to use Bluebeam's "Highlighter" for this and have taken the process paperless. I no longer have to wrestle drawings on my desk top."

- Jeff Hamilton, Bristol Compressors

Capitol City Design Inc.

"As a CAD Manager, Bluebeam Revu is a wonderful tool I use frequently. **For clients who do not have AutoCAD, converting my AutoCAD drawings to the prevalent PDF format let's them see and print my drawings. For clients that DO have AutoCAD, converting my drawings to the secure PDF format protects my drawings from being changed without permission.** Bluebeam smoothly integrates itself into AutoCAD. It is extremely easy to use, and best of all, it is about half the price of Adobe Acrobat Professional."
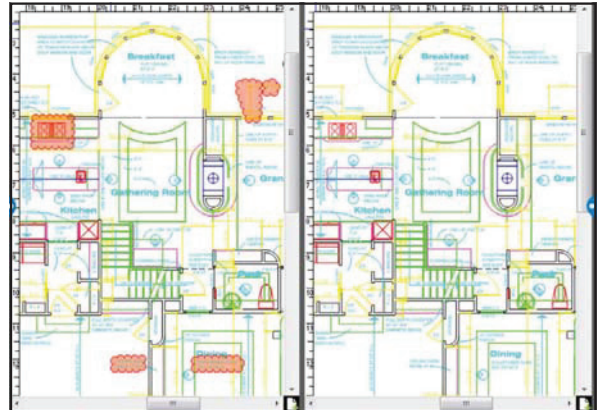
- Alex Trafton, CAD Manager

Figure 27 - Document Comparison

If a document is marked up or altered, Revu has the ability to automatically compare and find the difference. This eliminates the human error of simply not seeing a red-line or comment. In the image above, the differences are automatically highlighted with a red cloud.

Comparing Documents Overview

Revu allows easily exchanging file types by exporting and viewing them as PDF's. It also gives the ability to require a signature or password in order to view or alter the document.

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Dashboard Option	Assemble Systems	BIM 360 Glue	SimpleBIM	3DA Systems	Revu Blue Beam*	Navisworks
Pricing	$3,600/year	$150/seat/ month	(1-4)$350/seat (5-9)$170/seat	(PDF)$179 (Metadata)$149	Standard: $179/seat CAD: $239/seat eXtreme: $299/seat	$2,100 $8,400
Quantity Takeoff	✓	✗	✗	✗	✗	✓
Active Links	✓	✓	✗	✗	✓	✓
Excel Export	✓	✗	✓	✓	✓	✓
Markups/Comments	✗	✓	✗	✓	✓	✗
Bi-directional Communicaion	✓	✓	✗	✗	✗	✓
Import Revit Linked Models	✗	✗	✓	✓	✓	✓
Merge Models	✗	✓	✗	✗	✗	✓
Full Parameter Import	✓	✗	✓	✓	✓	✓
Interactive 3D Model	✓	✓	✓	✓	✓	✓
Clash Detection	✗	✓	✗	✗	✗	✓
Model Variance Comparison	✓	✗	✗	✗		✓
Accessibility Control	✓	✓	✗	✓	✓	✓
As Built Drawings	✗	✓	✗	✓	✓	✓

Figure 28 - Software Comparison

*Revu offers lower pricing per seat when purchased in bulk.
Upgrading from Standard to CAD includes the ability for one-click to PDF/3D PDF from AutoCAD, Revit, and Navisworks. Upgrading from CAD to eXtreme offers Optical Character Recognition (OCR), PDF form creation, Redaction, Scripting, and Strucutres.

Assemble Systems

Assemble can read numerous 3D files, allowing collaboration between disciplines. It allows users to tie custom Assembly Codes into the project - complete with associated costs.

Update: By the end of the month, Assemble will allow users to compare models in the 3D environment instead of being limited to the table view. Assemble will also allow the alteration of parameters outside of the selected Type Parameters - increasing its functionality,

BIM 360 Glue

BIM Glue allows users to merge various models into a single environment - allowing for clash detection. Clashes and views can also be marked up and sent to project members for notification - increasing communication. At its most basic, BIM Glue can be used as Cloud storage because you can upload any file type. It also allows users to upload 2D sheets for review and markup - allowing for collaboration outside of the office.

BIM Glue also has a mobile app available with full functionality. This will allow users to take their models on the go for viewing at any time they have an internet connection.

Blue Beam Revu

Revu allows for viewing of 3D PDF's, and a wide range of file types. The 3D PDF itself imports all project parameters, and even imports hyperlinks as activelinks. Revu Studio/Plan Rooms allow for numerous users to view and comment on a single document at the same time - similar to an online conference room. Revu has the capability to eliminate physical paper because all documents can be uploaded to the server, reviewed, and red-lined.

Upcoming Dates

End of October - Assemble will be updating their software to include increased customization, editability, and 3D model comparisons.

Reasoning & Conclusions

Through the research, I have found that it is possible to link important documents (Operations manuals, maintenance forms, specifications, etc.) to a 3D model.

> One of the biggest challenges however is not simply linking the documents, but sharing the information with necessary stakeholders. For example, if the building owner expects a hand-over of the BIM model, they need a platform to actually view and access the information with. From what has been discovered, Blue Beam and 3D PDF's may be the answer.

If interoperability issues inherent with IFC files were eventually solved, SimpleBIM would be an extremely powerful tool for all AEC practices.

> This is because SimpleBIM offers the ability to easily trim a model to include only necessary parameters and objects, and IFC files can be read by a wide range of software. SimpleBIM has the ability to greatly reduce file sizes which increases exchangeability, decreases needed storage space, and reduces processing time for software such as energy analysis. SimpleBIM may see increased functionality in the future as IFC issues are resolved.

Blue Beam Revu may be the ideal candidate for use as a universal Dashboard.

> Blue Beam offers a piece of software that includes nearly all necessary functionality for use as a dashboard. Virtually the only functionality that Blue Beam lacks is clash detection. It offers a fully interactive 3D model - complete with all custom parameters - and all the hyper-link parameters are active-links. Simply by double-clicking a hyperlink or URL will open the document or web-page. Blue Beam also allows for markups and comments on the documents which could potentially eliminate the need to print hard copies of certain documents - saving time and money. As Blue Beam is used more often and becomes more familiar, more functionalities continue to make themselves known. Its potentials keep growing.

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Reasoning & Conclusions

From what I have found, Autodesk 360 Glue may be one of the best options for project teams to use because it allows the viewing of many 3D model file formats, linking of important documents, merging numerous models, and detecting clashes.

It also offers a seamless method for notifying team members when something needs to be changed. When uploading a model to the Glue server, all project parameters - even custom parameters - are brought in. However, 360 Glue is not a plausible platform for end-users. This is because 360 Glue requires a subscription to view the models which will get very costly over time.

The most useful software to consider using would be Autodesk 360 Glue, Assemble Systems, and Blue Beam Revu.

I would not consider any one of these software to be inherently better than the other - they all serve different purposes. Assemble allows for more technical and numeric operations compard to 360 Glue's emphasis on visualization and clash detection. Blue Beam Revu offers a seamless and fluent solution to communication and collaboration within an office, and with outside stakeholders.

One of the main flaws holding BIM back is the interoperability issues.

As of now, many software do not completely communicate with one another. IFC files may be a generic exchange file format, but when exporting and importing those files, important information is often lost.

BIM requires that all teams involved in the design and construction of a project are versed in BIM software and actively use it.

What makes BIM so powerful is its coordination and collaboration abilities. As the saying goes, "a chain is only as strong as its weakest link". If a portion of the project team is not involved in the BIM process and practices, it will make no difference if the rest of the team uses BIM because the lacking team members will hold the entire process back. In effect, it would create a bottleneck for the entire project. This is because BIM is all about saving time and money by streamlining the communication and collaboration processes.

Although BIM has immense potential to make an immediate impact on the AEC industries, it still has quite a bit to go before all the kinks have been worked out.

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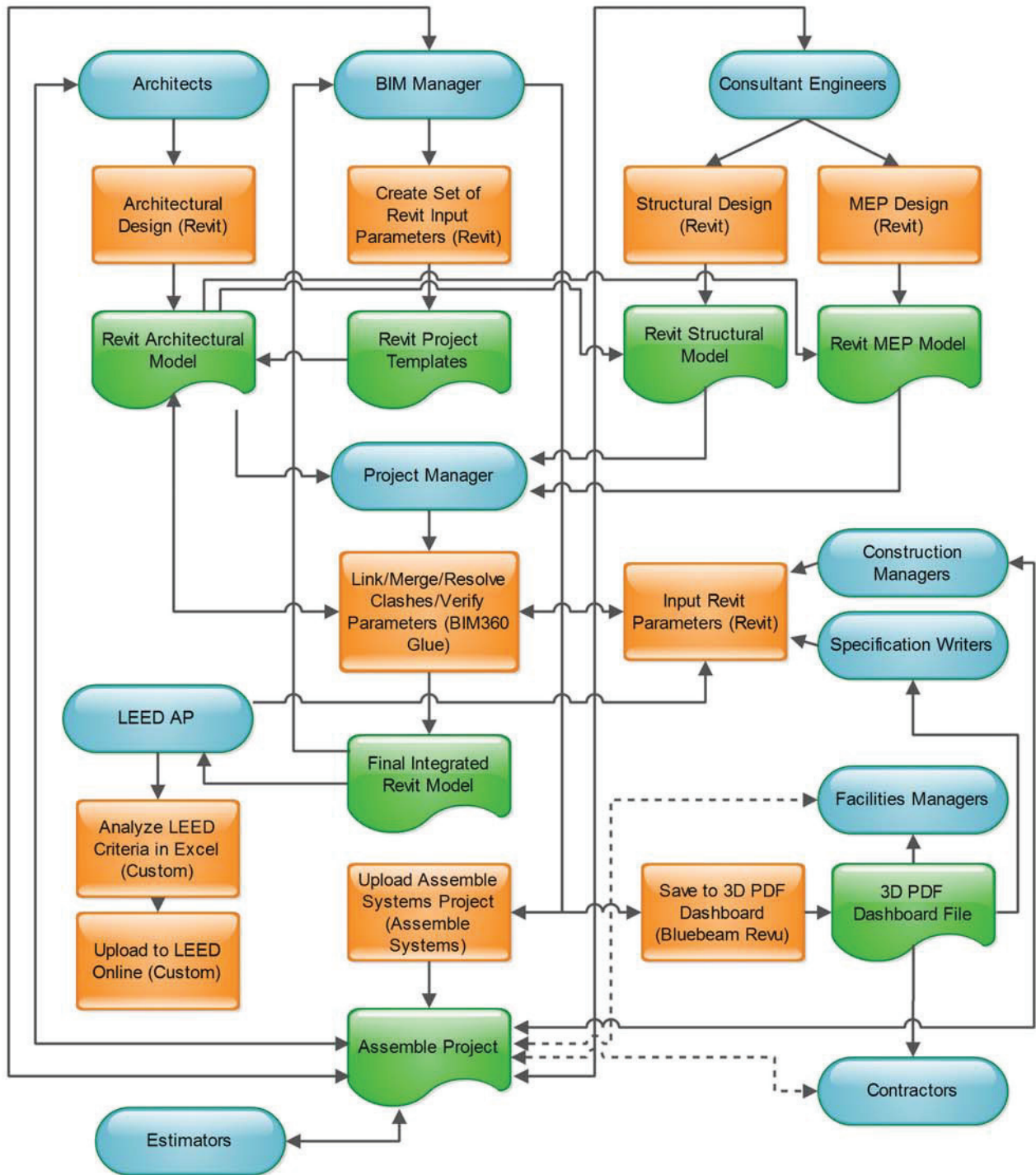
R. L. Engebretson Co. BIM Process Integration Flowchart with Software for Processes

Prepared by: Ganapathy Mahalingam; 10/20/2013

Figure 29 - BIM Software Flowchart

Future Applications

There is no doubt that BIM Cloud integration has the capability to exponentially increase the efficiency of the Architectural profession. By implementing BIM integration, firms have the ability to communicate with project members, consultants, and clients anytime, anywhere. If a conflict or problem arises during the design and construction process, it can be acknowledged and dealt with virtually instantly. Anywhere there is an internet connection, team members will have the ability to review project details and models - continuously staying up to date on project information.

By providing a wholistic, comprehensive model, all project teams (AEC) will have the ability to seamlessly model, review, mark-up, and alter the model. BIM Modeling provides instant access to all necessary information and documents including, but not limited to, Specification Sections, Operations and Maintenance Manuals, Maintenance Forms, product manufacturer URL's, and so on. This not only helps during the design and construction processes, but also allows for facility management throughout the building's life cycle. If a piece of equipment breaks down, the building owner can instantly view the Operations and Maintenance Manuals to attempt to fix the problem. If not, all the equipment's associated documentation can be viewed including manufacturer information, warranty information, and so on.

In order for BIM modeling to truly reach its full potential, rethinking the design and construction delivery process may be necessary. As of now, Integrated Project Delivery is the best delivery method for use with BIM modeling. This is because IPD was created with BIM in mind. IPD brings all project teams on board sooner in the process - keeping everybody informed and up to date. IPD does however require more time spent on the front end of the project because that is when a majority of the coordination occurs. Because of this, project fee structures may have to be revised to fit the new process. Increased time up front means more fees at the beginning; less time on the back end means smaller fees as construction wraps up.

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Potential Impact

Through this research investigation, it has become apparent that BIM modeling has the capability to alter and improve the entire architecture profession. BIM modeling can be a daunting beast, and as more firms begin to implement and use it, the more advanced and updated it will become.

Architectural offices will have the ability to provide services to the client and building owner past that of the building's completion.

> *With BIM modeling, facilities management becomes a manageable task for either the building owner themself or the architectural office. Each firm could potentially offer facilities management services to clients as need be. Otherwise, it is possible that the demand will be so great for facilities management that consulting firms may start up which are equipped specifically for such tasks.*

BIM modeling not only has the potential to radically alter and advance the architectural profession, but also to completely revolutionize the entire design and construction processes.

> *BIM modeling extends beyond that of the Architecture profession. Its benefits can be realized by the entire AEC industry by increasing collaboration and coordination. This will greatly reduce time and energy spent on change orders and design alterations - saving immense amounts of money.*

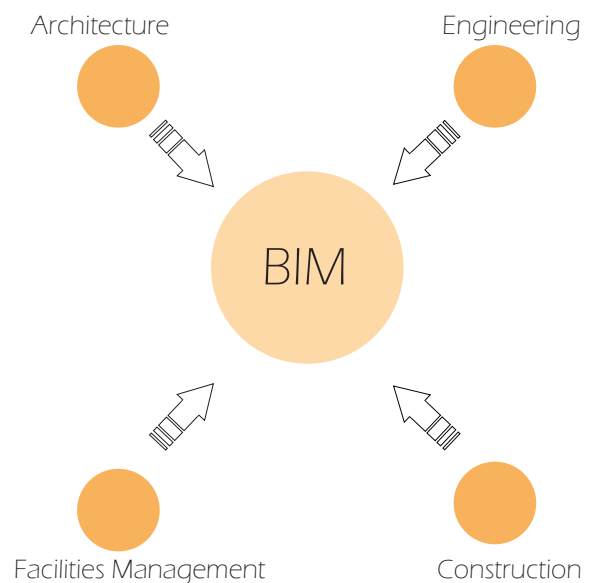*BIM and IPD will radically change the AEC industries.*

Figure 30 - BIM Collaboration Model

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Potential Impact

It is my belief that a completely new Architectural business model must be realized for BIM to make the greatest impact.

The amount of time spent at the beginning of the design process will be drastically increased as the BIM model is populated with all necessary information. This will however decrease the amount of time at the end of the construction because conflicts and change orders will be reduced due to increased communication and collaboration throughout the entire process. For this to happen, all stakeholders must be involved from the very beginning - the more involved and educated the project teams are, the easier the process will be.

New positions within AEC offices will be created to help manage BIM modeling, information databases, and software.

As BIM modeling begins to take hold in the industry, a new professional will arise from the turmoil. BIM models can be overwhelming with the amount of information packed into them. Because of this, many firms may find a need to hire a full time data manager to keep all necessary files in order.

Firms may find a need or desire to maintain their own web-server to store linked documents to allow all users access to the information.

A single server works fine within a firm itself, but in order to allow building owners and stakeholders access to important documentation, such as operations manuals and specifications, the documents need to be hosted on the web publicly. This will allow interested parties access to the files anytime, anywhere.

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Research Limitations

The GRA had a few limitations.

1. Communication was restricted to the speed of sending, receiving, and responding to emails because I was not working within RLE's office. This slowed the process at times because certain actions required permission or clarification before proceeding.

2. During the process, I downloaded many trial versions of products. However, trial versions often times do not function exactly the same as the full, licensed version. This led to the possibility of not getting a full picture of certain software.

3. Because I was not working on an actual, in progress project with RLE, it was difficult to fully understand the functionality and benefits of each software. I was given a sample project from RLE, but I did not help to create it, nor did I know much about the client's needs.

Along the same lines, I have had very little experience working in a professional office, so my knowledge of the actual profession of architecture is severely limited. This made it difficult for me to fully understand how BIM can benefit firms. I do not know how construction phases actually take place, nor do I understand fully how contractors and subcontractors affect the design and construction processes.

4. One of the main pieces of software that I researched was Assemble Systems. However, it took about 2 weeks to receive the actual software, so there was less time to work with it. This was a limiting factor because I did not have as much time with Assemble Systems.

5. Because BIM is still in its infancy, the working knowledge of various software capabilities is limited. Once more firms begin to utilize and learn BIM on their own, more information will become available.

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Assemble Systems

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BIM 360 Glue

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SimpleBIM

Video Tutorials

Revu Blue Beam

Video Tutorials

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[Collaboration in Higher Education]

MATTHEW DUNHAM. NORTH DAKOTA STATE UNIVERSITY
IN PARTNERSHIP WITH BWBR

ARCHITECTURE. STUDIO 771.
DR. GANAPATHY MAHALINGAM. FALL 2013

col·lab·o·ra·tion

noun

1.
The action of working with someone
to produce or create something.

Origin
Latin: mid 19th cent.: From Latin collaboration(n-), from collaborare 'work together.'
Collaborare - Collaboratio - Collaboration

[Collaboration in Higher Education]

GRADUATE RESEARCH ASSISTANTSHIPS. STUDIO 771

This project involves identifying the architectural characteristics of spaces that facilitate collaboration in higher education, deriving the spatial organization and circulation patterns that facilitate collaboration, and simulation of collaborative environments. This project is in partnership with the architecture firm BWBR located in St. Paul Minnesota. BWBR has been hired for the new Science and Technology building to be built at North Dakota State University. BWBR is responding to the request, by NDSU president Dean Bresciani, that the new building become a center for higher education collaboration.

[New NDSU STEM Building]

SCIENCE-TECHNOLOGY-ENGINEERING-MATHEMATICS

1) Provide state-of-the-art, safe spaces for science and technology instruction;
2) Free up and allow for better use of existing space to support research and teaching in STEM areas
3) Support the unanimous top capital project priority of all colleges, deans and senior academic leadership at NDSU, the business community and the state of North Dakota by providing excellent educational opportunities in the STEM fields of study.
4) Align with the third goal of the SBHE, which states "Economic development through quality education, research, training and service".

1 & 2

At the smallest level this is where people meet at a water cooler, or a coffee bar, or run into each other at the bathroom. This is also the level of collaboration where people meet up with others to perform tasks such as study and talk in small or one-on-one groups. This is informal as there is no structure to spontaneous, level two involves arranged gathering of a few people.

3

Overcoming Territory (Left brain) references the desire that each person wants their own space. At this level of collaboration it requires design to break down walls and bring people together. Opening up spaces, and channeling all arrival of the building through one entrance, forcing people to interact.

4 & 5

Involving the entire university or community requires the facility to be a destination which will draw people in. Level five is where regardless of space technology is key in bridging interactions through media to remote locations.

[Collaboration Levels]

*This taking of collaborative spaces was designed by Matthew Dunham in response to research and observation.

LEVEL 1
One on One: Strictly Spontaneously Informal

This is the level of collaboration where people meet spontaneous in passing. Also where two people may meet in passing and linger for a while together, these interactions do not often last more than 10min.

LEVEL 2
Small Nodes: Medium to Highly Structured

These are more structured then level one as they pertain to individuals in small groups who seek out spaces or environments to perform tasks. This may be studying, tutoring, or social. These interactions are not often as spontaneous but can be, as it involves more than 2-3 people.

LEVEL 3
Academic Groups: Overcoming Territory

Bring faculty, staff and students into one space to perform tasks. This can be study groups, lectures and events. This can be spontaneous as this often takes place in common spaces, but more often involves some structure.

LEVEL 4
Community Involvement: Destination Demanding

This demands there be a destination to bring in people from across the community and the university. This facilitates broader collaboration as people regardless of age and take utilize a similar destination.

LEVEL 5
National and Global Teams: Most Tech Savvy

Regardless of space, this means the high level of technology which is required to communicate globally in any size of group. This more often than not takes place in breakout spaces or more-semi private spaces due to the best sound and image clarity.

[History of Collaboration]
THE EXPONENTIAL CURVE

Throughout history there has never been such growth in communication and digital collaboration as now. This list includes all types of collaboration, from the invention of paper, to the postal service, the telephone, television, computers, and the Internet. Each one of these has played a role in how we collaborate today. It is visible to see the most exponential developments occurred within the last 200 years.

3500BC: Word of mouth and images
5th century BCE: Pigeon post
14bc Romans established the postal service
101bc First bound book
105bc Invention of paper as we know it
1450 Printing Press by Johannes Gutenberg
1492 Leonardo da Vinci theorize about flying
1650 First Daily News paper
1783 Hot air balloon invented
1787 Steamboat Invented
1790 Bicycle invented
1814 First Photograph Image achieved
1821 First sound box "Microphone"
1835 Morse code developed
1843 Long distance telegraph line Samuel Morse
1858 First trans-Atlantic telegraph cable
1867 First typewriter
1869 Transcontinental railroad
1871 First car invented (1985 First practical one)
1876 Alexander Graham Bell electric telephone
1877 Patents the phonograph, with a wax cylinder
1889 Paten for the direct dial telephone
1902 First Radio transmission across the Atlantic
1903 Wright Brothers invent and fly the first airplane
1907 First modern Helicopter
1910 First talking motion picture.

1914 Cross continental telephone call made
1925 Television signal transmitted
1927 Television broadcast in England
1944 Computers- government owned
1949 Network Television Invented
1951 Computers sold commercially
1958 Office use photocopier
1938 Television broadcast recorded/taped
1963 communications satellite is launched
1966 Xerox Fax machine invented
1969 First Man on the Moon
1970 Jumbo Jet launched
1971 Floppy Disc invented
1971 First email sent
1980 Sony Walkman invented
1981 Space Shuttle Launched
1981 First IBM PC computer sold
1984 Apple Macintosh created
1985 Cellphones in cars become widespread
1990 Prototype system for World Wide Web
1992 First text message sent
1992 The Internet system is created
1998 Mobile satellite hand-held phones
2000 Mobile G3 networks
2007 iPhone (1st generation)

Collaboration

THE EXPONENTIAL CURVE

19th Century

Electrification
Automobile
Airplane
Water supply and Distribution
Electronics
Radio and Television
Mechanized agriculture
Computers
Telephone
Air Conditioning and Refrigeration
Highways
Spacecraft
Internet
Imaging
Household appliances
Health Technologies
Petroleum and Petrochemical Technologies
Laser and Fiber Optics
Nuclear technologies

[Research Criteria]

1) Must pertain to; in-person interactions, academic related interactions between faculty and students, global interactions and collaboration done via on line networks.

2) What interior qualities facilitate collaboration, such as; lighting, airflow, sounds, furniture, spatial organization, circulation, technology needs, capacity, privacy, access to food, access to printing..etc.

3) What anthropometric needs are sought after when people [students, faculty, staff, visitors] choose locations for; studying, tutoring, group learning, team projects, presentations, gathering, and social interactions.

4) What does research and theories predict will be areas of technology development and educational growth patterns over the next three decades.

[Use of Research]

1) Provide current research data on both interior design and architectural strategies for creating environments which stimulate collaboration.

2) Turn over all findings to BWBR so that any and all applicable data can be used in their design process for the NDSU STEM building. This consists of not only final communicating final work, but updating BWBR with bi-month progress reports.

3) Compile a working list of specifically topic related literature and media resources beneficial to this project and all future collaborative-focused projects.

4) In conjunction with NDSU Studio 771, research will be compiled into a written journal article to seek publication once research is concluded.

[On Site Human Observation]
STUDYING STUDENTS AND FACULTY HABITS AT NDSU

Upon request by BWBR, on site observations will be conducted at 4 key collaborative nodes around NDSU, each chosen for a academic and student life purpose.

1) NDSU Memorial Union

2) NDSU Library

3) NDSU IACC

4) NDSU Downtown Barry Hall

[On Site Human Observation]
(IRB) STUDYING STUDENTS AND FACULTY HABITS AT NDSU

1) Where does collaboration happen in higher education environments?

2) What are commonalities between design elements, which encourage collaboration of humans within, studied areas and spaces?

3) How long do subjects linger or rest in spaces, based on interior space configuration, lighting, airflow, noise and furniture?

4) Observation of tasks which subjects are performing within the observed areas (e.g. reading, studding, using personal technologies, writing).

5) Analysis of collaborative group numbers to find out patterns of cluster sizes.

[Research]

Research has been conducted through on line media, through literature and site observation. Please note that the literature is included in the literature review found at the back of this document. The most critical findings are from Make Space by author and researcher John Wiley, punished in 2012 it is a detailed study done at Stanford University d.school and its Environments Collaborative Initiative. Another leading resource is the research done by the international architcture firm Gensler and they write a dynamic statement published in their last education research stating,"despite all of this connectivity, independence and study-alone time are the factors that define today's study experience." (Gensler, Changing Course, 2). Saying that as Higher Education seeks to design more collaborative spaces student culture still seeks out alone time for their most productive time on campus. In addition these published resources human observations were conducted on the North Dakota State University and their findings have become of importance to understanding the Fargo local culture. Noticing these habits allows designers to be more attentive to the spaces and whether we like it or not "Intentional or not, the form, functionality, and finish of a space reflect the culture, behaviors, and priorities of people within it. This suggests that a space designer is simultaneously a cultural translator and a builder. That said, space design has its own grammar that can be tweaked to bolster desirable habits" (Wiley, 38) Lastly Gensler research lab published this revealing statement stating, "When asked about what study tools they [students] use most, pen and paper ranked highest across all settings. Laptops and the Internet were a close second and third"…illustrating that colleges and universities need to reconsider the emphasis on investing in new technologies for their buildings" (7).

1. Learning From Observation
Using Social Norms to Inform Design Decisions

Observing how people [students, faculty, staff and visitors] use a space is influential in the design process as it directly informs natural social responses to environments. "One of the best ways to develop a collaborative environment is to observe and amplify the ways in which your community already feels empowered to take control" (Wiley, 36)

2. How Arrangements Maximize Use
Creating Spontaneous and Intentional Interaction

This section lays out spacial arrangements to maximize space and helps create space that is foundational for facilitating interactions and collaboration because "the built environment impacts our personal behavior on multiple levels, including territoriality, crowding, situational behavior, and personal space" (Built Environments, 2)

3. Making Space Relevant
Creating Nodes and Destinations for Dynamic Usage

"Dynamic learning environments are the competitive edge" says leading architecture research firm, Gensler in a report studying 250 universities. Utilizing the plans provided by BWBR highlighted elements where called out showcasing how the space will promote collaboration and academics.

1.

[Learning From Observation]

NEED NEW

John Wiley writes in his book, Make Space,"One of the best ways to develop a collaborative environment is to observe and amplify the ways in which your community already feels empowered to take control"(36), this was done by conducting human observations over a given period of three weeks, and multiple per-selected locations for strategic time periods. This information has provided insight into the natural habits of the ever changing generations. Prehapse one of the best statements aimed towards designers in regards to creating spaces to promote collaboration and interactions is"Do less. Leave some aspects of your space open-ended, even though your impulse might be to take care of every detail, resist filling every square foot with furniture or decoration" (Wiley,76). Human observations have revealed the benefits of this and the need for spaces to be built with room to grow and modify.

Each space has a post occupancy adaptation which naturally happens by its users, and this is a critical evaluation where designers can further maximize the potential by paying close "attention to user-initiated changes and respond to them with modifications to [the] space" (Wiley,36). Having spoken with staff members who manage each of the locations, this adaptation of space is a every evolving process that changes as the students needs and demands change.

"Studies show that the built environment affect retention, attention, motivation, learning, and academic achievement" (Built Environments, 1)

"Know what you want to get from each space, articulate it, and act on it" (Wiley, 66)
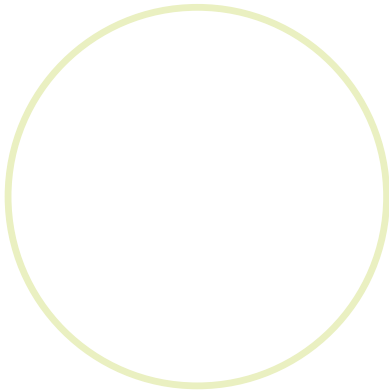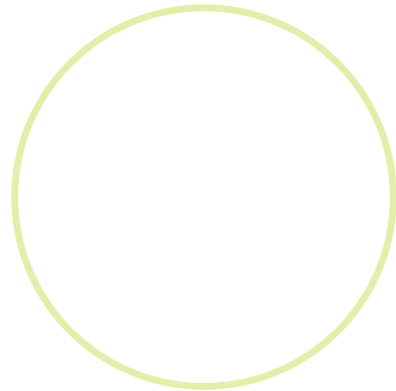
44%.
Of Students time on Campus is spent studying or working alone.
(Built Environments, 1)

"While WiFi connections are important, environments that are inspirational and support different models of learning... Keep physical campuses relevant" (Gensler, Changing Course 10)

"Studies show that the built environment affect retention, attention, motivation, learning, and academic achievement" (Built Environments, 1)

8%.
Of Students time on Campus is spent Studying in groups.
(Built Environments, 1)

71%.
Of students prefer studying alone.
(Built Environments, 1)

"Two things that can be adjusted in almost any space are orientation and ambiance" (Wiley, 25)
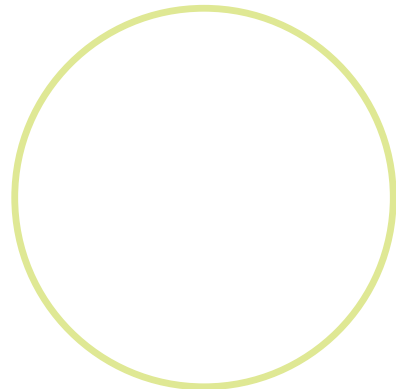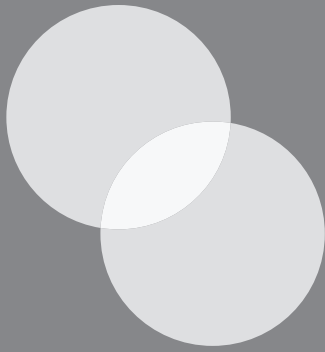
[Observations]

2,192.
Individual people observed
(Apx 6% error)

4.
Distinct NDSU Locations
Observed

3.
Weeks of observations done
at strategic hours and days
of the week to create an
even sample.

Overview

To best study the natural habits of local students and staff its was critical that some observations need to be done. As academic acclaimed author John Wiley and the Stanford University d.School Wrote "One of the best ways to develop a collaborative environment is to observe and amplify the ways in which your community already feels empowered to take control" (Wiley, 36). Once University approval had been granted to perform documented site observation of North Dakota State University, faculty, staff, students, and guests, a strategic plan of observation times was selected. It was soon clear that observations proved so entirely beneficial that more observation sessions were planned to further gather and study students habits of collaboration and social mapping.

even sample of the spaces observed.

The Buildings Observed

Barry Hall Down Town
NDSU Student Union
NDSU Library
IACC Technology Building

Prediction

Observations were a necessity for this research, but the level of value it would provide from the observations was not ranked high. The intention was to simply support published research and statistics with local human observations. Prehapse find more refined local contingencies and add them to the recent growing published works.

Campus Life

Universities run on macro and micro cycles, from classes in a day and hours bus schedules to annual cycles of semesters, holidays and graduations. Even at the most finite level such as peoples habits and social norms are visible mappings of cycles. These are far beyond daily routine composed of eating, class, lunch, studying and relaxing. These are nearly invisible characteristics of campus life, observed by onlookers studying students interactions and collaboration.

Locations

Each of the obsrved locations was chosen for a precise reason and for its importance to the project and final results. There has been a selection of quite study spaces and nodes where students retreat to and transition through, as well as destination study spots. As well as major transitional spots and bus drop off active spaces, as well as the technology hub and typical classroom building. Subjects where observed on multiple occasions over the period of several weeks and varying hours to best capture an

Results

Contained in the following several spreads is the most viable information gathered from the human observations of NDSU subjects, while studied at four key spaces.

69%.

In 69% of all observed group study sessions, people studying in groups tended to not all use their laptops/technology.

219

Cases of observed spontanious interactions .

Observations conducted studied not just one or two aspects of social mapping and use of space but counted numbers of people, observed tasks performed, trips to the drinking fountain, walking laps around the building and other interesting finds.

In 57% of cases where food was introduced into a quiet foccused group study session, the food caused the group to turn dramatically social oriented afterwards.

Nearly 90% of all lounge furniture in the observed spaces did not have arms, but did have higher backs and often clustered around low coffee tables. The remaining percentage was made up of tables and chairs.

76% of students observed sought out, and were observed sitting alone, and in a majority of cases students had laptops with them.

Students seated by window tables were more likely to stay longer [60+ minutes] in their spots than students on lounge furniture on the inner side of the space.

Students seated at tables were less likely to use a laptop or technology and primarily used other tools.

219 cases were observed of spontanious interactions between people such as "running into each

other" in the hallway. All but 11 cases, lasted only between apx. 44 seconds and 1.6 minutes. Assumed to be more but after observing this is the results.

Doorways and stairwell-landings seemed to be the most probable places for interactions between students and staff to happen. 2 out of three cases happened in said places.

80% of all observed phone usage was done on a smart phone such as an iPhone or Android.

Directly in front of the bathroom doors is where often conversations started for several seconds, between aquantences.

94 observed study sessions took place, where students seemed to me studying similar material and "helping" each other, this was primarily between two people.

Lounge furniture in an open space and high traffic area does not deter people from sitting in the space.

Students are prone to first seek out outlets located near seating before choosing seating.

Tables

Students seated at tables were less likely to use a laptop or technology and primarily used other tools.

91%.

Of students observed do not interact with anyone around them.

50/50

In all observed cases the demographic seemed to be 50/50 men and women.

Restroom Use: On average in the period of 2 hours: 21 women and 27 men.

already present did not say hello or greet the person in any way.

Providing clusters of lounge chairs and tables with odd numbers of seats, 3, 5, and 7 provide the best ratio for maximizing space. This is observed as students gravitate to sit every other chair rather than every seat. By designing clusters of 5, 3 chairs [the same three] will be used most, while two chairs will sit more often than not empty. This could minimally be solved by spacing out furniture or tightening them up.

In all 2,192 individuals observed 10% [131 people] had a spontanious iteration caused by crossing paths with a friend or faculty. In most cases one of the observed was seated or seemingly studying while the other(s) walked through the space.

NDSU Student Union Specific: In 69% of observed group

One thing lacking was adequate numbers of power outlets, preferable these seats more in the center of the room.

1% of students observed used lounge furniture for sleeping. Shortest observed "nap" was 19 minutes and the longest was 105 minutes.

71% of students observed who find a seat to study/sit, do not get up after sitting for anything such as: the bathroom, food, water, printing, etc. They stay seated.
Students seek out space to retreat to and work. Highest commodity space is lounge furniture with a near by coffee table or end table.

In all observed cases the demographic seemed to be 50/50 men and women.

When students saught out spaces to sit in neatly all cases the person sitting down or

Odds

Providing clusters of lounge chairs and tables with odd numbers of seats, 3, 5, and 7 provide the best ratio for maximizing space.

3%.

Of Students make a phone call while sitting alone.
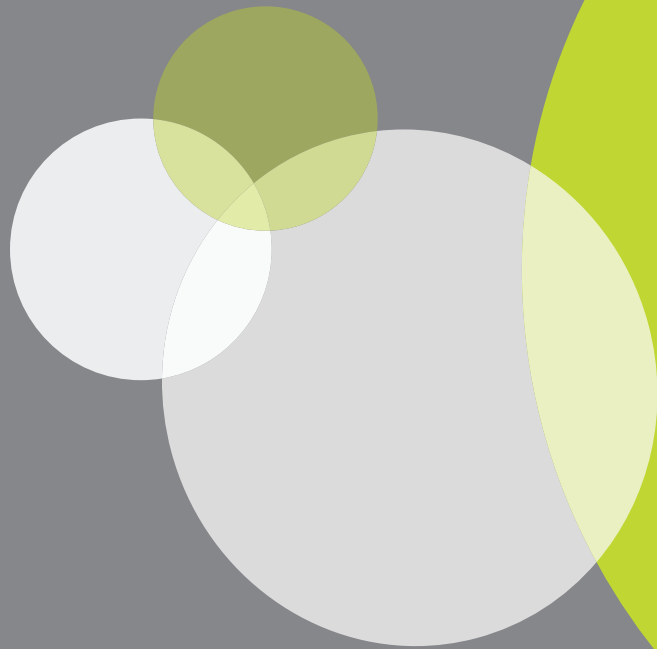
study sessions, people studying in groups tended to not all use their laptops/technology. In most cases members of the group used other tools such as note books, textbooks and phones. Also food was nearly always present in larger groups.

While observing peoples frequency at a coffee vendor, 81% of people would order to go and return to their predicted offices, and classes. 16% of people look for the closest table or chair to sit down at. Then 2% would wander around in visible circles looking for a far place to sit.

The average length of study in the union was between 44 and 48 minutes. The time often between standard 50 minute class periods.

There was a dramatic surge of traffic beginning predictably12 minutes before the hour on Monday, Wed, Friday. As Buses drop students off and faculty and students prepare for classes.

People studying alone are more likely to travel long distances to

seek out quiet relaxed study space than those in groups.

3 different groups [women] around the lunch 11:00am-1:00pm where observed doing waking laps. One group was counted doing 14 laps with 3 minutes between each sighting.

The Coffee Shop and Convenient store were the most active locations for spontanious interactions between aquantences.

Clusters of between 3-7 students form while waiting for a bus. The lobby would fill up for several minutes until the bus would arrive and everyone would leave.

2% of all observed people using the sapce took the time to sit down in the atrium lobby space. Mostly it was used by students preparing for class or eating lunch.

Estimated 95% of students arriving at Berry Hall Downtown arrived by NDSU bus from main campus and only are there for class.

3-7.

Clusters of between 3-7 students form while waiting for a bus. The lobby would fill up for several minutes until the bus would arrive and everyone would leave.

89%.

Of people seeking out the Library as a destination study space, regardless of working in groups or alone, students spent of 2 hours there.

31%.

Of observed people in the library used technology in the form of laptops.

1% used lounge furniture for napping.

76% Of students were observed studying alone rather than in groups.

89% of people seeking out the Library as a destination study space, regardless of working in groups or alone, students spent of 2 hours there.

4% of all observed students left their spot in the library to go get coffee from the Union, many of which returned within 15 minutes to their seat. Meanwhile they left their laptop or set up on the desk surface.

Cross talking, between people seated at separate tables or desks happened more in the library spaces than other campus spaces. Observed to the quiet environment

Spontanious interactions happened just as common within the setting of the library as other campus space.

31% of observed people in the library used technology in the form of laptops. *This does not take into account the use of iPods or phones.

During all observations sessions in the library computer clusters were nearly always occupied. When one computer became available it was re-occupied in an average of 4 minutes.

An observation of tasks revealed that the majority of tasks performed in the library did not consist of laptops of technology. Most common is text books, and note books.

2.

[How Arrangements Maximize Use]

Based section 1 and human observations this section, written out over the next several spreads graphically depicts spaces which will maximize and explain uses of furniture arrangements. This is perhaps the smallest level of informal (intentional) collaboration. While furniture arrangement does not create collaboration it can facilitate how people linger within the boundaries of a space or what task they are most likely to perform within those given spaces. Students and faculty intentionally seek spaces out to perform tasks, this may be computer work, reading, meetings with others, tutoring, meeting fellow faculty, students meeting fellow students and even regional and global collaboration.

On the right there is a list of criteria looked at and studies within each of the spaces; looking at such characteristics as light, sound, tasks, and location. Each of these play a role within creating spaces that facilitate random and strategic gathering.

This section analyses the difference between arrangements for 1 person, as well as for small groups of students and how the dynamic of collaborative spaces change when faculty or academic staff are added into to the group.

To include the furniture arrangement before the space arrangement may appear out of order when designing a building. However, if the desire is to creating the right atmosphere and space for intentional and spontaneous collaboration it begins in the smallest details. Making sure that productive space is left in strategic spaces and each space is designed with specific flexible and extreme versatility, not rigidity and isolation.

"Two things that can be adjusted in almost any space are

orientation and ambiance. Orientation:
how are people positioned to engage objects or each other?
Do you want the group to have shared focus on an object
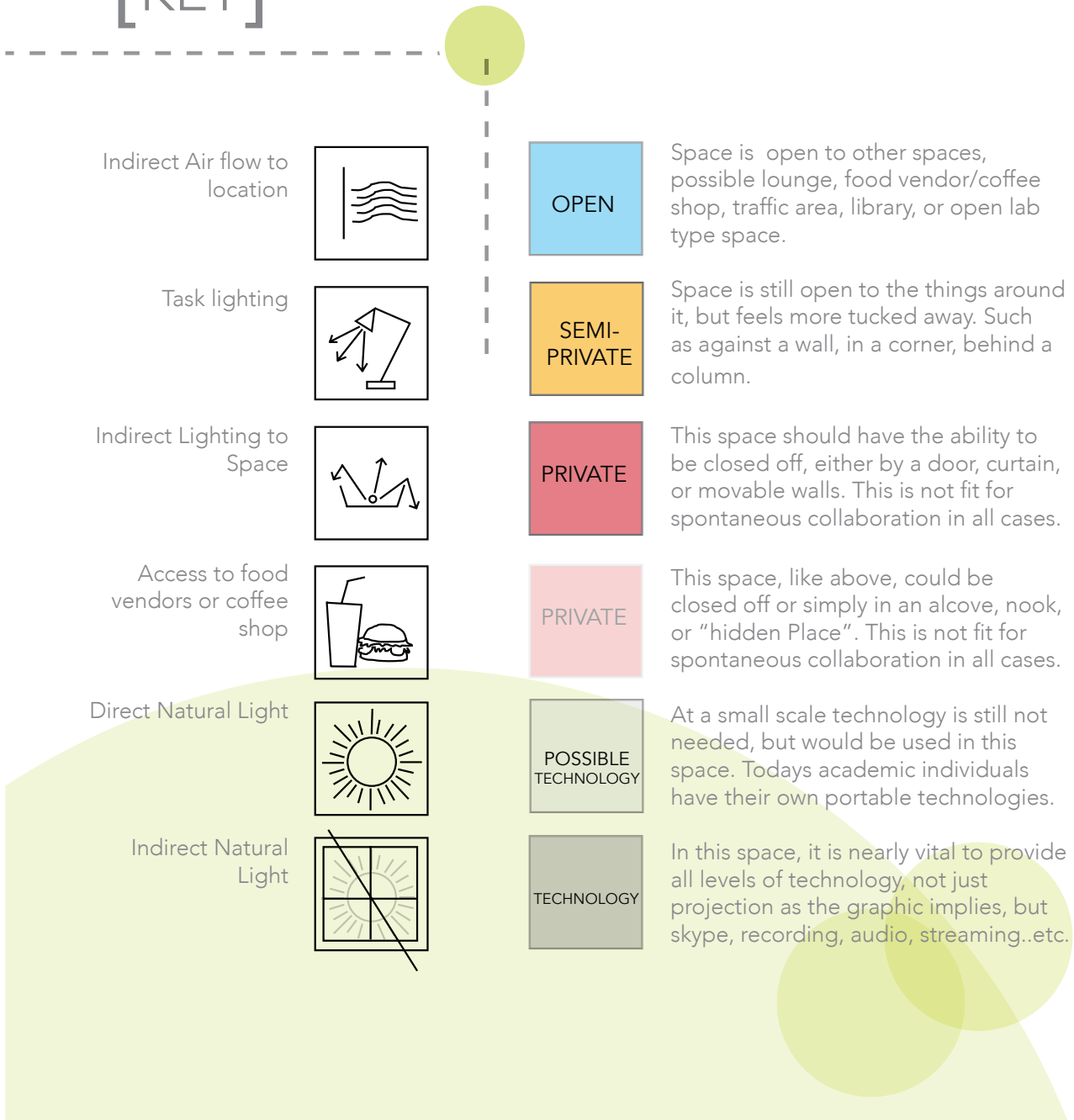or do you want them to be able to engage each other?

Ambiance: what is the vibe or mood you are
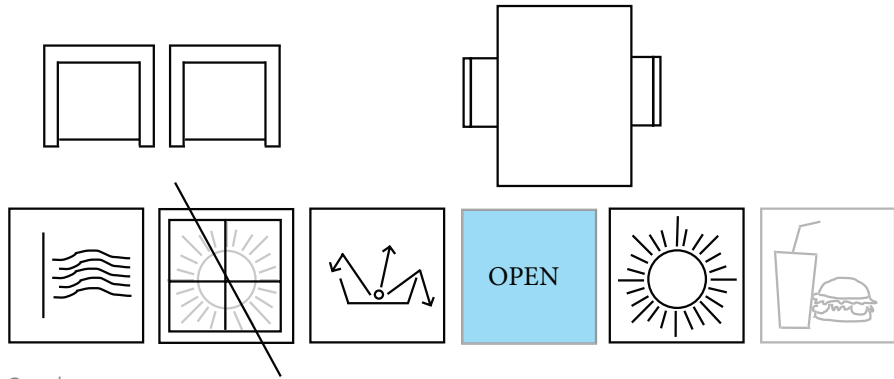trying to create, and what is the duration of the gathering?
Lowering the intensity or limiting the number of lights in a space
can shift a mood from active to reflective. Opening windows
can provide some energizing fresh air for a long meeting and a
little background noise that raises the energy level and increases
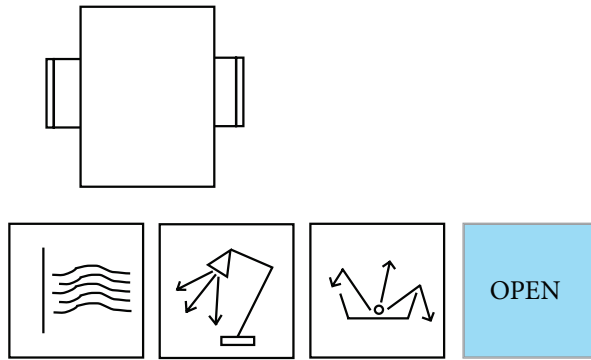awareness of the surroundings" (Wiley25)

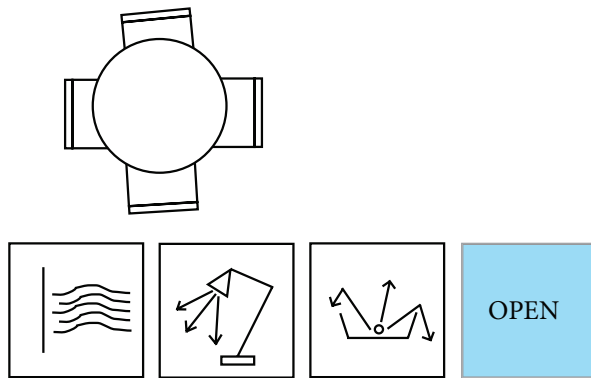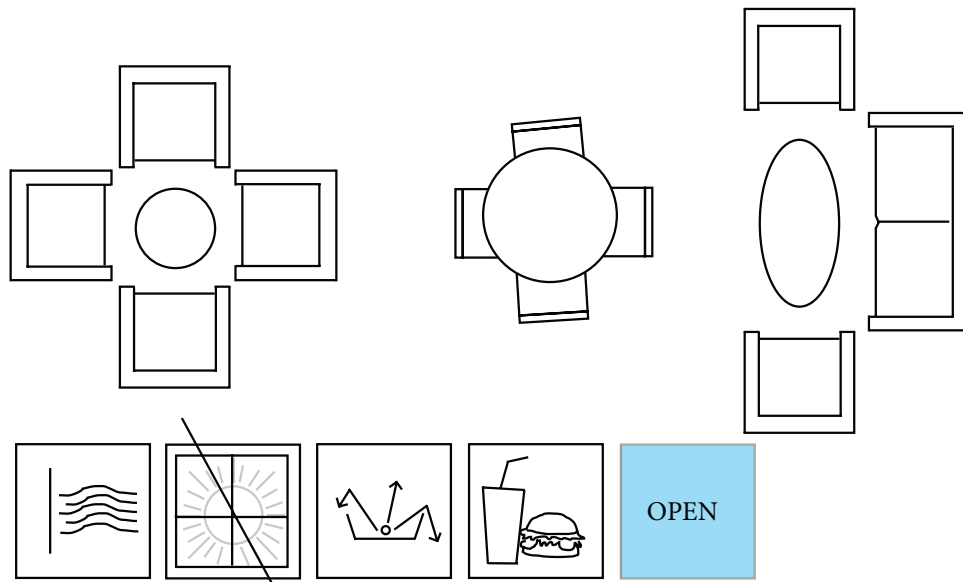|	
Task:	Pedestrian Movement Through Space:
Studying	No Traffic
Reading	Little Traffic
Writing	Average Traffic
Computer work	High Traffic
Socializing (talking).	Connection Point Traffic
Eating	
Movie Watching	Lighting:
Printing	Out Door Spaces
	Indoor Direct Naturally Lit Space
Location:	Indoor Indirect Naturally Lit Space
Small Alcove	Artificially Dim Lit Spaces
Lounge	Artificially Indirect lit Spaces
Hallway	Artificially Bright Lit Spaces
Private Room	Artificially Direct Task Lighting
Classroom Type Space	
Outdoor Space (weather permitting)	Sound
Access to Food/Beverage Service	Decibel Level
Access to Printing	White Noise Decibel Level
Access to Entry/Parking/Arrival	Ambient Music
Access to Faculty Offices	Background Noise
Accesses to Toilets	Pedestrian Movement Noise
	Other Conversations

[KEY]

Icon	Label		Category	Description

Indirect Air flow to location

OPEN — Space is open to other spaces, possible lounge, food vendor/coffee shop, traffic area, library, or open lab type space.

Task lighting

SEMI-PRIVATE — Space is still open to the things around it, but feels more tucked away. Such as against a wall, in a corner, behind a column.

Indirect Lighting to Space

PRIVATE — This space should have the ability to be closed off, either by a door, curtain, or movable walls. This is not fit for spontaneous collaboration in all cases.

Access to food vendors or coffee shop

PRIVATE — This space, like above, could be closed off or simply in an alcove, nook, or "hidden Place". This is not fit for spontaneous collaboration in all cases.

Direct Natural Light

POSSIBLE TECHNOLOGY — At a small scale technology is still not needed, but would be used in this space. Todays academic individuals have their own portable technologies.

Indirect Natural Light

TECHNOLOGY — In this space, it is nearly vital to provide all levels of technology, not just projection as the graphic implies, but skype, recording, audio, streaming..etc.
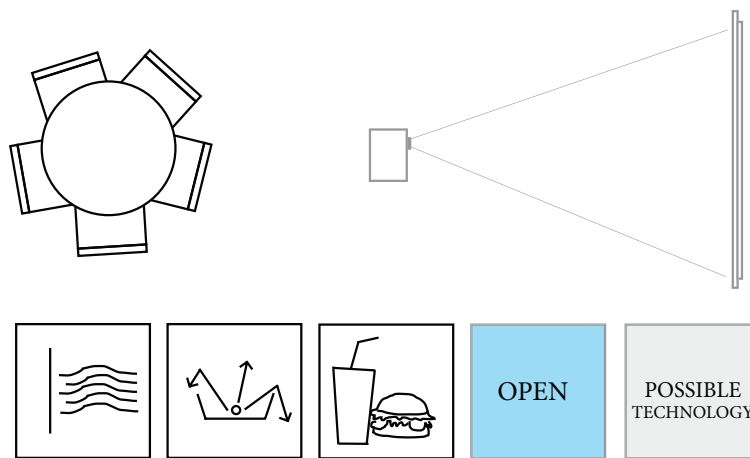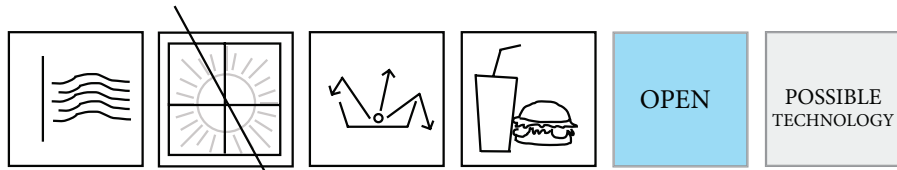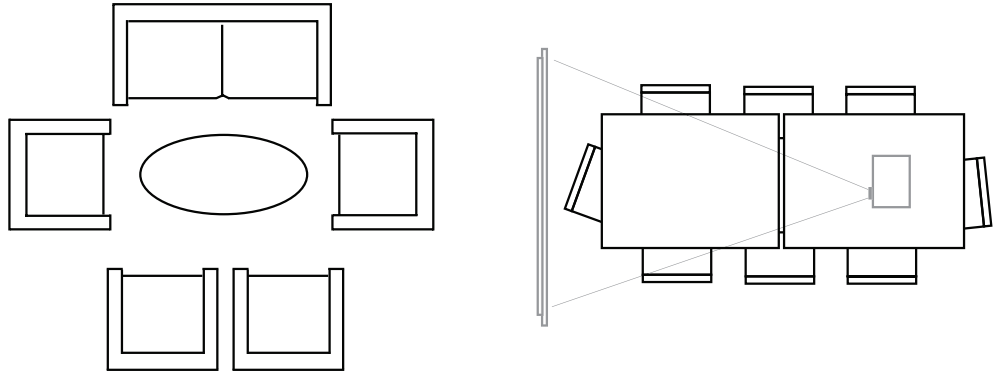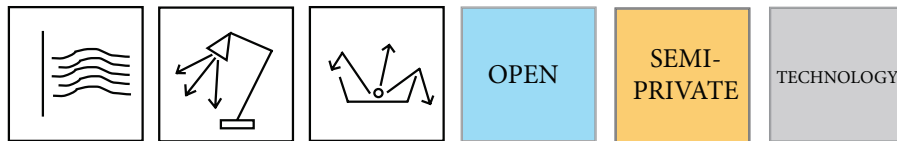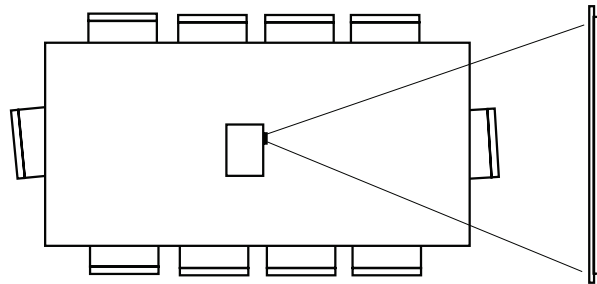
1-to-1 Students

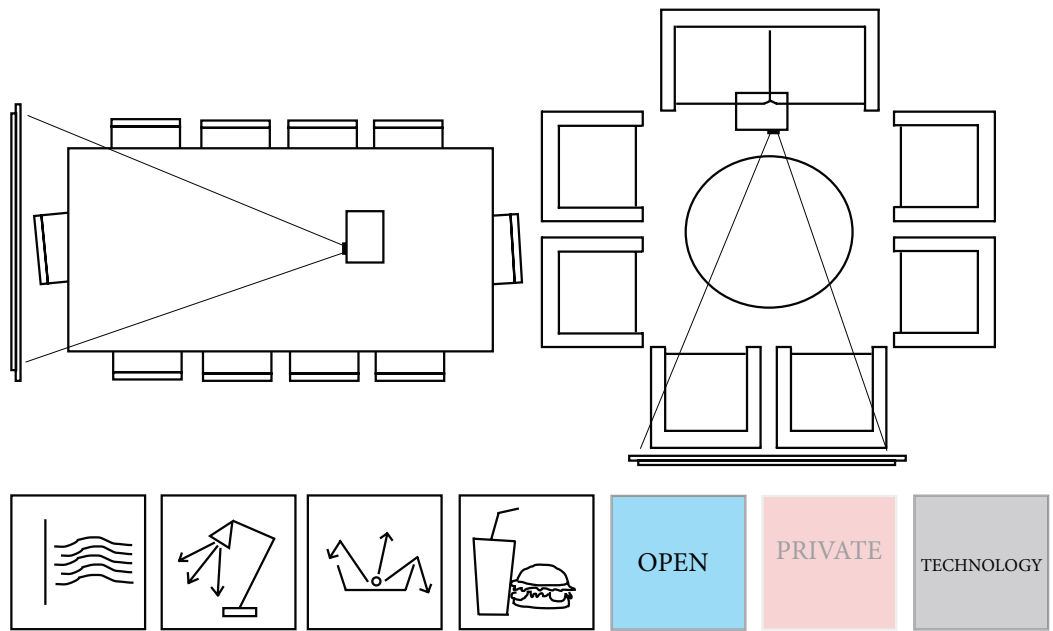1-to-1 Student/Faculty

2-to-1 Students/Faculty

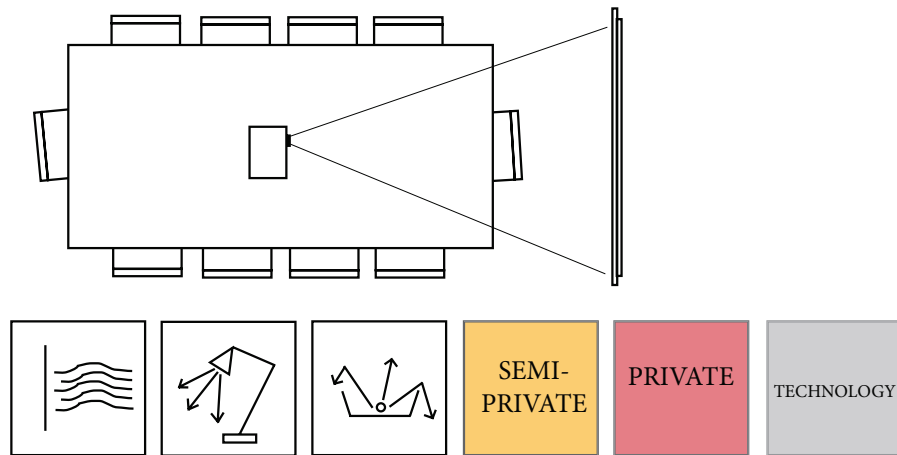Small Groups (≤4 Students)

Small Groups (≤4 Students)+Faculty

Medium Groups (5-7 Students)

| | | | | OPEN | POSSIBLE TECHNOLOGY |

Medium Groups (5-7 Students) + Faculty

| | | | OPEN | SEMI-PRIVATE | TECHNOLOGY |

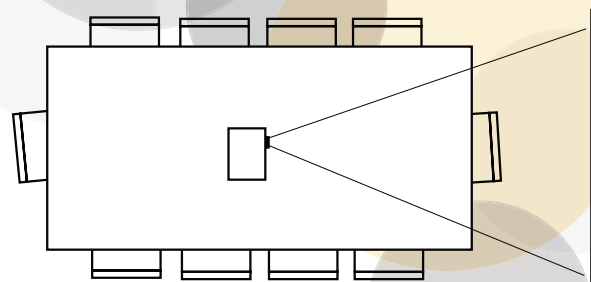Large Groups (≥8 Students)

Large Groups (≥8 Students)+Faculty

Departmental Collaboration

Campus Collaboration

Sate Wide Collaboration

National Collaboration

International Collaboration

3.
[Making Space Relevant]

This section is the combination of the observed and researched elements done in this study, taking the most applicable elements from observations and published resources and applying them to the working plan of the STEM Building. A study revealed that "Inside the classroom, the student wants to d-plug and interact with fellow classmates. They can watch lectures at home and would rather engage in collaborative learning on campus [in the classroom]" (Gensler, Changing Course, 3). This changes our demand for strict collaborative spaces and makes the challenge; designing spaces which are flexible and can work well for individuals and in a moment can turn into a busrt of spontanious collaboration between people.

Providing all the components within a building is a start towards creaking collaboration, but knowing what you want out of each sapce and designing for them is more important. Developing spaces to have everything they need for the current generation to promote collaboration may change within the next five to ten years as technology and norms evolve. The most accurate summery could be clearly said as simply leaving enough room within your project and enough flexibility within the overall design so that it is not bound by time but can be modified as generations and students/staff need it (Wiley,76). Perhaps even more socially unplanned and undesigned is the "metaphorical Cul-de-sac [which is] a spot at which to linger and chat before or after a gathering. Aim to create a comfortable pause zone, where conversations can transpire that might otherwise have been lost…our most successful cul-de-sacs are simply the arms and backs of couches" (Wiley, 98).
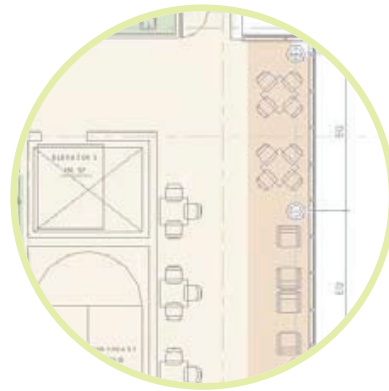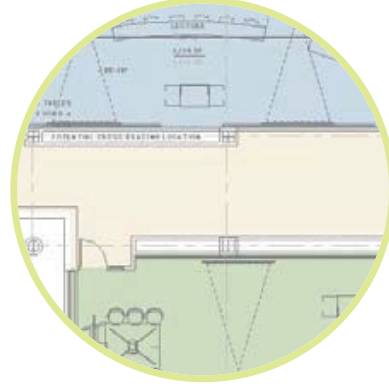
" Space is the
body language
of an organization"
Chris Flink

[GROUND FLOOR]

Technology Hub Centers

Computer clusters for short term work and printing. Key location as students pass through the building from buss to classes. "Being tech-savvy with a cutting edge environment is not necessarily about installing the latest of everything but supporting the technology that people instinctively use." (Make Space 185)

Building Dashboard: digital wall display of events, news, and school related information.
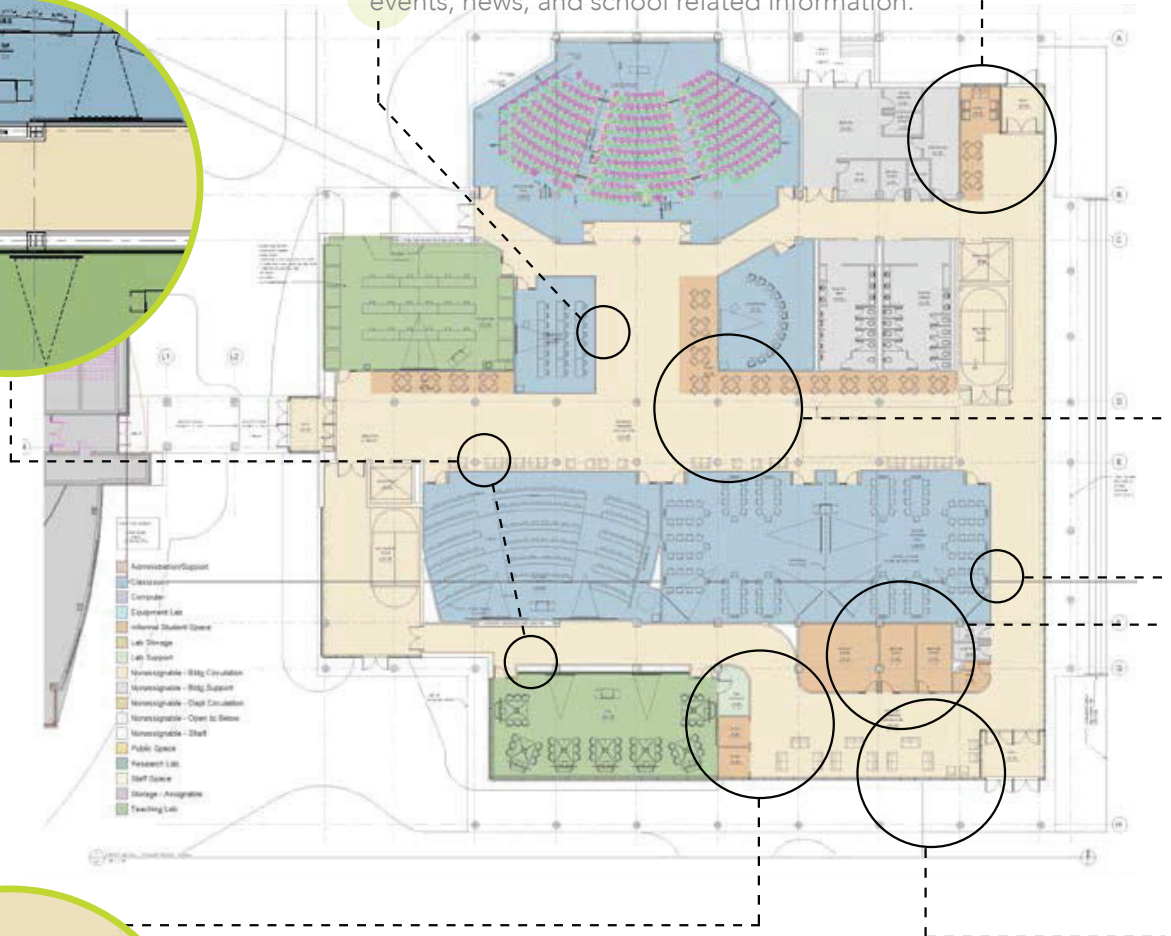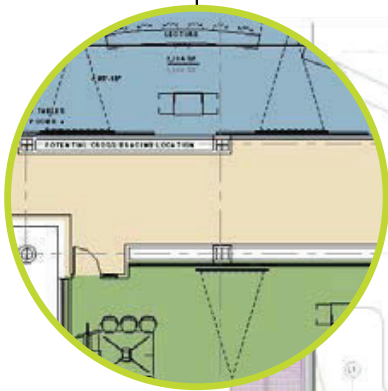

Open Group Study Nooks

Open group study areas which are semi-secluded with even a sight hint of a corner will create a "sense of ownership in an open space" (Wiley, 142). These should be fit with whitboards and possibly a projection screen or TV which can help facilitate collaboration and idea sharing.

Entrance Lounge Nook

Students who sit by the window and in a corner are more likely to stay upwards of 2 hours observation says. "Student Teams with access to a corner sport spent far more time in a space working on their projects than teams whose spaces were on an open wall" (Wiley, 142)
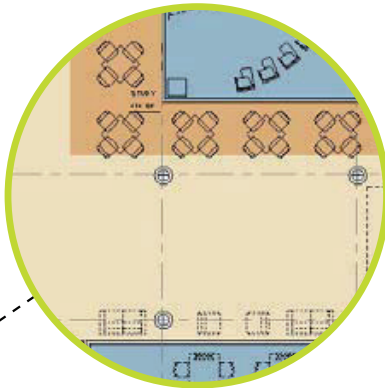
Tables on the Center Corridor

This will become an extension of the Union and people will gather here and eat and study. This should be outfit with numerous outlets and trash receptacles as students and staff will use table sapce for studying, meeting, study groups and eating.

Gallery Display of Student work and current research projects happening in the building.
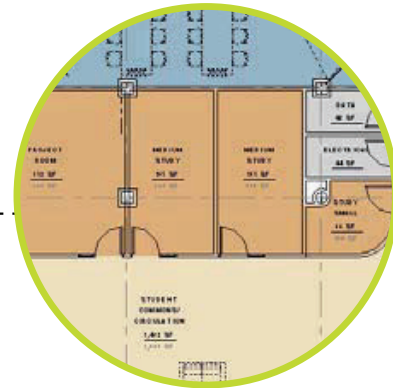
Closed Study Rooms

"Larger, open spaces should always have smaller, closeable spaces available nearby to provide privacy and escape" (Wiley, 133).
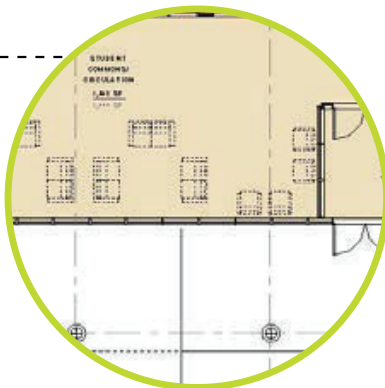
Open Lounge

Flexible seating in a lounge style will be sued for fix use studying and socializing. "Transitions are important. Let guests feel the energy of the space immediately, but allow them to enter it on their terms by offering a visible threshold between themselves and the action- through floor treatments, a glass wall, or a partial partition"(Wiley,101).

[SECOND FLOOR]

High-Top Study Space

A Bar surface allowing individual study or lunch with a pleasant vantage-point. People like to "see and be seen"(MIT,73) giving them a sense of security and peace. "A peanut gallery is a space where spectators can drop in and out of... Provides a strong visual delineation... A bar surface is terrific for this" (Wiley, 86)

Display Space: display space for projects and ideas being taught and discussed in the building.

Sought out Study Destination

Students see out destinations which are considered to be hidden from main places. Students will tend to linger in these spaces longer and often with peers and study.
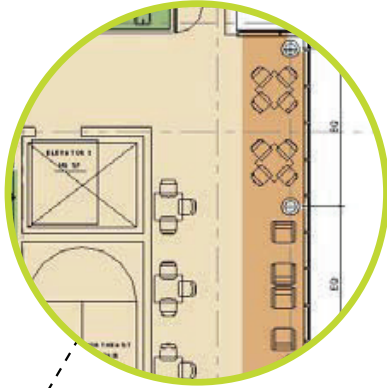
Variation in Furniture

"Deliver experiences, not just technology" (Gensler, Changing Course, 10). Having a mixture of tables by the window and lounge furniture will allow students a choice of destination. Complimented with lounge furniture along the inner wall supported by white boards and televisions will engage the sapce as a after-hour collaborative tutoring learning sapce. "Various physical, social, and psychological dimensions of the learning environment have been shown to play a role in affecting students" (Built Environments, 2)
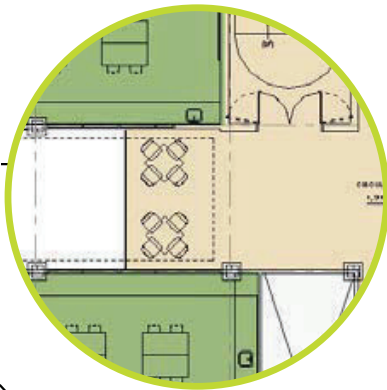

Sought Out Study Nook

Creating destinations and spaces which are unique help students feel comfortable and designed right can be a inspirational and strong learning space. "Dynamic learning environments are the competitive edge" (Gensler, Changing Course, 9)

Technology and White boards: of wall mounted televisions for interactive group study sessions. The wall would be entirely white-boards allowing students to perform equations and solve problems on the white-board like a classroom. "Corporate- style dry erase surfaces are often conventional and costly. Try using alternative materials in various shapes and configurations to inspire your audience" (Wiley,191).
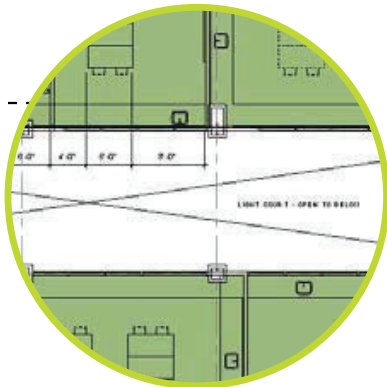
Visibility Between Rooms

Windows through the atrium space will allow things happening in the building to be open to onlookers and walkers, engaging the entire community. "See though walls; both visual transparency and acoustic privacy are important in collaborative spaces. Visual overlapping elevates the energy of being able to see others, while acoustic separation eliminates the distraction of overlapping conversations" (Wiley,129)

[THIRD FLOOR]

3rd Floor Escape

The higher up one goes in the building the less people that transition through the space. This three story building has the advantage of creating quieter spaces on the top level which students will demand for studying and on-on-one tutoring.

Sought Out Quiet Space

"…While students may not be going to the library for books, they still see it as prime space for studding and performing individual work- space that seems to be increasingly high demand and short supply" (Gensler, Changing Course, P.3) Space
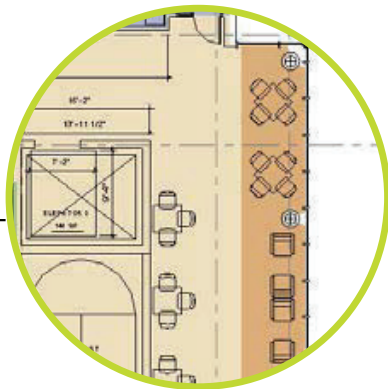
Flexible Use Space

These spaces should be supported with a variety of tools, even being in the open. Such as whiteboards on the wall, window shades for light controll, televisions or projection for group media work and outlets for entire groups of people to plug in. "Collaboration can shift from a hush to a scream in a moment. When teams are flaring, or generating ideas they might be physically standing, moving around, and doing things" (Make Space 144)
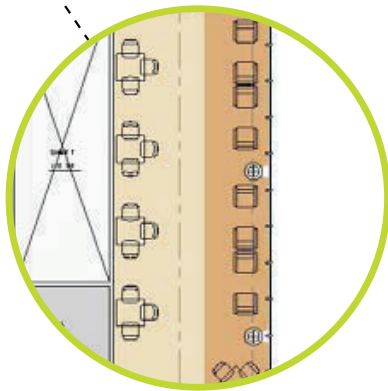
Quiet Destination Study Space

"Encourage relaxation amid a stressful and strained work environment by providing spaces for quiet reflection and temporary escape. Outfit these spaces with appointments and surfaces- pillows, wallpaper, etc- that grant permission not to work" (Wiley, 83)

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IMPLICATIONS of MODIFICATIONS to the INTERNATIONAL ENERGY CONSERVATION CODE (IECC) and ASHRAE STANDARD 90.1 in the UPPER MIDWESTERN UNITED STATES

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Modifications to the standards stated by International Energy Conservation Code (IECC) and ASHRAE Standard 90.1 are ongoing in response to growing performance expectations beyond the construction industry. As these standards are increasingly stringent, clients are often concerned primarily with cost constraints over energy performance. Can the mere substitution of one rigid insulation type for another pay for itself? Research compiled within this study sought to clearly and conveniently compile basic performance and necessary standards as they pertain to building envelope design, as well as a brief comparison of potential insulation types for professional reference in a manner that is easily accessible.

INTRODUCTION TO ENERGY CODES & STANDARDS

The structure of the International Energy Conservation Code (IECC) and ASHRAE Standard 90.1, as well as their respective development and adoption processes, parallels and variances in performance values are crucial to the full understanding of the implications of alterations to such standards. Though the summarized information provided is meant to summarize sections pertaining solely to the building envelope, the given information and research is intended to focus primarily on the Upper Midwestern United States. For this report, the region has been defined as northern Iowa, the upper peninsula of Michigan, Minnesota, North Dakota, South Dakota and Wisconsin.

CODE ADOPTION & DEVELOPMENT, MIDWEST STATE ADOPTION STATUS ANALYSIS

Energy code adoption typically accompanies a wider set of codes within the built environment; typically, they are adopted at state and local jurisdiction levels. Through legislative action or "regulatory agencies authorized by the authoritative legislative body…once adopted through regulation, the code becomes law within the particular…jurisdiction" (US Department of Energy, 2012). Legislative action follows the initial code adoption proposal, which typically includes public commentary, hearings and revisions. The process concludes with the final approval of both the jurisdiction's elected official and the commanding voting body, thereby writing the adopted codes into effective statutory law.

Typically preferred by local professionals, regulatory action encourages public opinion. State and local government-appointed committees of related industry professionals assess code requirements and provisions. The proposal, along with the committee's remarks, undergoes public review, where necessary alterations and further remarks are included for final approval.

Regardless of whether or not a state-wide building code has been adopted, the building energy code is considered to be "adopted and enforced at the jurisdictional level where building construction and permitting take place" (Cort & Butner, 2012). Jurisdictional levels include counties

or local municipalities; as there are countless thousands of such jurisdictions, it is nearly impossible to track the status and adoption of each. Instead, the Building Energy Codes Program of the Department of Energy tracks the code adoption status at the state level.
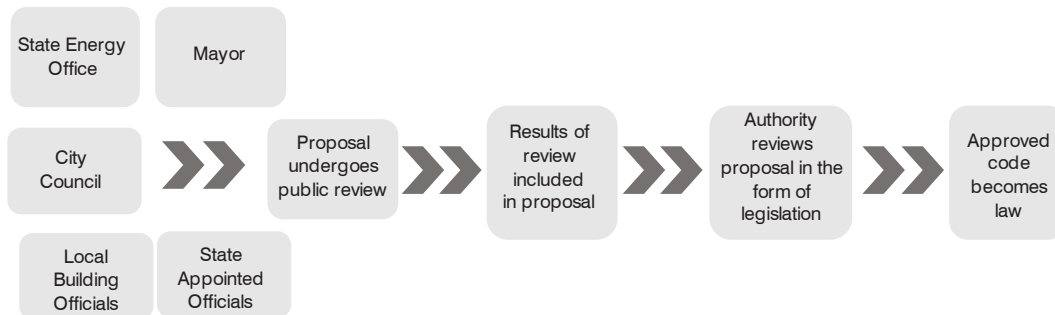
Fig. 1 – The Code Adoption Process

States within the Midwest Energy Efficiency Alliance (MEEA) which were examined in a 2012 study for the Building Energy Codes Program by Pacific Northwest National Laboratory to determine the effective code adoption rate at a local level and possible influential factors. North Dakota, Iowa, Illinois, Kansas and Missouri were examined; of the five states only North Dakota, Kansas and Missouri have not adopted a state-wide energy code, reporting smaller jurisdiction area adoption rates of 68%, 39% and 88%, respectively. Iowa and Illinois report with rates of 81% and 84%, respectively. It was concluded those with a statewide adopted energy code typically presented with significantly higher rates of jurisdiction code adoption than those without a statewide energy code. Although neither North Dakota nor Missouri have statewide adopted energy codes, results indicated adoption rates comparable to the averages of those with statewide codes (Cort & Butner, 2012).

When these codes are adopted statewide, they are either implemented as mandatory statewide code or as statewide code with jurisdictional adoption flexibility. The latter allows for flexibility through exemptions for specific locations or legislative structure in keeping with state tradition. Mandatory

statewide codes by comparison are far more rigid, flexible only in that jurisdictions may be permitted to adopt alternative codes provided they meet or exceed the adopted statewide code (Cort & Butner, 2012).

Much like adoption procedures, the development process of the International Energy Conservation Code (IECC) in addition to all other I-Codes also allows for public discussion and input critical to the encouragement of widespread regulation acceptance, trust and compliance. All I-Codes are developed and written into law in a manner comparable to societal bylaws. This governmental consensus process includes open public forum, decision transparency, representation of interests, due process, appeals and majority consensus are all fundamental means with which the International Code Council (ICC) code development process is directed (International Code Council, n.d.).

MODIFICATIONS to
CODE are SUBMITTED

MODIFICATIONS
ARE POSTED &
CIRCULATED

FINAL EDITION
PUBLISHED

CODE
DEVELOPMENT
HEARING HELD

FINAL ACTION
HEARING HELD

FINAL ACTION
HEARING HELD

RESULTS of
PUBLIC HEARING
are POSTED,
CIRCULATED

REQUEST FOR
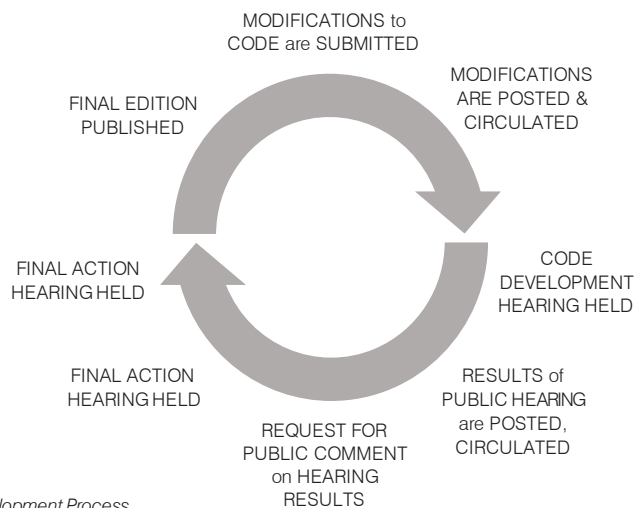PUBLIC COMMENT
on HEARING
RESULTS

Fig. 2 - The I-Code Development Process

The cyclical eight-step development process accommodates early public input; any individual may submit a code change proposal prior to current cycle deadlines. Submitted proposals are posted thirty days prior to the development hearing, where again the public may again partake; at no cost,

any are free to attend, debate and testify. Following floor discussion of proposals, committee action provide the code development committee opportunity to make recommendations on code change proposal settlements. The hearing then concludes with assembly action, where committee actions may be challenged by present ICC members (International Code Council, n.d.).

Results of the public hearing are posted and circulated; the code development committee then seeks public comment or challenge of the dispositions given by committee or assembly action. Any code modifications that received comments are included in the public comment agenda in addition to any code modifications with successful assembly action. Any code changes that without public comment or assembly action are subjected to simple majority block votes; all remaining final decisions on code change proposals are also subjected to votes cast by those whom the ICC refers to as "eligible voters consisting of designated Governmental Member Voting Representatives and Honorary Members". Proposed code changes are included in the following edition of the respective I-Code, where each edition is revised on a three-year rotation with specific code groups due for revision each year (International Code Council, n.d.).

The IECC and all other I-Codes are recognized as "the first and only set of coordinated, consistent, and comprehensive construction, fire and energy codes" (International Code Council, n.d.), indicative of the development cycle's effectiveness.

ASHRAE standards utilize a similar development process, following measures set by the American National Standards Institute (ANSI) for both standards development and due process. ANSI provides the ASHRAE standards development process with the same neutrality, open involvement and information sharing as the governmental consensus process utilized by the ICC for I-Code development. The institute does not create standards, but accredits compliant standard developing organizations. Once accredited, the organization is given "formal recognition that a body or person is competent to carry out specific tasks", as defined by the ISO / IEC Guide 2: 2004.

IECC 2012 & ASHRAE 90.1-2010: A COMPARISON

The 2012 IECC and ASHRAE Standard 90.1 both provide minimum performance standards and principles of construction practice, though they are not necessarily adopted at the same frequency. Construction Technology Laboratories, Inc. reports that ASHRAE Standard 90.1 is more frequently adopted for commercial building code than IECC (VanGeem, 2010).

The International Building Code (IBC) energy conservation requirements depend on the technical provisions of the IECC as these provisions apply to all buildings, whereas the Standard specifically addresses high-rise residential, new commercial construction, additions and renovations to existing buildings, equipment and systems alone; where the energy code exempts new work with historic buildings, the Standard does not. The IECC also addresses low-rise residential construction, where Standard 90.1 does not.

The IECC and Standard 90.1 separate standards for each respective building system type. Specific to the thermal performance of wall assemblies within building envelope, the following are significant variances between the IECC and Standard 90.1 (Makela, E., Makela, E., & Williamson, 2011):

- HEATED / SEMIHEATED SPACES. The IECC sets no delineation between the two spaces. Standard 90.1 sets separate standards for heated and semiheated with less rigorous assembly requirements for the latter. As the IECC considers all spaces to be heated, the building envelope standards are considerably more stringent than those set by Standard 90.1.

- GENERAL and MANDATORY PROVISIONS. The technical requirements or general / mandatory provisions of Standard 90.1 are organized into six sections; for components to be inspected, these provisions are more detailed than what is required in the IECC.

- THERMAL REQUIREMENTS for OPAQUE ASSEMBLIES. Though designated climate zones are the same, U- and R-values are not always the same between Standard 90.1 and the IECC. Within these requirements, one is not typically more stringent than the other. Figure 4 indicates variance in all classes of construction with the exception of insulation entirely above deck and metal building roofs in climate zones six and seven; attic roofs (and other), climate zone six; wood framed (and other) above grade, climate zones six and seven; below grade walls, climate zone five.

OPAQUE THERMAL ENVELOPE REQUIREMENTS						
IECC 2012 / ASHRAE 90.1-2010						
	CLIMATE ZONE 5		CLIMATE ZONE 6		CLIMATE ZONE 7	
INSULATION - INSULATION ENTIRELY ABOVE DECK (U)	0.039	0.032	0.032	0.032	0.028	0.028
ROOF - METAL BUILDING (U)	0.035	0.037	0.031	0.031	0.029	0.029
ROOF - ATTIC & OTHER (U)	0.027	0.021	0.021	0.021	0.021	0.017
MASS WALLS - ABOVE GRADE (U)	0.078	0.09	0.078	0.08	0.061	0.071
MTL BUILDING - ABOVE GRADE (U)	0.052	0.05	0.052	0.05	0.052	0.044
MTL FRAMED WALLS - ABOVE GRADE (U)	0.064	0.055	0.064	0.049	0.064	0.049
WD FRAMED & OTHER - ABOVE GRADE (U)	0.064	0.051	0.051	0.051	0.051	0.051
BELOW GRADE WALL (C)	0.119	0.119	0.119	0.092	0.092	0.063
MASS FLOORS (U)	0.074	0.057	0.064	0.051	0.055	0.042
MTL JOIST FRAMED FLOORS (U)	-	0.038	-	0.032	-	0.032
JOIST/FRAMING - FLOORS (U)	0.033	-	0.033	-	0.033	-
WD FRAMED & OTHER - FLOORS (U)	-	0.033	-	0.027	-	0.027
UNHEATED SLAB ON GRADE FLOOR (F)	0.54	0.52	0.54	0.51	0.400	0.510
HEATED SLAB ON GRADE FLOOR (F)	0.58	0.688	0.58	0.688	0.550	0.671
SWINGING OPAQUE DOOR (U)	0.37	0.5	0.37	0.5	0.37	0.5
ROLL-UP or SLIDING (U)	0.21	-	0.21	-	0.21	-
NONSWINGING OPAQUE DOOR (U)	-	0.5	-	0.5	-	0.5

Fig. 4 – OPAQUE THERMAL REQUIREMENTS, COMPARE IECC TO ASHRAE. SHADED CELLS INDICATE COMMON VALUES; WHITE INDICATES VARIANCE BETWEEN THE IECC AND STANDARD 90.1

- ABOVE / BELOW GRADE WALLS. Required values for above- and below-grade walls are nearly the same between the IECC and Standard 90.1, but guidelines for determining whether a wall is above or below grade are not. The IECC maintains that any wall up to

15% above grade and 85% or more below grade is considered a below-grade wall. Standard 90.1 allows any portion of a wall above- or below-grade to be treated as such, regardless of the wall's above- to below-grade area ratio. Where the wall is above-grade, the assembly is to meet above grade wall requirements, as with below-grade.

- THERMAL REQUIREMENTS for RESIDENTIAL BUILDINGS. While both documents make a differentiation between residential and nonresidential values, both define residential construction differently. In general, Standard 90.1 is more likely that buildings may be determined residential; the IECC, commercial.

COMPARING the NEAR FUTURE & RECENT PAST of IECC & ASHRAE
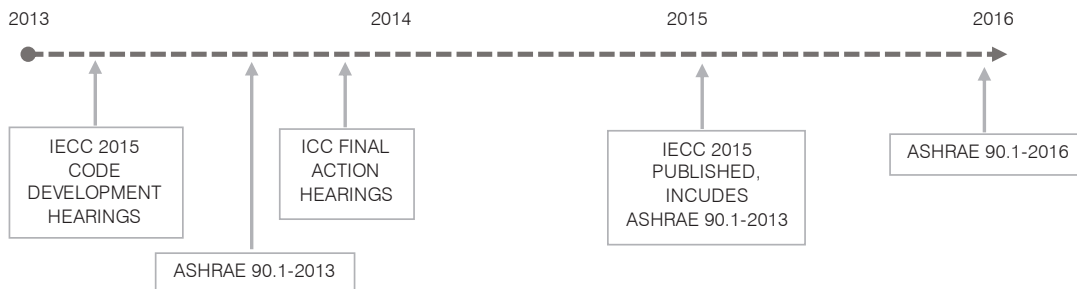
Fig. 3 – Future Regulatory Landscape

ASHRAE 90.1 BUILDING ENVELOPE REQUIREMENTS: 2007 TO 2010

In the development of Standard 90.1-2010, the aim is to achieve 30% energy savings in comparison to Standard 90.1-2004, though this energy use reduction may not be achieved for all building types in all locations.

- Zone five saw more stringent thermal performance values for all classes of construction with the exception of above-grade mass walls, below-grade walls, wood framed / other floors, and nonswinging opaque doors; these values from Standard 90.1-2007 remained the same.

- Zone six received more stringent thermal performance values for all opaque assembly requirements but mass walls above grade and nonswinging opaque doors.

- Zone seven received more stringent values for all except mass walls above grade, swinging and nonswinging opaque doors.

UPCOMING: ASHRAE 90.1-2013

The recently published form of Standard 90.1-2013 includes revisions 40 to 50% more stringent than 90.1-2004, including over 100 modifications to 90.1-2010 (Pearson, 2013). Specifically, Regulated Loads only include the 50% target with "only regulated energy end-use loads as included in the 90.1-2004 baseline" (Liu, 2012), whereas the whole building approach includes a 40% reduction target including all energy end uses.

IECC BUILDING ENVELOPE REQUIREMENTS: 2009 TO 2012

From 2009 to 2012, the IECC underwent substantial changes to restructure the provisions for both residential and commercial buildings. The two types were divided, resulting in entirely separate administrative provisions, general provisions, definitions, climate zones and reference standards (Mapes & Conover, 2012). The "distinction(s) between framing materials, thermal breaks, and curtain walls/storefronts with respect to thermal requirements" (Mapes & Conover, 2012) were removed from the code entirely. Though not thoroughly examined in this report, tables with required values for fenestration components in commercial construction were replaced by a simplified table which categorizes all fenestrations as either fixed, operable or entrance doors (Mapes & Conover, 2012).

Opaque thermal envelope assembly components, defined by ASHRAE as "all areas in the building envelope except fenestration and building service openings such as vents and grilles",

were examined. These values for climate zones of the Upper Midwest were modified in the following manner:

- Zone five requirements received increased performance requirements for insulation above deck, metal building roofs, mass walls above grade, metal buildings above-grade, unheated and heated slabs-on-grade, and swinging and nonswinging opaque doors; all others remained at 2009 values.

- Zone six requirements received increased performance requirements for insulation above deck, metal building roofs, attics, mass walls above-grade, metal buildings above-grade, wood framed / other walls above-grade, mass floors, heated slabs-on-grade, and both swinging and nonswinging opaque doors; all others remained at 2009 values.

- Zone seven requirements received increased performance requirements for insulation above deck, metal building roofs, attics, mass walls above grade, below-grade walls, mass floors, unheated slabs-on-grade; all others remained at 2009 values.

UPCOMING: IECC 2015

Proposals for the IECC are divided into three categories; CA, proposals that increase energy efficiency; CB, proposals that extend flexibility and usability of the code; and E, proposals applicable to the IEBC. As of 18 October 2013, the Summary of Final Action Group B Changes was published; the approved proposals will then move on to face authoritative approval.

Proposals that increase energy efficiency include the simplification of opaque envelope tables to include only one requirement for each assembly type, replacement of all IECC Commercial provisions, instead citing and requiring compliance with ASHRAE/IES Standard 90.1. In addition, the modification of the continuous air barrier requirements was proposed in order to compare all three compliance options (U.S. Department of Energy, 2013).

There are a significant number of proposals intended to aid in the facilitation of compliance. A compliance checklist with ample forms and documentation are included; in addition, details which govern the construction inspection are to be improved. Specific building project types are excluded from commercial compliance and may receive criteria specific to an exempt buildings category.

PROMOTING ENERGY CODE COMPLIANCE

Certain utility companies offer extra services in which businesses may take advantage of renewable energy, energy conservation, energy management and billing studies for new construction. Following the completion of simulated energy audit predictions, design recommendations are offered order to reduce energy consumption and increase project energy-cost savings.

Autodesk Simulation CFD was utilized as a potential means of performing these same simulations in completed research. Designed to determine computational fluid dynamics for both thermal and fluid flow simulation, CFD performs several analyses: steady-state heat transfer, transient heat transfer, steady fluid flow, unsteady fluid flow, flow through porous media, open channel flow, and mass transfer analysis.

RESEARCH METHODOLOGY

Fourteen typical wall assemblies were presented and analyzed with the substitution of varying rigid insulation types at 2- and 3-inch thicknesses. Wall assembly types include:

- CMU with face brick (CB-1)
- CMU with EIFS (CE-1)
- CMU with stone veneer (CST-1)

- CMU with precast concrete panels (CP)
- CMU with precast concrete panel and furring (CP-1)
- CMU and CMU (CC-2)
- CMU with metal panel (CM-1)
- Precast concrete panel (PCS)
- Metal stud with EIFS (SE-1)
- Metal Stud with metal panel (SM-1)
- Metal stud with face brick (SB-1)
- Metal stud with precast panel (SP-1)
- Wood stud with face brick (WB-1)
- Wood stud with wood siding (WS-1)

and examined insulation types include expanded polystyrene (EPS), extruded polystyrene (XPS), polyisocyanurate, spray-applied polyurethane, and mineral wool. Further investigation was completed for EPS, XPS and polyisocyanurate rigid insulation board; each selected type of EPS, XPS and polyisocyanurate at 2- and 3-inch thicknesses was substituted into the assembly U-value of each wall type. This allowed for the clear determination of the best and worst thermal performance among all of the provided wall assemblies.

It appeared that Polyisocyanurate Type I, Class 1 and Expanded Polystyrene Type XI were consistently the best and worst performing insulation, respectively. Though a discrepancy later arose regarding the correct determination of metal stud, wood stud and metal furring R-values, this method of determining high and low performing insulation still remains valuable.

DEVELOPING A SIMULATION TESTING MATRIX

Testing methods for the thermal performance of building materials are set forth by ASTM Standard C1363-11; it is used for "large homogenous or non-homogenous specimens…

WALL TYPE	THICKNESS	C-ZONE	INT. TEMP	EXT. TEMP	
				deg F	deg C
CB-1	2"	5	67	20	-7
				75	24
		6		15	-9
				70	21
		7		11	-12
				68	20
	3"	5		20	-7
				75	24
		6		15	-9
				70	21
		7		11	-12
				68	20

	POLYSTYRENE TYPE XI				
TEST NO.	TEMP. MEASUREMENT POINTS (deg F)			TOTAL HEAT TRANSFER (WATTS)	THERMAL RESISTANCE
	INTERIOR	MIDPOINT	EXTERIOR		
1_PS					
2_PS					
3_PS					
4_PS					
5_PS					
6_PS					
7_PS					
8_PS					
9_PS					
10_PS					
11_PS					
12_PS					

Fig. 4 – Example Clip of Modified Testing Matrix for Upper Midwest Climate zones

[and] applies to building structures or composite assemblies of building materials for which it is possible to build a representative specimen that fits the testing apparatus". Note that this method replaces Testing Methods C236 and C976.

In order to tailor thermal performance results to the environments in which a hypothetical project would be built, one centrally-located city was selected from within each climate zone in the defined Upper Midwest states. The average high and low temperatures in the warmest and coldest months of the year at each climate zone were consolidated; an overall average high temperature and overall average low temperature are set as exterior temperatures.

Interior temperatures remain at 67 degrees Fahrenheit (19 deg C).

DIGITAL SIMULATION & TESTING

Each of the 14 wall assemblies were modeled as two-foot square components in Revit Architecture 2014. At this step, materials were not yet applied as only generic geometries were necessary.

Typically, materials such as face brick masonry or concrete masonry unit (CMU) structural walls were modeled without mortar joints, simply as a solid extruded box at the proper nominal thickness, whereas steel studs and metal furring were modeled true to their form, spaced at 24 inches and 16 inches respectively. Each wall assembly was modeled twice; separate geometries were required for each assembly with the original 2-inch rigid insulation in place, and a substitution 3-inch of the same insulation type.

The digital models were then exported as Spatial ACIS files (.SAT), a solid modeling format in which a text file stores three-dimensional geometric information in order to exchange data between multiple software programs. Once the .SAT model has been imported into the design study, materials may be applied; this occurs during the Setup phase. In this case, new "Solid Materials" were added to the library for each type of rigid insulation examined. Values and characteristics required for these newly created materials are specific heat, thermal resistivity, and density. Initial conditions are applied to the face of the air volume in contact with the exterior finish face of the assembly; here the specific temperature may be set. The process is repeated to set initial conditions for the interior air volume.

A digital Hot Box apparatus, the manner in which Simulation CFD may apply varied boundary and initial conditions renders it comparable to that of a dual-chamber Hot Box apparatus described in ASTM C1363.

Though Simulation CFD is a highly powerful program and bears the well-known interface typical to other Autodesk software, other alternative software may likely produce more easily obtainable data for thermal heat transfer. The software is entirely capable of producing the

needed output values, but simple and timely simulations are better suited for Revit Architecture's thermal analysis tools.

CONCLUSION

PROJECTION OF RESEARCH FINDINGS, POTENTIAL IMPACTS

Though the intent of the conducted research was to ultimately apply the requirements set by the IECC and Standard 90.1 to assemblies used in practice, the cyclical nature of energy code and standard development, while intentionally set in sequence to allow manufacturers and related professionals to adapt to developments, demands the attention and understanding of all involved industry parties.

The performance curve set in place within the past decade are becoming exponentially more rigid, lean and stringent. Clear explanation and accessibility of applicable energy standards are absolutely necessary. The greatest downside to the conducted and compiled research was the time investment required to become adequately familiarized with the building envelope requirements in order to begin exploring insulation specifications, preparing and dissecting simulations.

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