CONTEMPORARY STRATEGIES FOR SUSTAINABLE DESIGN

A Dissertation

by

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ABSTRACT

This exploratory research examined the degree of adoption and impact of the concepts of Building Information Model (BIM), Integrated Project Delivery (IPD), Integrated Design Process (IDP) and Building Energy Simulation (BES) on the design processes of advanced architectural firms when executing sustainable design. Six offices identified by the press for a strong commitment to sustainable design and influence in the design of high performance buildings were selected as cases. In semi-standardized interviews, these firms presented their perceptions of the influence of BIM, BES, and IPD/IDP. The results show that a generalization of sustainable design processes is possible. A design process for sustainability (DEPROSU) model was created by collecting best practices from data gathered from the interviews and the critical literature review. Secondary contributions show that BIM, IDP/IPD and BES have a synergistic effect in sustainable design methods, and that the human resource profile from these firms has evolved towards multi-skilled professionals knowledgeable in BES, BIM, parametric design, sustainability and construction processes. This research provides evidence of commonalities found in the design processes of the selected firms. These commonalities, which have been represented in the DEPROSU model, can potentially be validated as protocols or standards for sustainable design, providing architectural design practices with concrete patterns for improvement and or validation of their design methods.

DEDICATION

To my lovely wife Catarina Thomson and my daughter Mila Farias Thomson

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1. INTRODUCTION

1.1 Overview of the Dissertation

Three emerging concepts, Building Information Modeling (BIM), Building Energy Simulation (BES), and Integrated Project Delivery (IPD) and Integrated Design Process (IDP), provide a new opportunity to address the challenges of achieving sustainable communities and ameliorating the impacts of global warming. Architecture firms are demanded to produce buildings that are more energy efficient and conservative of resources. Simultaneously, the tools and technologies in support of design processes are evolving at a fast pace. Contemporary designers may hesitate to adopt and combine several new tools or technologies that are yet uncertain in effectiveness (de Wit & Augenbroe, 2002; Ali, 2010).

This exploratory research examined the degree of adoption and impact of the three concepts of BIM, IPD, and BES on the design processes of advanced architectural firms when executing sustainable design. Three offices in the U.S.A., two offices in the U.K. and one in Malaysia were selected due to their commitment to sustainable design and influence in the design of high performance buildings as identified by the press. In semi-standardized interviews these firms presented their perceptions of the influence of BIM, BES, and IPD in the overall design process for high performance buildings.

The analysis from the data supports several conclusions across a wide range of topics. The results show that a generalization of sustainable design processes is possible. A design process for sustainability (DEPROSU) model was created collecting best practices from data gathered from the interviews and the critical literature review. Secondary contributions show that BIM, IDP/IPD and BES have a synergistic effect in sustainable design methods, and that the human resource profile from these firms has evolved towards multi-skilled professionals knowledgeable in BES, BIM, parametric design, sustainability and construction processes.

This research was limited to studying the perceptions of BIM, energy simulation and IPD in sustainable design methods within a small number of leading architectural design firms. It did not assess the effectiveness of the methods used by the firm or the quality of the resulting designs. The research also did not assess the quality, effectiveness or accuracy of the digital tools used by the firms. Issues such as the construction process, final cost, and embodied energy of building components or materials were considered out of scope. The selection of participants was based on a convenience sample that could reduce confidence or reliability of the conclusions. The research with a similar method could be repeated using interviews of other designers to increase reliability of the conclusions.

1.2 Description of Sections

This dissertation is organized in the following sections:

- Introduction: an overview of the research and its motives, a brief overview of the global warming effects and how better buildings could contribute to palliate that effect. This section also contains a definition of technical terminology to help the reader understand the content and an explanation of the research objectives.
- Literature Review: a review of the current literature about sustainable design methods, Green Building Rating Systems (GBRS), BIM, IDP and IPD, BES and BIM, and about the combination of IPD, BIM and BES in a design process.
- Methods: detailed description of the methods used to conduct my research, and the theoretical framework to justify the execution of those methods.
- Selection of the Contributing Firms: a special section dedicated to justify participants' inclusion, showing a selection of their designs.
- Data Analysis: the analysis of the raw data to guide my conclusions, and finally
- Conclusions: a discussion of the contributions, limitations of the research, and suggestions for future work.
- In the Appendix 1, the reader will find the raw data and material produced by the research. Appendix 2 contains all the documents submitted for approval by the Institutional Review Board. Appendix 3 explains the choice of firms for inclusion in the research, based upon their commitment to sustainable design and the acclaim for their designs. Appendix 4 contains the original documents used to create the eco-balance formulas presented in the conclusion section.

1.3 Research Objectives

The objectives of this research were to:

1. Compare the workflow of acclaimed sustainable architectural design firms;
2. Identify differences (if any) in strategies of design, both theoretically and in current practice, with respect to BIM, IPD/IDP and BES;
3. Explore how sustainable design methods can potentially improve from use of BIM, IPD/IDP and BES;
4. Identify perceptions and attitudes of different stakeholders towards the design of high performance buildings;
5. Identify trends or future changes in sustainable design methods using BIM, IPD/IDP and BES, according to the experiences of the selected firms.

The idea behind this research is to produce a theoretical framework for using new technologies to aid sustainable designers by reviewing the practices of highly reputed architecture firms. There are many challenges to use of these tools, such as (a) interoperability, (b) the process and workflow in an IPD/IDP process and the available tools (varying depending on the firm's budget) and (c) the staff's training in using them.

This research is intended to contribute an understanding of the potentials of using advanced technologies and strategies for different case scenarios, and helping designers to make decisions for their own design process. By doing so, I attempt to answer the following research questions:

1. Is it possible to standardize a design method that pursues sustainability?
2. Can BIM, BES and IPD/IDP create a synergetic effect in sustainable design methods?
3. How can designers prepare to face the challenges of sustainable design?

In the next paragraphs, I discuss the impact buildings have on the environment and the importance to address sustainability.

1.4 Impact of Buildings

Architecture and building are identified as being of major importance in reducing the intensity of global warming and ameliorating the impacts on humanity, according to the IPCC Summary Reports (Pachauri & Reisinger, 2007) and Stabilization Wedges (Pacala & Socolow, 2004). Existing research shows that the most important decisions occur at the earlier stages of building design, and have the greatest impact on the Life Cycle Cost of the building (Jernigan 2007).

Responsible architectural design that reduces energy consumption of buildings is a major concern in this era of global warming and environmental issues. The reduction of both carbon dioxide emissions and the consumption of fossil fuels are paramount in trying to palliate global warming. Institutions such as the U.S. Department of Energy (DOE) (www.doe.gov), Intergovernmental Panel on Climate Change (IPCC) (www.ipcc.ch), U.S. Green Building Council (USGBC) (www.usgbc.org/leed), EnergyStar (www.energystar.gov), Environmental Protection Agency (EPA) (www.epa.gov) and others, are encouraging design that reduces energy consumption and carbon footprint. The importance of energy analysis up-front in the building design process is crucial to tame the impact of buildings on climate change and reduce life cycle costs of facilities. The illustration of the relation of the built environment with energy consumption is shown in Figure 1, adapted from http://architecture2030.org.

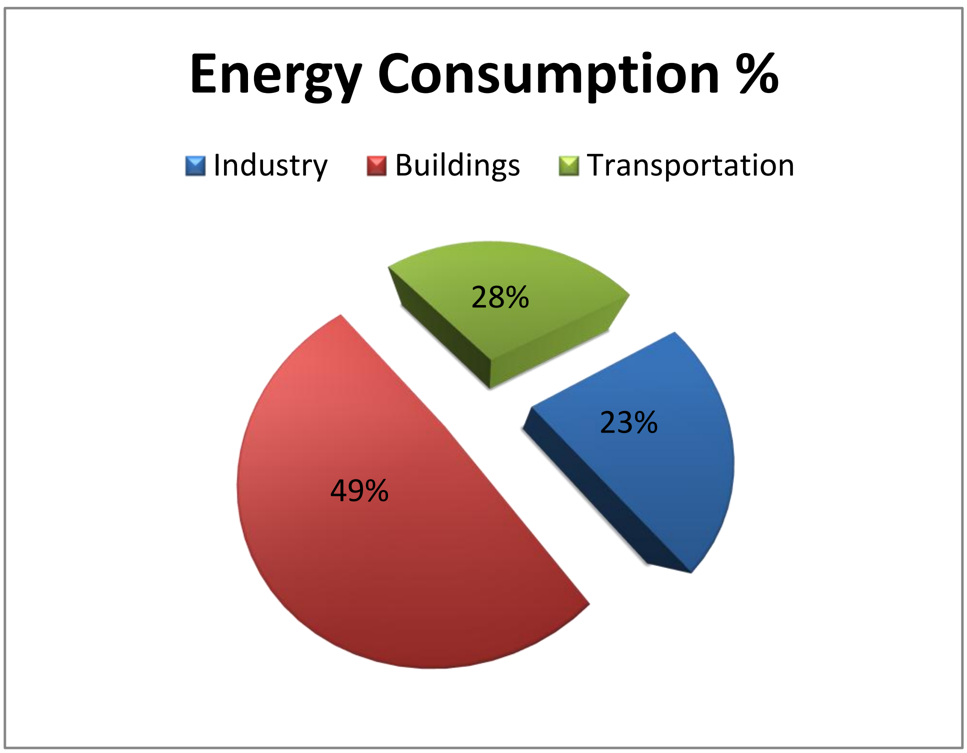

Figure 1: 2008 U.S. Energy Consumption by Sector (adapted from U.S. Energy Information Administration (2009)).

Buildings have a large impact on the environment through consumption of natural resources. Building operation accounts for 40% of U.S. energy use (DOE, 2005);

building operations also contribute over 38% of the U.S.'s carbon dioxide emissions and over 12% of its water consumption. Moreover, waste from demolition, construction and remodeling contributes to over 35% of all non-industrial waste (EPA, 1998). Construction and remodeling of buildings accounted for 3 billion tons or 40% of raw material used globally in a study made prior to 1995 (Lenssen & Roodman, 1995).

The 2030 Challenge is a commitment by a growing number of participants in the building industry to achieve carbon neutral construction by the year 2030. Basically, the 2030 Challenge asks the global architecture and building community to commit to the following goals, as described in their website http://architecture2030.org:

- All new buildings, developments and major renovations shall be designed to meet a fossil fuel, Green House Gases (GHG)-emitting, energy consumption performance standard of 60% below the regional (or country) average for that building type.
- At a minimum, an equal amount of existing building area shall be renovated annually to meet a fossil fuel, GHG-emitting, energy consumption performance standard of 60% of the regional (or country) average for that building type.
- The fossil fuel reduction standard for all new buildings and major renovations shall be increased to:
    - 70% in 2015
    - 80% in 2020

- 90% in 2025
- Carbon-neutral in 2030 (using no energy derived from fossil fuels or emitting green house gases to operate).

They suggest that these goals could be accomplished by implementing innovative sustainable design strategies, generating on-site renewable power or purchasing renewable energy. The 2030 Challenge has been adopted as a goal by such influential organizations as the American Institute of Architects. Many advanced architectural firms are currently designing with those goals in mind, such as HKS, Lake|Flato and HOK, which are included in this convenience sample.

One researcher suggests that a "good design is determined at the interface or cusp between human needs and nature's needs, and is determined by the translatability between these two worlds", and for that "translatability", urban and building designers need to rely on specialists of each field (Fisk, 1995). To achieve an ecological and sustainable future, the design process needs to be multidisciplinary (Yeang, 2008). The design process for high performance buildings is currently undergoing a radical change to incorporate the Integrated Project Delivery (described in a section later), Building Information Modeling, and Building Energy Simulation. In contrast to conventional project delivery processes that defer work by consultants until the late stages of detailing, more effort is devoted to the conceptual and schematic stage when using the IPD process and contracts. Arguably the adoption of BIM within design firms facilitates the use of IPD. Some scholars believe that BIM will play a critical role as a shared model not only by supporting this frontloaded process for integrated design but also by facilitating communication in the whole life cycle of the building (Eastman, 2008; Clayton et al., 2009). It is also well known that the success of BIM implementation depends upon the workflow and process. Different designers have different approaches to sustainable issues, and probably different workflows according to the design scale. Design technologies such as BIM, energy simulation, daylighting simulation, 4D simulation, structural simulation and Computational Fluid Dynamics (CFD) may more likely be incorporated in the processes used by advanced sustainable architectural designers. Some authorities suggest a combination of specific tools, but these may be biased by a commitment to the specific software developer (Levring & Nielsen, 2011; Krygiel & Nies, 2008; Ali, 2010). Today's 3D CAD (3 Dimensional Computer Aided Design) and BIM provide a new opportunity for designers (Eastman, 2008). BIM vendors are continuously incorporating many standalone energy simulation tools, such as DOE-2.1e, eQUEST, Energy-10, EnergyPlus, IES-VE and BLAST, into their own products (Sabol, 2008). Additionally, a data format gb (Green Building XML) has been developed to provide a standard data exchange mechanism between software applications, such as BIM and energy modeling software (Sabol, 2008). Design firms are under pressure to keep updated on technology advancements, but are trapped between clients and software companies (FMI, 2011). This means that clients are often dazzled by the capabilities of software shown by developers, and push firms to use those technologies even when the AEC industry is not yet prepared for them (2011).

In the next section, I present the importance of addressing global warming effects through architectural design.

1.5 Current Situation for Sustainable Architectural Design Methods

Techniques of sustainable design combined with the processes and application of new tools to aid design are not well documented. The urgency of being sustainable obliges us to find quickly sound solutions to the problem. The literature review section shows a few examples of processes and strategies implemented in larger firms or very specialized consultants (Levring & Nielsen, 2011, Krygiel & Nies, 2008). The cost for acquiring hardware and software, as well as strategies for training staff, are rarely discussed or publicly documented. Less experienced designers might wish to adopt a widely accepted method that describes in detail the strategies behind each step and costs of implementation and training, including hardware and software acquisition. The goal is to understand the potentials of using advanced technologies and strategies in different cases or scenarios, and help other designers who wish to adopt those concepts in their own design workflow.

1.6 Definitions

Several terms relevant to this research lack concise, widely accepted definitions or may be unfamiliar to the reader. For the purpose of this research, some of these terms are defined:

Building Information Modeling (BIM): emerging technology that consists of a digital representation of physical and functional characteristics of a facility and serves as a shared source for information about a building or facility (NIBS, 2008).

Computer Aided Design (CAD): the use of computer systems to assist in the creation, modification, analysis, or optimization of a design (Sarcar, Lalit and Mallikarjuna, 2008).

Clash detection: by using a virtual 3D building model, systems from all disciplines can be brought together and checked both systematically and visually, so conflicts are identified before construction. Coordination among designers and contractors is enhanced and errors and omissions are significantly reduced, accelerating the construction process, reducing costs and minimizing the likelihood of legal disputes (Eastman, 2008, pp.19).

Design methods: procedures, techniques, aids or 'tools' for designing (Cross, 2008).

Design phases: according to the AIA (AIA, 2007) best practices, the design process is divided into phases of schematic design, design development, construction documents, bid or negotiation and construction administration. In Schematic Design (SD), the architect consults with the owner to determine project goals and requirements. Often this determines the program for the project. Deliverables for SD often produces a site plan, floor plan(s), sections, an elevation, and other illustrative materials; computer images, renderings, or models. Typically the drawings include overall dimensions, and a construction cost is estimated. In the Design Development (DD) phase, designers use the initial design documents from the schematic phase and take them one step further. This phase lays out mechanical, electrical, plumbing, structural, and architectural details. Deliverables for DD often include floor plans, sections, and elevations with full dimensions. These drawings typically include door and window details and outline material specifications. In the Construction Document (CD) phase, once the owner and architect are satisfied with the documents produced during DD, the architect produces drawings with greater detail. The deliverables for CD are a set of drawings that include all pertinent information required for the contractor to price and build the project. In Bid or Negotiation phase, the first step is the preparation of the bid documents to go out to potential contractors for pricing. The deliverable is a construction contract. Once this document is signed, project construction can begin. In the Construction Administration (CA) phase, services are rendered at the owner's discretion and are outlined in the owner-architect construction agreement. Different owner-architect-contractor agreements require different levels of services on the architect's part. CA services begin with the initial contract for construction and terminate when the final certificate of payment is issued. The architect's core responsibility during this phase is to help the contractor to build the project as specified in the CDs as approved by the owner. The deliverable is a successfully built and contracted project.

Eco-balance: according to Pliny Fisk - founder of the Center for Maximum Performance Building Systems (CMPBS) and author of the first green building program in the world- eco-balance is a state or condition of a building where its needs (energy, oxygen, food, water), are completely satisfied by its immediate surroundings (Fisk, 2009). More specifically, for instance, the amount of oxygen required for each occupant to do their daily work should be produced exclusively by the vegetation existent on its site, and so on. The understanding of the exact building needs helps to set up ambitious goals based on a perception that the building and its environment are a holistic system.

Ecodesign: can be defined as “designing the biointegration of artificial-systems-to-natural-systems” (Yeang, 2008, pp.22).

Green building: according to Charles Kibert, is a “healthy facility designed and built in a resource efficient manner, using ecologically based principles” (Kibert, 2008, pp.6). The ASHRAE GreenGuide (Grumman, 2003) defines green design as a design that respects nature with its own order of things, and a design that minimizes the negative human impact on the natural environment.

High performance building: an approach to building that uses best-available technologies to significantly improve the performance of buildings from several standpoints. According to the National Renewable Energy Laboratory (NREL, 2005),

> *Uses whole-building design approach to achieve energy, economic and environmental performance that is substantially better than standard practice. Whole-building design creates energy efficient buildings that save money for their owners, besides produces buildings that are healthy places to live and work. (NREL, 2005).*

Integrated Design Process (IDP): a collaborative process that focuses on the design, construction, operation and occupancy of a building over its complete life-cycle, with a clear definition of environmental and economic goals and objectives. The IDP requires a multidisciplinary design team that includes or acquires the skills required to address all design issues flowing from the objectives (Zimmerman, 2002).

Integrated Project Delivery (IPD): a collaborative alliance of people, systems, business structures, and practices that employs a process that harnesses the talents and insights of all participants to optimize project results. As a result, IPD provides a better value to the owner, reduces waste and maximizes efficiency through all design phases, fabrication, and construction (AIA, 2007). The main difference with IDP is that IPD includes a contractual agreement of sharing risks and benefits from the project in equal parts, and an agreement of no liability between stakeholders.

Interoperability: the capacity of BIM tools from multiple developers to exchange building model data and operate on that data, a capability that is critical for team collaboration (Eastman, 2008, pp.468).

Workflow: the sequence of steps in a business process. According to Belhajjame et al.:

> *A workflow consists of a sequence of connected steps. It is a representation of a sequence of operations, and can be interpreted as work of a person, a group of persons, an organization of staff, or one or more simple or complex mechanisms. (Belhajjame, Collet, and Vargas-Solar, 2001).*

Tacit knowledge: (as opposed to explicit knowledge) is defined as work related practical knowledge. It is often associated with intuition (Wagner and Sternberg, 1958).

The next section will review the current literature on the topics of:

- Sustainable Architectural Design;
- Green Building Rating Systems (GBRS);
- Importance of Building Performance Assessment;
- Building Information Modeling (BIM);
- BES and BIM;
- Integrated Design Process (IDP);
- Integrated Project Delivery (IPD).

2. LITERATURE REVIEW

The literature review included the following areas: (a) Sustainable architectural design; (b) Green Building Rating Systems (GBRS); (c) Importance of Building Performance Assessment; (d) Building Information Modeling (BIM); (e) BES and BIM; (f) Integrated Design Process (IDP) and (g) Integrated Project Delivery (IPD); with selected case studies to show their benefits. The literature converge in terms of stressing the importance of a multidisciplinary design team using evidence to support design decisions, the importance of energy efficient buildings to tame the impact on the environment, and the impact that technologies to aid design have made into the design process (BIM, BES). The literature review substantiates the importance of understanding the concepts of BIM, IPD/IDP and BES and also establishes that there is not yet a consensus or well-understood set of practices to bring them together.

2.1 Sustainable Architectural Design

There are diverse views on the topic of sustainable design drawn from scholarly publications, reviews of practice, and government and non-profit documents. This section presents a general discussion about how designers are approaching sustainability. There is no consensus on defining a sustainable building or design. It all depends on how far someone wants to go in analyzing the impact of the building on the environment along its life cycle. Beyond the direct impact of operating the building, the embodied energy could also be estimated as well as the Life Cycle Cost (LCC) and Life Cycle Assessment (LCA) of the building. Embodied energy refers to the total energy required in the acquisition and processing of raw materials, including manufacturing, transportation and final installation; while CC is the ability to model the building's financial performance over its life cycle; and LCA is the evaluation of the environment and resources impact of a single material, product, or the whole building (Kibert, 2008). Ecodesigners, such as Pliny Fisk and Kenneth Yeang, tend to analyze the impact of a building using a holistic approach including LCC and LCA evaluations (BLISS, 1997; Fisk, 1995; Yeang, 2008). Fisk also uses the eco-balance approach to determine how many natural resources are needed for a building according to its occupants and the activities or tasks performed for the operation of the building (Fisk, 1995, 2009).

2.1.1 Scholarly Works about Sustainable Architecture and Design Processes

It has been suggested that sustainable design must incorporate the principles, processes and cycles of nature (Vallero & Brasier, 2008). It must include an exploration of different forms to reduce ecological footprint and hopefully achieve eco-balance or net-zero energy performance (on-site production of the required energy for its functioning). A sustainable design strategy needs to surpass the short-term economical benefits and see the design from a holistic viewpoint. In their view, the built environment needs to re-create the way nature works: nothing is wasted. Operations and facility management must be included into the equation as well for an accurate evaluation of the building performance. Vallero and Brasier further differentiate two design process approaches: the traditional-linear process, and the transitional model. The linear model tends to set as priority variables such as monetary costs, scheduling constraints and quality. The transitional model includes a rating using a GBRS (LEED, BREEAM, and Green Globes, among others). The focus of the transitional model is to move the technical input earlier in the design process, so the schematic design alternatives can be tested in advance to assure a better overall performance of the building. The main difference between the linear process and the transitional process is the level of interaction and feedback among all stakeholders, which is more intensive and constant in the later one.

The transitional model also suggests the implementation of explicit knowledge and evidence-based decision-making in the design, besides tacit knowledge. Woo et al. studied the use of intuition to start a design (tacit knowledge) versus the use of scientific evidence to support their design choices (explicit knowledge) (Woo et al., 2004). The use of tacit knowledge may be replaced by the adoption of simulation and a multidisciplinary team within the design process. Other researchers have also observed that contemporary architecture design is moving towards an emphasis on sustainability and reliance upon evidence-based design to support design decisions (McCullough, 2010; Hamilton & Shepley, 2009). Hamilton and Watkins (2008) introduce designers to the concept of evidence-based design for creating high performance environments. With a focus on the methods by which designers and their clients can design better buildings, the author presents critical analysis of the effects of reliable research combined with careful observation of built projects (assessment).

Fisk (2009) selected datasheets from different sources (Appendix 4) to calculate the approximate effort needed to achieve eco-balance. I have adapted its formulas into an Excel® spreadsheet format in Appendix 4 to be re-used for different projects. The value of these datasheets is to quickly visualize how far the project is from producing no impact on the environment, so the designer can prioritize the strategies to be implemented addressing those issues. Most likely, each project will be very far from achieving eco-balance, but the idea is that the community as a whole should combine strategies and efforts to address those issues, depending on each building's strengths.

The spreadsheets are divided into the following topics: (a) Air, (b) Lumber, (c) Cropland, (d) Electricity, (f) Biomass and (g) Water.

Nigel Cross (2008) proposed a stage rational design process and related methods. His design process' main objective is to define and clarify the overall design problem with its sub-problems and then to create the overall solution with its sub-solutions. Cross recommended different methods for each design stage, stressing the importance of following the methods with rigor and interpreting the outcomes creatively, using unconventional thinking. He also suggested using strategic thinking about the design process. Pushing the boundaries of methods for tailoring strategic design frameworks is critical to achieve better and more efficient design processes. The importance of this work is the inclusion of other aspects of design suggested by other scholars, such as programming (Peña & Parshall, 2001) and the establishment of performance goals (Augenbroe, 2011). Table 1 presents a summary of the methods and goals (Cross, 2008):

Table 1: Design stages in Cross's model, methods and aims (adapted from Cross, 2008).

Stage	Method	Goal
Indentifying opportunities	User scenarios	identify and define an opportunity for a new or improved design.
Clarifying objectives	Objectives tree	clarify design objectives and sub-objectives, and the relationships between them.
Establishing functions	Function analysis	establish the functions required, and the system boundary of a new design.
Setting requirements	Performance specification	make an accurate specification of the performance required of a design solution.
Determining characteristics	Quality function deployment	set targets to be achieved for the engineering characteristics of a design artifact, such that they satisfy customer requirements.
Generating alternatives	Morphological chart	generate the complete range of alternative design solutions for a design artifact, and hence to widen the search for potential new solutions.
Evaluating alternatives	Weighted objectives	compare the utility values of alternative design proposals, on the basis of performance against differentially weighted objectives.
Improving details	Value engineering	increase or maintain the value of a design artifact to its purchaser whilst reducing its cost.

Gero (1995, 2004) worked on a notion of Function, Behavior and Structure (FBS). Function variables describe what the design object is for. Behavior variables describe what the design object does, and finally, form variables describe what the object is, in terms of its components and relationships. A designer then derives behavior from structure and ascribes function to behavior (Clayton, 2006). According to the FBS theory, there are eight processes or operations in design, which are related to the main three concepts previously described. The final three processes are reformulation of structure, behavior and function that represent various iterative loops in the design process. These iterative loops in the design process are also seen in the design processes of the firms investigated in this research. Their design alternatives at early design stages pass through several stages of refinement where they are tested with simulation or they are evaluated by design consultants. Each design consultant has a specialty that corroborates that the form, behavior and structure requirements of the project are met.

The Virtual Product Model (VPM) (Clayton, 1996) tried to test the concept that a design process can be formalized in computable steps to represent the function of a design object, producing as a result, a hypothetical form solution for those functions, and deriving behaviors that enable a test of that hypothesis (Clayton et al., 1996, 1999). This formulation resembles closely to Gero's function, behavior and structure, and was derived from a cognitive model of design rather than a product model. In the VPM, the form was defined as the geometry and materials. The forms were modeled with AutoCAD. Function was defined as the requirements, intents, and purpose of the design, and behavior was defined to be the performance itself. In theory, a design architect could work in his/her own environment and then offer the model to an engineer who would translate the CAD graphic model into a model that could derive performance. To test the generality of the ideas, Clayton created four example performance models and supporting "interpretation" interfaces: (a) energy analysis, (b) cost analysis, (c) building code analysis, and (d) spatial function analysis. The development process was exploratory and heuristic and was an attempt to push the limits and involvement of computers into the design process.

Peña and Parshall (2001) created a method called "problem seeking" distinguishing between the architectural programmers and design architects. Architectural programmers are responsible for developing a detailed description of needs and requirements (called a "brief" in the United Kingdom) while design architects synthesize the proposed solution into a form to be evaluated. According to the authors, design architects are too permissive towards modifying the program to match the shapes that they have designed or selected. The argument is that programmers should have enough authority to develop a complete, thoughtful, and relatively fixed program to which design architects must comply.

According to Clayton (1999), the design professions are probably trifurcating into function experts, form experts, and behavior experts. The concept of integrated but distinguished models (function, form and behavior) mirrors the skill-set among designers and the division of labor on design projects. A function architect would be the equivalent of the architect programmer, working with the client to define explicitly the requirements for the project. A form architect would prepare a virtual model to represent a solution alternative (architect designer, geometry specialist, BIM specialist). The behavior architect would use software tools to predict the performance of the solution (energy simulation in early design stages).

According to Augenbroe (2011), the importance of analysis in high performance building design is to understand how to use simulation or other methods to quantify building performance, i.e., how analyses influence decision-making process in design.

Traditionally, design solutions were determined by prescriptive terms that specified qualities of the solution rather than its expected performance. Building codes and regulations have also contributed largely to this problem by adopting prescriptive specifications. However, many regulations are currently being modified to support performance standards (Foliente, 1998, 2000). The main characteristic of performance based design (PBD) is the up-front formulation of performance requirements, and the management of a process to assure its accomplishment through dialogues between all stakeholders. This characteristic is shared with IPD and IDP principles, where a major effort is put into early design stages by a multidisciplinary team to define design and performance requirements and to work as a team to satisfy them (Barrett, 2008). Building performance simulation is not only a computational tool, but covers a broader process that starts much earlier and ends later. The main steps are (1) agreement about **performance criteria**, (2) agreement about **ways to measure** them and (3) **making rational design decisions** and consider trade-offs between potentially conflicting/hard-to-meet performance targets within the imposed time and budget limits. The authors posit that informing the decision-making process is critical, and a very detailed simulation in itself is not – it can be counterproductive due to its over-engineered models and time consuming simulation runs. Augenbroe stated that just a few of the tools that claim to support early design decisions have been used in practice, regarding them as not well integrated, or too simplistic. Additionally, uncertainty of energy models usually overwhelms the separation in performance between competing design options, making the simulation results worthless to inform design decisions. Finally, simulation tools have proprietary representations of buildings, in most cases not explicitly specified. How can the user know if the tool is adequate? The role of "simulationists" will be an integral part in the performance criteria management. In some cases an advanced simulation will be needed, where in other instances a simple calculation or expert judgment will suffice.

Another author describes an integrated design process for architects and engineers (Yudelson, 2009). He suggests that systems are more powerful than individuals and that high performance design depends upon a team. Design talent is different among designers and one cannot rely on superior design talent alone to get superior results; hence the integrated design process is important. Because the demand for high-performance buildings is increasing, there is a unique opportunity to change the project delivery process, and produce significant innovations and cost savings simultaneously. The author also distinguishes what is not an integrated design approach. He points out that a highly technological solution to a particular problem may not be the product of an integrated design approach. Integrated design is a multidisciplinary activity that welcomes feedback from different stakeholders and accepts as a major goal the long-term function and health of the building and its occupants. The author includes a description of the Eco-charrette process, an explanation for why some designs are successful and others are failures, and the benefits of High Performance Buildings at all levels (occupants' productivity and health, tax reduction, energy savings, etc.). However, there is no mention of the use of BIM in the integrated design approach, other than the possibility of using energy simulation earlier in the design process and making use of clash detection at late stages.

Kow & Grondzik (2007), state that Integrated Design is “knowledge applied in parallel”, which refers to a simultaneous interaction among stakeholders, while conventional design is “knowledge applied in series”, which is a sequence of steps (linear, not simultaneous). The importance of integrated and collaborative design is clearly stated, but the discussions during design stage and the dynamics of collaboration remains a mystery in the case studies presented, where the focus was on the design concepts, goals and achievements (metrics). The book mentions the use of digital technology to simulate building performance, but mostly presents manual procedures, e.g., daylighting assessment of physical models with sensors and measurement equipment. Nonetheless, the book is a great asset in terms of providing valuable information to designers to evaluate performance, and by giving valuable insight and suggestions about the careful design of building envelope and systems. This includes information about strawbale construction, insulation materials, structural insulated panels, double envelopes and green roofs. It also includes analysis of lighting (daylight factor and zoning, side/top lighting, light shelves, internal reflectances, shading devices and electrical lighting). Moreover, the book discusses active and passive strategies for cooling and heating (geothermal, cross/stack ventilation, cooling towers, ground source heat pumps, natural ventilation, etc.), and energy production and water and waste (composting toilets, living machines, water catchment systems, etc.).

Another book includes examples of sustainable designs built by two of the design firms interviewed in this sample: Foster + Partners and TR Hamzah and Yeang (Maunsell et al., 2002). The authors describe issues of the impact of tall buildings on the local environment and occupants in the City of London, U.K. The main issues treated are the construction and operations, the use of materials, the relation between tall buildings and transportation, and how to make tall buildings more energy efficient. This report is helpful for understanding the way designers think and work, but their workflow on the use of BIM or digital technology is not addressed.

Yeang (2008) explains in *Ecodesign: A Manual for Ecological Design,* all the principles that should be applied for an ecological building design (Yeang, 2008). The sequence (workflow) of crucial steps outlined in the manual may be modified by the designer, depending on the various factors that affect a design problem. Yeang provides in his manual roadmaps for a design decision making process according to different challenges. These challenges are identified in several ways, and I highlight the following:

- To reduce heat-island effect;
- To reduce the consequences of transportation;
- To improve internal comfort conditions;
- To optimize passive-mode options;
- To integrate biomass with the building's inorganic mass;

- To conserve water;
- To manage wastewater;
- To incorporate food production; and
- To design from source to reintegration (cradle to cradle).

The manual offers a very comprehensive and detailed explanation of all the factors to consider, from an ecological viewpoint and from a designers viewpoint, stressing the multidisciplinary and holistic approach to design. The author asserts a need for significant change in design processes:

> *This assessment [ecodesign] calls for a total change, not just in how we currently perceive architecture and the built environment but also in the environmental context of our design and how we must respond to these by configuration and by process. It is evident that a radically different model of these human activities that can be permitted in the natural environment and of the way that we design our built environment is needed. (Yeang, 2008).*

He also claims that buildings are likely to be damaging to the environment:

> *"Ecologically speaking, the building is also a potential waste product, which has to be recycled just like a soft-drink can or a plastic bottle*
> *(Yeang, 2008, p. 421)."*

Apart from tangentially showing examples of CFD simulation, this manual does not suggest the use of BIM technologies or simulation to aid the design.

The Menara Mesiniaga building (1992) designed by Yeang was object of a study comparing its features to LEED 2.1 requirements to see what possible certification it could achieve (Chan, Fung, Lam & Liu, n.d.). The result was a Silver LEED certification even considering that the building preceded BIM and any Green Building Rating System (GBRS). This is an example that it is possible to design sustainable buildings with current standards without the use of BIM, GBRS and even simulation altogether, but adoption of these technologies is highly suggested. The benefits of their adoption are identified as an acceleration of the design process (Eastman et al., 2008), reducing errors that could increase costs and contamination during construction stages (Kibert, 2008; Kymmel, 2008), reduce energy consumption and carbon dioxide emissions (Tupper & Fluhrer, 2010), among others.

Sir Norman Foster is one of the most highly acclaimed architects of recent times. Quantrill (1999) has written a biography of Sir Norman Foster as an architect and discusses the ideas behind some of the most significant projects of his career. Foster + Partners is part of the convenience sample of this study; therefore this book was reviewed to search for significant information I could use in my interview. The book addresses many questions about how Foster + Partners approach the design problem and the performance of the building (combining architectural design with site and climate analysis and environment engineering design), but it does not delve into the digital design workflow of the firm.

2.1.2 Trends in Sustainable Architectural Design

Krygiel & Nies (2008) discuss schematic design, construction cost, construction processes, daylighting, energy simulation and total building energy use. They have paid special attention to daylighting issues. BIM models can be used for daylighting analysis in different stages of design, and designers are encouraged to conduct these analyses due to the significant possible savings in electricity, and potentially higher quality indoor environment. The benefits associated with natural light can be summarized as a positive effect on human health and productivity, since they include increased productivity levels, lower absentee rates, better grades of students in school, increased retail sales and healthier occupants. The authors provide references to different energy and daylight simulation tools, as well as possible workflows for energy and daylight simulation. The book also details the experience of one firm transitioning to BIM and the strategies implemented for training. Although it is a very complete and architectural-practice oriented, this book treats buildings more like individual components, rather than parts of an eco-system. It is focused on the use of simulation and evidence-based design decisions.

Levring & Nielsen (2011) presented a workflow strategy combining BIM with different tools for sustainable design, such as Autodesk® Project Vasari, Autodesk® Ecotect® Analysis, Revit® Architecture, DesignBuilder, RADIANCE, and DAYSIM. An integrated workflow based on best practices was presented through case studies showing how to gain instant feedback on visual, acoustic, and thermal comfort. The workflow was related to specific design phases and included libraries, material translations and templates for Revit Architecture 2012, Ecotect Analysis 2011, 3ds Max 2012 and Sigma Enterprise 2010, as well as pre-defined Excel sheets for viewing and comparing results. The authors developed a strategy based on getting technical understanding of the tools, mapping different tool possibilities and limitations, understanding interoperability issues and mapping tools to design themes and processes (e.g., visual comfort, site and climate, etc). The focus was on Autodesk products and a discussion of alternative tools from other competitors was not present. The presentation offered valuable insight about the combination of different tools, and the value of implementing BIM as an innovation process rather than an optimization process (operational level). However, a discussion about implementation costs (acquisition of software/hardware) and strategies for training staff would help designers wishing to adopt these methods.

Kolarevic & Malkawi (2005) discuss the emerging approach to architecture where the building performance is a guiding design principle. The book is a collection of papers presented in a Symposium called “Performative Architecture” held at the University of Pennsylvania in October 2003, where diverse specialists discussed the matter. The book provides diverse examples and approaches to performance-based design, claiming that building performance is highly relevant in contemporary practice and will become increasingly relevant. This approach elevates the performance of the building to the equivalent importance of form-making for other architects. The emphasis is the use of digital technologies of quantitative and qualitative performance using simulation to test the effectiveness of decisions. This new strategy extends the already broad palette of design approaches applied to the built environment. The book portrays how well-known designers approach design of high performance buildings using digital technologies and simulation, pointing out the potential of performance simulation in architectural design. However, there is no clear explanation of the workflow used by the contributing designers and how they are using the tools.

2.1.3 Institutional Efforts to Help Sustainable Design

Various government agencies, professional associations and non-profit organizations have provided advice to architects in how to design buildings that are sustainable.

The U.S. DOE along with other key collaborators developed the *Advanced Energy Design Guides* (AEDGs) series to expedite the construction of highly energy-efficient buildings (ASHRAE, 2007). The guides have been developed in collaboration with the American Institute of Architects (AIA), the Illuminating Engineering Society of North America (IESNA), the USGBC, and the U.S. DOE. These guides provide a prescriptive path to achieve 30% energy savings for small commercial buildings, warehouses, and K-12 schools beyond the minimum code requirements of ANSI/ASHRAE/IESNA Standard 90.1-2004.

The AIA Firm Survey (2009) states that the use of sustainable design has increased in popularity. The AIA survey defines sustainable design as using a holistic approach that includes (but is not limited to):

- Design that conserves water, energy, and natural resources;
- Adapts to surrounding conditions;
- Reduces carbon footprint;
- Improves building performance;

More than 68% of the registered firms indicated that at least one new residential construction project begun in 2008 had the characteristics of a sustainable design, and 61% of firms mentioned that at least one nonresidential project with sustainable design features was in the development.

The literature converges in terms of stressing the importance of a multidisciplinary design team (integrated design process or IPD), the importance of energy efficient buildings to tame the impact on the environment, and the impact that technologies to aid design have made into the design workflow of advanced firms (BIM, BES). Additionally, design methods are shifting from a traditional-model (tacit approach) to a transitional-model (explicit approach), where design decisions are made based upon science or evidence. Participants in this study were selected for their acclaimed sustainable designs. I did not previously know their level of expertise in digital tools or their design methods. After data collection, each of the firms was shown to be following the transitional model. This transitional model, if continuously followed by more firms, might make a permanent change in the AEC industry.

In the next sub-section I discuss the importance of building performance assessment for architectural sustainable design.

2.2 Importance of Building Performance Assessment

The lack of a standardized method for documenting building performance leads to several shortcomings in the life cycle management of building information (Hitchcock, 2003). Despite the widespread use of the terms previously defined, truly sustainable commercial buildings with zero impact on the environment (Life Cycle Assessment, closed material loops, renewable energy systems and full integration into the eco-system) are virtually nonexistent (Yeang, 2008). However, continuous advancement in the incorporation of sustainability and eco-design principles is progressively improving the performance of buildings towards the ultimate goal of zero impact. Green building rating programs can certify a building that has reduced its impact into the environment up to some extent. It is more realistic to say that the majority of the so called sustainable buildings today are less harmful than the average, but they are not literally “sustainable” (Turner & Frankel, 2008). MacDonald (2000) states that if someone tries to define what a high performance building is, without establishing the scope, metrics and approach, it will probably require an enormous development effort. However, for the purpose of this research, we will call sustainable designs or buildings the ones that were designed under the principles of reducing the overall footprint on the environment. The positive outcome comes from the associated high quality and performance of the building, compared to code compliant buildings (Yudelson, 2009), where the benefits include the following:

1. Utility cost savings for annual energy and water that are typically 30 to 50 percent in comparison to a benchmark, base case, or typical building, along with reduced "carbon footprint" from energy savings;
2. Maintenance cost reductions from commissioning, operator training, and other measures to improve and ensure proper systems integration and ongoing performance monitoring;
3. Increased value from higher net operating income and increased public relations for commercial buildings;
4. Tax benefits for specific green building investments such as energy conservation and solar power, and local incentives, depending on location;
5. More competitive real estate holdings for private sector owners, over the long run, including higher resale value;
6. Productivity improvements for long-term building owners, typically 3 to 5 percent;
7. Health benefits, including reduced absenteeism, typically 5 percent or more;
8. Risk management, including faster lease up and sales for private developers, and less risk of employee exposure to irritating or toxic chemicals in building materials, furniture, and furnishings;

9. Marketing benefits, especially for developers, large corporations, and consumer products companies;
10. Public relations benefits, especially for developers and public agencies;
11. Recruitment and retention of key employees and higher morale;
12. Fund raising for colleges and nonprofits;
13. Increased availability of both debt and equity funding for developers;
14. Demonstration of commitment to sustainability and environmental stewardship.

To summarize, understanding mistakes from designs will enable designers to avoid them in the future. High performance building design has shown several economic benefits that should drive commitment to sustainability. On a global level, the main drivers for pursuing sustainability are a dramatic change in climate, the increasing scarcity of fossil fuels and the international demand for reducing carbon dioxide emissions (Levring & Nielsen, 2011). Other key drivers are ethical considerations, economics and marketing purposes (Yudelson, 2009), as well as an unprecedented level of government initiatives and improvements in sustainable materials (FMI, 2008).

The next sub-section will discuss another driver for commitment to sustainability: Green Building Rating Systems.

2.3 Green Building Rating Systems (GBRS)

There are many systems to rate building's performance. Understanding the differences among GBRS will clarify the reasons for selection of a particular one and the impact it can make upon the design method. In contemporary practice, GBRS are considered a standard for measuring designs. Different rating systems are used in different geographic markets and for different building types. The certification process will have an influence on the approach to the design of "green features", such as HVAC systems, predicted greenhouse gas emissions, or the percentage of improvement based on annual energy cost. Every GBRS has a different emphasis that will orient the simulations and change design strategies. The literature shows that the same project building will get different points under different rating systems, and that a project can be certified under one system but it may fail under another system (Roderick, McEwan, Wheatley, & Alonso, 2009). Moreover, several low-energy buildings do not always operate as they were designed (Torcellini et al., 2006). Because of this lack of consistency and suspect validity, it is relevant to explain important aspects of the widely used GBRS available. In parallel, Yeang (2008) posits that designing to meet rating targets generally result in a design based on existing systems where innovation is not encouraged.

Building Research Establishment Environmental Assessment Method (BREEAM) is the oldest building assessment system (Kibert, 2008). It was developed in 1988 under the supervision of the Building Research Establishment (BRE) in U.K. The original idea was to help transform the construction industry of office buildings to high performance standards. Widely adopted in European and Asian countries and in Canada, BREEAM assesses the performance of buildings in the following areas (Kibert, 2008):

- Management: overall management policy, commissioning, site management and procedural issues;
- Energy use: operational energy and carbon dioxide (CO_2) issues;
- Health and well-being: indoor and external issues affecting health and well-being;
- Pollution: air and water pollution issues;
- Transport: transport-related carbon dioxide and location related factors;
- Land use: Greenfield and brownfield sites;
- Ecology: ecological value conservation and enhancement of the site;
- Materials: environmental implication of building materials, including life-cycle impacts;
- Water: consumption and water efficiency.

BREEA has two diff erent categories: one for “design & procurement assessment” (earlier stages of design); and the other for “management & operation” assessment when it is occupied (Kennett, 2008). The performance in each category will be awarded with credits (up to 102), whose sum gives an overall score with a scale of Unclassified (<30%) Pass (≥30%), Good (≥45%), Very Good (≥55%), Excellent (≥70%), and Outstanding (≥85%). Energy assessment is driven by carbon dioxide emissions, and allows up to 15 credits, which accounts for 14.7% of the overall score. The rating is determined by comparing the building’s carbon dioxide index to a value extracted from an Energy

Performance Certificate table as a benchmark for comparison. The reason for the assessment of carbon dioxide emissions derives from a focus on global warming, which is mainly driven by greenhouse gas emissions (EPA, 2010; Brand, 2009). BREEAM requires the comparison of the project against a benchmark, which obliges designers to create two models: the base-case or benchmark, and the proposed model. Currently, BREEAM covers office buildings, new industrial buildings, homes and retail (Roderick et al., 2009; and Kibert, 2008).

LEED (Leadership in Energy and Environmental Design) was developed by the U.S. Green Building Council (USGBC) to accelerate the adoption of green building strategies in the U.S market (LEED, 2009). It is recognized as the most widely used rating system in the world (Kibert, 2008). Despite being referred to as a singular, LEED is a suite of building rating systems:

- LEED-NC: new construction;
- LEED-EB: existing buildings;
- LEED-CI: commercial interiors;
- LEED-CS: core and shell projects;
- LEED-H: homes;
- LEED-ND: neighborhood development;
- LEED-R: retail;
- LEED-S: schools;
- LEED-HC: healthcare.

Similar to BREEAM, LEED is structured into seven prerequisites and credits. It permits a maximum score of 69 points. The major categories are the following, with maximum points in parenthesis (Harputlugil & Hensen, 2006; Kibert, 2008):

- Sustainable Sites (14, with one pre-requisite);
- Water Efficiency (5);
- Energy and Atmosphere (17, with three pre-requisites);
- Materials and Resources (13, with 1 pre-requisite);
- Indoor Environmental Quality (15, with two pre-requisites);
- Innovation and Design Process (5).

Each credit under the categories above will give 1 point if the requirement is met, with the exception of energy performance and renewable energy credits, in which a number of points will be given according to the improvement in the performance. Similar to the BREEAM approach, the level of energy performance is assessed in comparison to a benchmark building. The inclusion of a LEED Accredited Professional in the team will give 1 point to the overall rating. The certifications are divided into five groups from best to worst: (a) Platinum (52-69); (b) Gold (39-51); Silver (33-38); Certified (26-32); and No Rating (25 or less).

In general terms, a major difference between BREEAM and LEED is that project design decisions tend to be driven by desire to reduce carbon dioxide emissions in BREEAM. On the other hand, the main goal in LEED is to reduce energy consumption of buildings, which creates different routes to compliance. However, both rating systems account energy in a similar percentage compared to the whole score: 14.5% in LEED, and 14.7% in BREEAM.

Within the certification process of the previously mentioned GBRS, each measure of performance is based on building codes, protocols or standards, such as (Hitchcock, 2003):

- ASHRAE Standard 62-2007 (Indoor Air Quality, Indoor Environment Quality);
- ASHRAE Standard 90.1-2004 Appendix G (minimum energy performance);
- ASHRAE Standard 62.1-2004 (ventilation);
- ASHRAE Standard 55-2004 (thermal comfort);
- ASHRAE 189P;
- IESNA Lighting Handbook 2000;
- U.K. National Calculation Methodology (NCM), based on Approved Document PartL2A (Department of Communities and Local Government, 2008);
- U.K. Building Regulation;
- National Australian Built Environment Rating System (NABERS);
- ISO 140001;
- Environmental Profiles;
- Building Cost and Performance Metrics: Data Collection Protocol (DOE);
- Performance Measurement Protocols for Commercial Buildings (ASHRAE, 2010);
- EPA Energy Star (promotes net-zero and carbon neutral buildings);

- Water Efficiency (EPAct 1992), among many others.

Most of the ASHRAE Standard methods and protocols are used in the United States to account for LEED credits, together with the IESNA Lighting Handbook for daylighting credits (IESNA, 2000), and EPAct. As an example, ASHRAE Standards can be used to show that the environmental quality credit (EQc3.2) is improved over code-compliant buildings. Another example is that daylighting levels (EQc8.1) for specific times of the year comply with the IESNA standards for a specific task (Beltrán & Farías, 2009). On the other hand, the U.K. Building Regulation and the U.K. National Calculation Methodology are naturally used in Europe. NABERS is used in Australia, and ISO norms are international, so the variety and possible combination of methods may seem overwhelming to some architects.

To conclude, there are some differences between BREEAM and LEED. BREEAM is carbon dioxide emissions driven, while LEED is building performance/energy savings driven, which affects the priorities in the design. BREEAM requires an external third party to certify the building, while in LEED, a LEED AP can be provided internally by the design firm. Federal or government funded projects (hospitals, educational, transportation, etc.) tend to select the GBRS used most commonly at the location of the building or agency: BREEAM in the U.K., and LEED in the U.S.

The next sub-section presents information about innovative technology for design that many scholars argue contributes significantly in sustainable design: Building Information Modeling.

2.4 Building Information Modeling (BIM)

Building Information Modeling (BIM) is an emerging technology in the Architecture, Engineering and Construction industry. According to the AIA Firm survey (2009), the number of firms that have acquired BIM software has doubled since 2006 to 34%. BIM is a digital representation of physical and functional characteristics of a facility and serves as a shared source for information about a building or facility (NIBS, 2008). The object-oriented modeling of BIM facilitates access to comprehensive building data, including components and their real properties that can be used in design, construction, and operation. Moreover, parametric design capabilities in BIM can enable fast and interactive design changes (Lee, Sacks, and Eastman, 2006). The most popular BIM tools are Autodesk Revit, Bentley Architecture and Graphisoft ArchiCAD (Eastman, 2008, pp.468).

The evolution of BIM tools has led to a set of capabilities supporting design and construction and interfaces to the underlying data structure. BIM software provides objects that represent architectonic elements, parametric 3D modeling, rendering functions, automated drafting, rich graphic and non-graphic information stores, and interoperability to analysis programs (Clayton et al., 2010).

One of the attempts to address the issue of BI m   odel’s complexity is the release of the AIA California Chapter’s *Organizing the Development of a Building Information Model* (Bedrick, 2008). Representations of building elements per se in a BIM tool are exact (intended to be or not), and can give a false indication of the precision level acquired in a given point of the design process. In addition, BIM can be used for costing, scheduling, performance simulation, code checking, visualization, etc., but it is not always clear what is the purpose of the BIM and whether it can be used to support additional purposes. A Model Progression Specification (MPS) started to take form in 2004, with its core in the definition of “ evel of Detail” (OD). Five levels have been established from conceptual design stage through as-built documentation. The LOD definitions can be used to define phase outcomes and to assign modeling tasks. However, to allow for future intermediate levels, the levels have been labeled 100 through 500 anticipating the establishment of levels between the current LOD definitions. The levels are 100 (Conceptual Design); 200 (Approximate geometry- Schematic Design); 300 (Precise geometry – Design Development, Construction Documentation, Procurement); 400 (Fabrication – Construction Administration); and 500 (As-built - Operations).

Eastman (2008) defines BI as   “a modeling technology and associated set of processes to produce, communicate, and analyze building models” (Eastman, 2008). Effective use of BIM will require designers to adopt new business models and methods of not only design, but also production (2008).

Kalay (2006) describes the IT (information technology) revolution on the design professions, with a special focus on architecture. The author states that technology will not radically alter the cognitive processes of a designer's work, but it will alter the practice of design. Current practices will be replaced by new ones; however, there is no clear speculation on how BI i s changing architecture's design process.

Another work states that the most important and least addressed issue of BIM is the required change in business practices needed (Smith & Tardif, 2009). Second, is the evaluation of the cultural changes associated with BIM adoption, since those changes are a challenge to the industry of technological transformations (Smith & Tardif, 2009). The authors define education of professionals as the largest and often hidden investment for the cultural shift. As a consequence of further education in the new methods, the profession would achieve greater value than that achieved by simply automating existing processes.

Other researchers studied the use of digital tools to aid sustainable design and analysis. Schlueter and Thesseling developed an Autodesk Revit API program to link parametric modeling and energy performance testing (Schlueter & Thesseling, 2008), while Azhar et al. (2011) developed a conceptual framework to streamline the LEED certification process saving time and resources. Levring & Nielsen (2011) presented a workflow strategy combining BIM with different tools for sustainable design. The authors offered valuable insight about the combination of different tools, and the value of implementing

BIM as an innovation process rather than an optimization process. However, the method lacked a more holistic viewpoint of sustainable design and a discussion about implementation costs and strategies for training personnel.

Ibrahim, Krawczyk, and Schipporeit (2004) analyze two different methods for data creation or design with a BIM model, which are identified as the Integrated Model and the Distributed Model. According to the authors, all design projects are a collection of designed parts belonging to the final product, which is a group of designed elements as well as vendor-provided elements. The integrated model is a single source for all design data and all design information. On the other hand, the distributed model is a separate referential model used by the separate participants in the process, where each individual (consultant) has a model referenced by the original architect's model. Either method will enhance the value of the final design by increasing accuracy of data coordination, while simultaneously creating a repository for all product information related to the final design, facilitating information retrieval (Ibrahim, Krawczyk & Schipporeit 2004).

Succar (2008, 2009) introduces a notion of maturity of adoption of BIM. Maturity of BIM can be examined through three complementary dimensions: **Nodes, Stages** and **Lenses**. **Nodes** refer to project stakeholders and deliverables used to communicate among them (owners, operators, project managers, architects, engineers, developers, contractors, facility managers, suppliers, etc). All these players and deliverables can be grouped into other three overlapping circles: (1) **BIM Policy** circle (stakeholders responsible for generating standards, guidelines and contracts); (2) **BIM Process** circle (participants of the IPD process, leaderships, infrastructure, human resources and product/services); and (3) **BIM Technology** group (developers of tools necessary for the correct implementation: network providers, hardware companies, software companies, information management services, etc.). The next step is to understand **BIM Stages:**

1. **BIM Stage 1**: Object-based **modeling** – starts using the tool, but at this level is still uni-disciplinary. BIM tools and processes are implemented in Design, Construction or Operations. Change in the Policy circle is low, change in Process is medium and change in Technology is high.
2. **BIM Stage 2:** Model-based **collaboration** – at least two disciplines exchanging models and information. BIM is used in multiple phases of a design project, such as Design Development, Design Operations, Construction Documentation (4D, clash detection) and Operations. Policy change level is medium; Process change is medium and Technology change is low; and
3. **BIM Stage 3:** Network-based **integration** (integrated practice). BIM is used in all project lifecycle phases, and it is shared by three or more disciplines. Building performance is assessed earlier through simulation, and Life Cycle Assessment (LCA) and Life Cycle Cost (LCC) are included in the assessments. Change in Policy is high, change in Process is high and change in Technology is high.

The author also posits the question about BIM capability and maturity levels (NIST, 2007) and how to assess BIM performance measurement.

BIM adoption is accelerating toward universality in the United States (AIA, 2009). In a survey in 2009, more than 33% of the AIA registered firms indicated they had already acquired BIM software in 2008, which was twice as many as in 2005. An additional 5% of firms indicated they plan to acquire the software in 2009. BIM tools penetrate more deeply in larger firms, with nearly 100% of firms that average 100 or more employees make use of BIM, while only one third of firms with less than 10 employees use the technology. Among all the firms that are already using BIM software, more than two-thirds (about 67%) are using it for billable work (a 5% increase compared to 2005), while 90% of large firms were actively using the software in 2008. Moreover, the rate of use of technology associated with BIM increased for several phases of billable work in 2008. Compared to 2005, the use of BIM for the bidding phase grew 15%, and for the construction administration phase grew by 12%. By far, the largest number of respondents in the survey indicated the use of BIM software for 3D visualization and construction documents during 2008. One-third of the firms consulted are also using BIM software to share models with consultants, and 29% mentioned the use of BIM for 3D clash detection -also called 4D simulation, which enables designers to identify coordination errors with multiple consultants.

In an alternative formulation of progression of adoption, the AEC industry is passing through three levels (Clayton et al., 2009):

1. In the low-end adoption level (BIM-A), BIM tools are used to accelerate existing tasks and operations. BIM provides better tools for design visualization,

documentation and the improvement of various tasks in the design process, in comparison to a traditional CAD procedure. In spite of a relatively simple and simplistic adoption level, participants reported high profit margins when they utilized BIM continually from schematics throughout production drawings.

2. The second level—labeled BIM-B—assumes BIM methods as the catalyst for changing the business model of a firm into an IPD process (collaborative design and production). At this level, BIM models are used as a repository of cross-disciplinary information. The interoperable BIM model is shared within the group, and different simulation and analyses are performed through this model. At this stage, BIM-B is closely aligned with an IPD model for contractual relationships.
3. The third level, called BIM-I, makes use of interoperable BIM models across a wide network of designers, consultants, contractors, suppliers, and operators. BIM-I is still a visionary and long-term goal, but there is an agreement among the industry about the potential high value and increase in productivity.

The study also makes use of the model suggested by Rogers that an innovation progresses through several categories of adopters (Rogers, 2003). These groups are:

1. Innovators: look for new technologies and implement them into their business models despite the associated risks;
2. Early adopters: are benefitted from the pioneering efforts from the Innovators, since they accept the new technology even when the business case is uncertain, but they are already well-positioned to gain benefits (i.e., large firms);

3. Early majority: accepts the technology when it is already mature and proven, and then they follow the opinion leaders;
4. Late majority: adoption occurs when a contextual pressure occurs and where adoption is vital for the survival of the firm; and
5. Laggards: avoid or ignore the technology and adoption trend, either because of isolation or because they are already out of the market.

The ubiquitous adoption of BIM-A will be achieved soon, since the technology seems to be reaching the tipping point of early majority adoption. The adoption of BIM-B will be reached when a threshold of adopters has accepted BIM-A and the goal of interoperability among stakeholders is achieved. BIM-I requires very extensive penetration of BIM-A and BIM-B; hence, it can be expected to become a significant strategy only after the other strategies have been widely diffused across the AEC industry.

The model predicts that large firms and firms using integrated design processes will benefit the most from BIM-A adoption. In BIM-B and BIM-I the value of the technology will depend on how many industry members have adopted the technology. BIM-B can significantly reduce the communication cost among designers, consultants, and prime contractors; and also increases the scope of the project and adds value to it. BIM-I should, in theory, reduce dramatically the cost of communication among these same stakeholders and also suppliers, sub-contractors, owners, and facility managers. If the number of participants that have adopted the strategy increases, then the value of the adoption increases exponentially. Because the value of BIM-B and BIM-I is susceptible to network effects, the technology achieves the status of being a disruptive technology (Clayton et al., 2009).

The use of BIM can vary according to the type of projects, and more specifically, to the size and scale of a particular firm. Larger firms tend to get the maximum benefit from it, because they can afford more training, and because they usually work in more complex projects where the full potential for using BIM is more evident. Smaller firms tend to struggle with training and the cultural/business model shift (Autodesk, 2007). Because their reduced staff is always working on projects, smaller firms often cannot afford to take people out of production duties for training. Additionally, the steep learning curve of BIM and the complete shift in business practices takes time (2007).

2.4.1 Interoperability

For the purpose of this research, interoperability has been defined as the capacity of BIM tools from multiple developers to exchange building model data and operate on that data, and is considered critical for team collaboration (Eastman, 2008, pp.468). In the fields of architecture and construction, there are many attempts to provide good data exchange and facilitate communication between different stakeholders and design tools; however, most of those attempts have had only limited success. Most software companies work in an isolated way, trying to make their product suites stronger and more comprehensive (Sabol, 2008), attempting to preserve commitment of clients to their products. Every software has its own proprietary algorithms or language, which may not “speak” or translate well with other languages. Therefore, users experience a lack of good interoperability, which translates into wasted time re-working models to recover specific data so that design consultants can work with updated and reliable models (Eastman, 2008). Interoperability problems are more frequent when translating BIM files into energy simulation formats (Laine et al., 2007; Bazjanac, 2004), or when design consultants (MEP, landscape, lighting, etc.) have not adopted BIM. In this section, I will review some attempts to improve interoperability.

2.4.2 Efforts Made to Overcome Interoperability Issues

Experimentation in object-oriented product models for buildings led in 1994 to the formation of the Industry Alliance for Interoperability (IAI) as a consortium of software companies, building owners and design organizations (www.buildingsmartalliance.org). The name was later changed to the International Alliance for Interoperability. The IAI established a goal of developing a comprehensive data model for buildings using an object-oriented approach that could support software interoperability throughout the phases and disciplines of the construction industry.

The IAI goal of a comprehensive data model for buildings was manifested as the Industry Foundation Classes (IFC) which have now reached version 2.x. IFC is intended as an open digital data standard for exchange of information in the building industry and has received support from many software developers, including Graphisoft, Autodesk and Bentley.

Eastman et al. (2010) argue that achieving full interoperability between BIM tools could be possible through *Industry Foundation Classes* (IFC) standard building model schema. However, without description of information exchange in construction project workflows, the flexibility of IFC is limited. As a solution, the authors suggest the description of specific scenario of use cases and precise information to be exchanged (Eastman, Jeong, Sacks, & Kaner, 2009).

As the World Wide Web achieved explosive growth and universal adoption, focus in the research community adjusted to include the Web as a medium to support design operations. Extensible Markup Language (XML) was derived to provide a way to specify the semantics of documents distributed on the Web. The history behind XML is that in the 1970's, three employees at IB (Cha rles Goldfarb, along with Ed o sher and Ray Lorie) invented GML (which stood for Goldfarb, Mosher and Lorie), as a way to mark up technical documents with structural tags. Later their work evolved into the Standard Generalized Markup Language (SGML) and was adopted by the ISO in 1986. The most well known application of SGML is HTML (Hypertext Markup Language), which defines a specific set of tags suitable for websites. In the late 1990's Jon Bosak, Tim Bray, James Clark and others invented XML (eXtensible Markup Language). The W3C (World Wide Web Committee) immediately tried to reshape HTML as an XML application, resulting in the XHTML format. The advantage is that using XML, software developers can determine how to store, import and process almost any kind of data (Anderson, 2004). The strategy of using the Web to exchange product data for buildings led to the formation of the aecXML group to formulate open standards, definitions and text tags for the building industry. Green Building XML (gbXML) is an outgrowth of that work and establishes a neutral, open format to support energy simulation (http://gbs.autodesk.com). GreenBuildingStudio and gbXML will be explained in detail in the Simulation section of this Literature Review.

The IAI and aecXML merged to form the BuildingS ART alli ance™ (www.buildingsmartalliance.org). BuildingS AR T alliance™ has been established to coordinate the intense changes coming to the fragmented real property industry in North America. The focus of the organization is to guarantee lowest overall cost, optimum sustainability, energy conservation, and environmental stewardship. The National BIM Standard (NBIMS) is their principal product.

In conclusion, there are major efforts trying to solve issues with interoperability to facilitate data exchange in multidisciplinary design teams. Software developers seem to prioritize interoperability within their own suite of design packages and designers might suffer from it. This study asked participants about their perceptions of the use and exchange of data from BIM and BES within either an IPD or IDP process.

Interoperability affects information exchange, and has an impact upon a multidisciplinary design team that shares data in an integrated design process. The next sub-section discusses BES and BIM.

2.5 BES and BIM

Sustainable design processes usually rely upon BES software to establish expected energy consumption of building designs (Krygiel & Nies, 2008; Torcellini, 2006). BES accounts for loads, solar radiation, mechanical systems, lighting and equipment loads, and HVAC by using annual weather data and building descriptions as input to a simulation of energy use. BES is used as the basis for building code compliance in many jurisdictions. One of the major simulation trends for building system models is to integrate simulation and other performance models into BIM to allow not only visualization but also seamless performance assessments (Coffey, 2008). Nonetheless, designers more often than not have the challenge of understanding output results from BES (Bleil de Souza & Knight, 2007). BES tools are best suited for examination of risk and to test "what if." However, in spite of questionable accuracy and validity, they are often used to demonstrate that a particular design alternative is able to meet certain performance requirements (Hand et al. 2008).

2.5.1 List of Popular BES Tools Used by Architectural Firms

From the extensive list of BES tools available, designers often prefer to use those that can better inform the decision making process (Attia, Beltrán, Herde & Hansen, 2009). Attractive qualities include:

- A user friendly Graphical User Interface (GUI),
- Better usability and information management and
- Integration of intelligent design knowledge (guidelines for building codes and rating systems compliance).

Additionally, 3D representation and manipulation is perceived as valuable for designers.

Some of the available simulation tools in the U.S. are listed by the U.S. Department of Energy (DOE, 2011; Crawley Hand, Kummert & Griffith, 2005):

DOE-2.1e. (DOE, 1993): An hourly, whole-building energy analysis program which calculates energy performance and life-cycle cost of operation. Development of DOE-2 started in the late 70's and the current version is DOE-2.1e. DOE-2.1e has five subprograms: Building Description Language (BDL), which is used to describe the building design with respect to energy use; and four simulation programs (LOADS, SYSTEMS, PLANTS and ECONOMICS respectively) that are executed in sequence, being one the input for the next (Crawley, et al., 2005). DOE-2.1e was considered the standard tool for energy simulation for decades and serves as a basis for other very popular tools. A newer version, DOE-2.2, has incorporated numerous improvements but has not achieved widespread adoption.

Energy-10. (Sustainable Buildings Industry Council, 1996): A program for small commercial and residential buildings that integrates daylighting, passive solar heating, and low-energy cooling strategies with energy-efficient envelope design, and mechanical equipment in annual hourly analysis. This allows for detailed simulation and performance analysis of buildings of 10,000 ft^2 or less, hence the name, Energy-10. Similar to eQUEST, it starts with a baseline case and creates design alternatives to compare energy performance improvements.

EnergyPlus. (DOE, 1996): A new-generation building energy simulation program from the creators of two earlier energy simulation programs: BLAST (BLAST Support Office, 1992) and DOE-2. The BLAST (Building Loads Analysis and System Thermodynamics) system is a set of computer programs that predicts heating and cooling energy consumption in buildings and analyze energy costs. .EnergyPlus is one of the most powerful simulation tools available, and it is free for download; however, its lack of a user-friendly GUI makes it unpopular among architects and building designers. It is composed of two basic modules: a heat and mass balance simulation module, and a systems simulation module. Its daylighting model inherits features from DOE-2.1e /Window5 fenestration

(LBNL), split-flux inter-reflection model and anisotropic sky models. Window5 is a publicly available computer program that calculates total window thermal performance indices.

eQUEST. (Hirsch, 1998): A graphic user interface to a simulation engine based on DOE-2.2, developed by James Hirsch and Associates. This is one of the most popular tools due to its ease of use, 3D building representation and graphics production capabilities. It includes a building creation wizard that walks the user through creation of the model, an energy efficiency measure (EEM) wizard and a graphical results display module.

HEED. (Milne et al., 2004): Free software that calculates whole building simulation, energy efficient design, climate responsive design, energy costs, and indoor air temperature. It is very popular in the state of California, where its output results can be used for accreditation of energy use improvement over building code compliant buildings. It is also intended for very early design stages for "building envelope" dominated designs. After beginning a new project, the software first provides a "California Title 24" compliant building to serve as a benchmark, and then it creates a second design alternative (usually 30% better in performance). The second design is improved by mixing passive design strategies and cooling design strategies for the local climate (geometry, orientation, shading design, etc). The user can then either describe a completely different design or modify the automatically created designs and compare how the changes affect the energy consumption. The software can be downloaded from www.aud.ucla.edu/heed

RADIANCE. (Ward, 1989): RADIANCE was developed at the Lawrence Berkeley Laboratories (LBL) by Ward (1989). RADIANCE is a state-of-the-art illuminance prediction and synthetic imaging system based on the ray-tracing method (Ward and Rubinstein 1988; Ward 1994), allowing accurate calculation of interior luminance/illuminance levels. RADIANCE has been used extensively for accurate daylighting simulation on every design stage. In addition to implementing backward ray-tracing methods, RADIANCE employs Montecarlo techniques to calculate illumination at a point inside a space (Ward and Rubinstein 1988). There are no limitations to the number of surfaces that RADIANCE handles in scene geometry. RADIANCE is basically a suite of two different programs working together to generate an image: Gensky and Gendaylit. The Gensky program develops sky patterns such as the CIE standard overcast sky or clear sky with and without sun. Gendaylit has a sky model generator that produces a RADIANCE description based on the Perez all-weather sky model (Mardaljevic 2000). The latest version of the RADIANCE 4.0 has the capability of simulating Complex Fenestration Systems (CFS) (Ward 2009; Konstantoglou et al.,2009; Saxena et al., 2010).

DAYSIM. (Reinhardt & Herkel, 2000). In 1999, Reinhart and Herkel proposed a new method for predicting annual daylight illuminance distribution in a space (Reinhart and Herkel, 2000). In another paper, Reinhart and Walkenhorst (2001) presented a validation of simulation results from DAYSIM comparing it to the measured data for a simple model office building. DAYSIM is a RADIANCE-based (Ward and Rubinstein 1988) daylight simulation tool that implements Daylight Coefficient method (Tregenza and Waters 1983) coupled with the Perez all-weather sky luminance model (Perez et al., 1993). DAYSIM also provides daylighting analysis matrices such as Daylight Autonomy (DA) and Useful Daylight Index (UDI) that can be graphically represented. In conjunction with daylighting analysis DAYSIM also has a glare analysis module called Evalglare (Wienold 2006) that has been integrated into DAYSIM 3.0. Additionally, DAYSIM can simulate advanced daylighting systems such as light-shelves and windows with blind systems. A user friendly GUI and the capability to simulate advanced lighting systems makes DAYSIM a powerful tool for architectural daylighting analysis. However, DAYSIM is incapable of simulating Complex Fenestration Systems (CFS) or to calculate the impact of daylighting on the heating and cooling energy performance of a building.

2.5.2 List of Integrated Design Energy Analysis Suites

This section shows some of the integrated design suites available commercially. These tools largely bundle one or more of the energy simulation tools listed above with enhanced interfaces and capabilities. Basically, they are provided by the three most powerful vendors in the market: Bentley, Graphisoft and Autodesk.

AECOsim. (Bentley, 2011): Bentley developed the AECOsim family of applications to provide interdisciplinary building design, analysis, and simulation software focused on helping Architectural, Engineering, Construction, and Operations (AECO) firms to deliver high performance buildings. These applications enable designers to use information models to predict design and performance of building systems within a multidisciplinary environment using decision-support capabilities, considering the project lifecycle of design, construction, and operations. AECOsim works with most of the commonly available design tools from Bentley, Autodesk AutoCAD and Revit, Graphisoft ArchiCAD, and others in an integrated workflow through open standards. AECOsim is divided into three separate packages:

- AECOsim Building Designer: is a 3D modeler used to create geometry with direct links to analysis applications for interdisciplinary optimization, generating construction documentation for paper or dynamic PDF output. AECOsim is capable of clash detection and also produce photorealistic images and animations.
- AECOsim Compliance Manager: has been developed to streamline LEED certification. It enables LEED certification teams to manage large amounts of data required for the LEED certification process through automated workflows. It includes a centralized online LEED data repository that

documents electronic submissions providing sophisticated reporting capabilities, historical analysis, and access to past projects for best practices information.

- AECOsim Energy Simulator: has been developed to determine building energy loads and explore building HVAC systems and design configuration options by simulating and analyzing building energy performance using EnergyPlus as the simulation engine. Users can create 2D/3D energy models and documentation and generate reports of peak loads, annual energy calculations, energy consumptions, carbon emissions, and fuel costs. The calculations can utilize customizable runtimes for fast results. All reports are ASHRAE 90.1 compliant. AECOsim Energy Simulator supports standard file formats such as i-model, gbXML, IFC, DXF, and DWG.

ECOTECT. (Marsh, 2000): proprietary tool by Autodesk, but originally developed by Dr. Andrew Marsh, ECOTECT evaluates environmental design, environmental analysis, conceptual design, validation; solar control, overshadowing, thermal design and analysis, heating and cooling loads, prevailing winds, natural and artificial lighting, life cycle assessment, life cycle costing, scheduling and geometric and statistical acoustic analysis. Some ECOTECT features have been incorporated into the new releases of Autodesk Revit Architecture. ECOTECT major feature is the highly visual content, which makes it one of the architectural designers' favorite products for sustainable design analysis. ECOTECT can create models and export to different formats to work in other programs, such as EnergyPlus, Radiance, Daysim, DOE-2, ESP-r and others. ECOTECT can also import 3D models from most used CAD formats, such as .dwg, .dxf, and others. Current versions include a comprehensive scripting engine that allows designers to create parametric changes into the model. This software is intended for providing feedback in early design stages only.

Green Building Studio (GBS). (Autodesk, 2004): Autodesk's GBS is a Web-based energy analysis software that performs whole building analysis to assist in optimizing energy efficiency earlier in the design process. Its data exchange format (gbXML) is now considered to be a neutral and standard format for BIM and energy simulation, and its energy simulation engine is based on DOE-2. The main critique it has received over the years is the "black-box" type of information-processing from GBS, where the user receives an output file without completely understanding some of the assumptions made by the web-service (GSA, 2007).

IES-VE (McLean, D., 1994): The IES Virtual Environment is an integrated system for building performance analysis. It was created in the United Kingdom and it is used by architects, engineers, planners, and facilities managers. Operating from a central building model, IES can simulate multiple green building strategies in one packaged simulation engine, similar to eQUEST, Energy-10, GBS and other energy simulation programs. IES-VE incorporates ApacheSIM, a dynamic thermal simulation tool that can be linked to MacroFlo for natural ventilation and infiltration analysis, to SunCast for detailed shading and solar analysis and finally ApacheHVAC for component based simulation analysis. IES is capable of simulating natural ventilation, HVAC energy performance, natural daylight simulation, life safety evacuation, air movement using Computational Fluid Dynamics (CFD) and life-cycle cost engineering. Autodesk Revit MEP 2010 includes IES-VE as its simulation engine plug-in.

Vasari (Autodesk, 2010): Vasari is a new tool developed by Autodesk, which shares a graphic user interface with Revit for a quick and interactive generation of a GBS 3D thermal model. It is still in a Beta version and has the ability to create, edit and test massing models using glazing percentage, sill height, overhang's depth dimension, plus location and orientation. Current versions include some CFD simplified analysis and other physical behavior simulation.

In the next sub-sections I discuss the use of IDP and IPD as an introduction to the shift from a traditional to a transitional model.

2.6 Integrated Design Process (IDP)

A comprehensive definition of integrated design processes was provided at the National Workshop on Integrated Design Process in Canada in 2001:

> *The Integrated Design Process (IDP) is a method for realizing high performance buildings that contribute to sustainable communities. It is a collaborative process that focuses on the design, construction, operation and occupancy of a building over its complete life-cycle. The IDP is designed to allow the client and other stakeholders to develop and realize clearly defined and challenging functional, environmental and economic goals and objectives. The IDP requires a multidisciplinary design team that includes or acquires the skills required to address all design issues flowing from the objectives. The IDP process proceeds from whole building system strategies, working through increasing levels of specificity, to realize more optimally integrated solutions. (Zimmerman, 2002)*

According to the report (2002), the main components of the Integrated Design Process are the following:

1. Interdisciplinary work between designers, engineers, operations people, costing specialists, future occupants and other significant actors participating at the beginning of the design process;
2. The addition of a specialist in the field of sustainability, energy performance and comfort;

3. No separation between individual building systems in the total budget. Budget restrictions are set at the whole-building level;
4. Discussion of the importance of performance issues, and a consensus on building performance between the client and the architects;
5. Clear definition of the performance goals and strategies that will be updated throughout the design process;
6. The addition of subject specialists, such as daylighting, for specific consultations with the design team;
7. Development of various design alternatives that will be tested with energy simulation, to provide evidence-based design choices.

Kow & Grondzik (2007), state that IDP is “knowledge applied in parallel”, which refers to a simultaneous interaction among stakeholders, while conventional design is “knowledge applied in series”, which is a linear sequence of steps rather than simultaneous activities. According to the authors, the steps towards an IDP are: (1) establishing commitment; (2) team formation and setting goals; (3) information gathering; (4) conceptual/schematic design; (5) testing of design alternatives; (6) design development; (7) construction; and (8) assessment/verification (Facility Management and operations of the building).

The main difference between IDP and Integrated Project Delivery (IPD - discussed in the next section) is in the contractual agreement. An IDP does not necessarily bind stakeholders into risk sharing/benefits or liability issues. The collaborative environment and common goals of high performance buildings are shared in both concepts, but IPD goes one step further in terms of creating the legal framework for the team. In summary, IDP is possible without IPD, but an IPD is not possible without IDP.

2.7 Integrated Project Delivery (IPD)

IPD, as mentioned before, stands for Integrated Project Delivery. Several states in the U.S. have created guidelines to facilitate high-performance designs that highly suggest the incorporation of Integrated Project Delivery principles. Pennsylvania created the Governor's Green Government Council (GGGC); the City of New York Department of Design and Construction created the "High Performance Building Guidelines"; and the Government of North Carolina created the Triangle J Council of "High Performance Guidelines: Triangle Region Public Facilities" (1999). Contractors are beginning to realize significant improvements in several areas of project performance (FMI, 2012):

- Schedule reduction and earlier revenue generation by building owners;
- Productivity improvements;
- Reduced rework;
- Fewer field conflicts and crisis coordination in the work area;
- More collaboration and less conflict between project stakeholders.

Contractual delivery models are based upon agreements on responsibilities for each stakeholder in every phase of the project design. The most common models for project delivery are shown below in a rank from worst to best according to the IPD principles (AIA, C. C., & Hill, M., 2007):

- Design-Bid-Build (also called Hard-Bid);
- Multiple Prime;
- Design Build under Best Value Selection with Bridging;
- Construction Manager at Risk;
- Design-Build under Best Value Selection with Criteria;
- Design-Build under Qualification Based Selection;
- Integrated Project Delivery.

However, my study is limited to the delivery models that were brought into discussion from the participants during the interviews: Design-Bid-Build, Design-Build and IPD.

Variations of IPD models can be found in the AIA IPD model contracts, the AGC IPD (ConsensusDOCS 300 series) model contracts and the Alliance contracting forms. However, not every delivery model incorporates all the IPD principles. According to the AIA Integrated Project Delivery Guide (AIA, C. C., & Hill, M., 2007), the IPD principles are:

- Mutual respect and trust;
- Mutual benefit and reward (sharing risks);
- Collaborative innovation and decision making;
- Early involvement of key participants;
- Early goal definition;

- Intensified planning;
- Open and enhanced communication;
- Appropriate technology (BIM);
- Organization and leadership.

“ ut ual respect and trust” represents the commitment of the team to work collaboratively towards the common goal. “ utual be nefits and rewards” means that all stakeholders will share the savings, bonuses and also risks. “Collaborative innovation and decision making” is an interdisciplinary effort to achieve the best possible outcome puts the focus on the project rather than the protection of self-interest. Any team member with an “attitude” should be eliminated from the team. “Early involvement of key participants” means that the three groups (owner, designer and constructor) will be actively involved in the decision making of the design and construction process since the very beginning. “Early goal definition and intensified planning” relates to the former idea of early involvement, where the goals for the project in every aspect will be defined by the entire team. “Open and enhanced communication” stresses the importance of Web-based or BIM transparency for information management during the design process, towards an open, direct and honest communication. “Appropriate technology” relates to the use of open standards (such as BIM tools, IFC, gbXML) to solve interoperability issues that may arise. “Organization and leadership” looks for specific roles in leadership (champions) by members of the team, to improve communication and reduce risks.

Although IPD is possible to achieve without using BIM, the AIA report on Integrated Project Delivery (AIA, 2007) recommends BIM as an essential driver with the potential to support IPD activities.

2.7.1 Critique of Project Delivery Methods

The Design-Bid-Build (DBB) model is price-driven. If we observe the DBB delivery model, the constructor is not allowed to participate in the conceptualization of the project, which breaks one of the rules or principles of the IPD process immediately (collaborative innovation and decision making). In addition, general contractors bid on the project, with the lowest qualified bidder being selected, which attempts to the high quality goal of the project. Moreover, although a project using this model can be theoretically delivered, the tension and conflicts among participants often results in higher costs from change-orders, repairs and lawsuits, which again, attempts against the mutual benefits and rewards principle, along with the mutual respect and trust (Kibert, 2008). However, some of the IPD techniques could be used until a certain degree, such as design assistance from an external agent (not a potential bidder); the use of BIM in a primitive level; and web-based information sharing (a service system that provides messaging, sharing documents, file hosting and updating, task management, milestones and team directories). The DBB model offers very few opportunities for integration in the design process (AIA C.C., 2007; CMAA, 2010).

The **Design Build** (DB) model has three variants: (a) “Qualification Based Selection”, which is based on the selection of the best organization for the project; (b) “Best Value Selection with Criteria”, where documentation provided by the owner establishes the selection based upon qualifications, design and price), and (c) “Best Value Selection with Bridging” where the documentation is also provided by the owner, but price-driven based, rather than qualifications and design. In the DB model, the design team which is also the constructor has the sole responsibility on the design and construction process. The advantage is risk reduction for the owner since the design and constructor is one single entity. The DB model requires the early involvement of the owner in the project criteria definition, establishing the level of quality expectations, quantitative performance requirements, etc. However, as soon as the construction process starts, the owner’s participation is decreased. The owner must be careful to not have too much control over the construction process to avoid assuming unwanted risks. DB is permitted for some public work in the state of California, and it is the only traditional project delivery model where the owner can be removed from risk associations with the project. The advantages of this model can be seen as an improvement in the project delivery time (the designer-builder wants to finish it as soon as possible to start another project), and cost savings. In addition, since the designer and constructor is one single entity, usually there is an established rapport and an efficient and coordinated working system between the design portion of the team and the constructor portion. Because the DB team has sole responsibility for the project, collaboration is facilitated. The clarity of responsibility and authority can also improve interdisciplinary interactions with design consultants, sustainability consultants, the use of BIM, etc. A challenge for this model is to establish the benefits of saving time and costs for the designer-builder (AIA, C.C., 2007, 2009).

Finally, in the **Integrated Project Delivery** (IPD) process, the owner is part of the team by contract and is constantly involved in the design and construction process, while in the DB process the owner involvement may vary across a spectrum. The success of the IPD implementation depends upon the ability of the stakeholders to meet their commitment to one another (Kymmell, 2008). The AIA Integrated Project Delivery Guide (2007) discusses in its chapters the following issues:

- Principles of IPD (previously mentioned);
- The setting up of an integrated project (team formation, communications, BIM, defining roles, scope, goals, cost, schedule, quality, performance and legal considerations);
- Delivering an integrated project (building the team and establishing the design/construction stages);
- Multi-party agreements (contractual issues); and
- Delivery model commentaries.

As mentioned before, the IPD process includes a multi-party agreement (owner, designer and constructor), a single purpose entity and an integrated form of agreement sharing risks and rewards among participants. Multi-party agreements vary in form, but they share several key attributes (AIA C.C., 2007):

- Participants are bound under a single agreement;
- The agreement creates a temporary organization of management and decision making processes;
- Decisions are made upon unanimous consensus, and seek “best for project” outcomes;
- Compensation and rewards are tied to a team, not to an individual effort;
- Processes are customized to support a collaborative environment; and
- Roles are decided upon “best person” or entity qualifications.

The IPD is a temporary, but formal contract to execute a particular project. One difference between the IPD and the DB model in contractual agreements is that a savings clause is possible in DB when using Lump Sum or Guaranteed Maximum Price (GMP). However, the designer-builder services in DB are often not specified, such as criteria developments, evaluations of alternatives or other work prior to the definition of the GMP. Regarding risk allocations, the differences between IPD and DB can be seen in the Table 2 (adapted from an AIA C.C., 2009):

Table 2: Differences in risk between IPD and Design-Build.

Risk	IPD	Design-Build
Design risk	Collective	Designer-builder
Construction risk	Collective	Designer-builder
Unforeseen/differing site conditions	Owner	Owner
Force majeure risk	Owner	Owner
Scope changes	Owner	Owner

In the IPD model, the owner guarantees project costs, which includes allowing the "target cost" to increase for changes that are not caused by the designers or builders. In the Design-Build model, the designer-builder warrants the competence of the construction documentation and assumes construction risk. The owner, on the other hand, assumes risks that are not caused by the designer-builder. Before the owner should consider using an IPD model, the following conditions should be analyzed (AIA, C.C. 2009).

- Legal limitations: public or private;
- Owner personality: capacity to trust, to be innovative, decision making ability;
- Owner objectives: collaborative and integrated design process, amount of control over the design process, fixed budget, earlier completion of the project, etc.;
- Project requirements: complexity and size of the project;
- Finance: willing to spend more up front and less later on;

- Stakeholders: efficient design review process, internal experts or ability to hire third party expertise, sensibility of end users or the local community;
- Market: availability of qualified and experienced stakeholders (designers and constructors), availability of workers and materials for the construction process.

It is worth mentioning that at the very beginning of an IPD session, the tri-party leadership (owner, designer and builder) may agree to seek a green building rating certification. The reason for owners to desire green building ratings is based on the higher market value the building obtains after certification, especially if the building represents a brand or a public institution.

AGC (Associated General Contractors) ConsensusDOCS contracts are one form of IPD and were developed in collaboration with owners, contractors, subcontractors, specialty contractors, sureties and design professionals to protect the best interest of the project. The contracts under ConsensusDOCS forms were drafted by experts in the AEC industry, and assign risks and align the project team according to the owner’s goals. The objective of the contracts is to reduce cost contingencies and disputes between stakeholders, and to obtain maximum advantage out of the project team, getting the best contractors, prices and project outcomes. Similar to the AIA IPD model and the Alliancing model, the AGC model favors a collaborative approach to design and construction, and a consensus between all stakeholders about the overall success of the project as a common goal. The three models are trying to change the traditional price-driven delivery model of construction, where the quality of the project is in constant jeopardy. The “best for the project” approach is also used under the AGC contract model (AGC, 2010). The ConsensusDOCS300 series was developed for IPD contractual agreements. It comprises 3 sections: 300 (tri-party agreement), 301 (BIM Addendum) and 310 (Green Building Addendum).

In the 300 Tri-Party Agreement, the owner, designer and constructor sign the contract at the very beginning of the process, where they are required to collaborate in the planning, design, development and construction of the project. The decision making process relies upon a consensus among the parties. In addition, distribution of project risks and rewards are different from distribution of risks and rewards using traditional contracts, and no GMP or lump sum is established, so the participants will not have a conflict of interest or counterproductive behaviors. The right to audit establishes that collaboration should be based upon transparency of decisions and open-book accounting. However, the parties establish a benchmark for measuring the overall success of the project, the performance of each party and how the saving/losses will be distributed. Lean construction is also a requirement during the whole process and the implementation of “lessons learned” is sought by the AGC ConsensusDOCS300 for constant improvement through continuous assessment. One difference with the other models is that the designer keeps the ultimate responsibility according to state licensing laws. Another unique consideration under the AGC model is that disputes should be resolved in a consensus with the management group, but when there is no consensus, the parties can opt for using a project neutral party or a dispute review board to diminish the costs, time and overall impact of disputes (AGC, 2010).

The 301 Building Information Modeling Addendum (BIMA) is intended for use on projects where the owner desires the utilization of BIM models. The Addendum globally addresses legal and administration issues related to BIM, such as the conversion of 2D documentation to 3D documentation. The use of BIM models can improve communication among participants sharing data for estimating quantity, geometry or any other metric information. A BIM execution plan is also included in this addendum to determine the reliance for the BIM model. Again, the 301 BIMA is based on a collection of best practices in the AEC industry, and it is divided into the following sections: (a) Definition of Affiliated Contract; (b) Definition of Contract Documents; (c) Definition of Governing Contract; (d) Information Management; (e) Record User Role; (f) Record Contact Information; (g) Meeting and Conferring on BIM Execution Plan; (h) Object Property Data; (i) Object Constitution Data to define what information a particular model represents; (j) Project Owner‘s Entitlement to use Full Design ode l after completion of the Project; and (k) Non-exclusive License that entitles every stakeholder to rights to use it even after the construction process is done (AGC, 2010).

Finally, the 310 Green Building Addendum (GBA), was developed using contractual best practices to collectively identify the participants, define their respective roles and goals for the project, and the implementation and coordination efforts necessary for achieving high performance buildings, especially if the owner is seeking a green building rating certification. Furthermore, the GBA addresses the allocation of responsibility and risk, sharing of liability, and changes to the design/construction of the project in order to achieve green building goals, as well as commissioning of operations. A Green Building Facilitator (GBF – entity or person that could also be an independent third party consultant) is defined to identify, coordinate, implement and submit the required documents for green building program certification or to achieve the established goals. The GBA is flexible in operation, adapting the collaboration process according to the participant's skills and knowledge, or complementing it by hiring third parties. However, for projects on a design-build delivery track, the GBA would need specific changes to address the design and construction responsibilities within a single entity or Project Participant (AGC, 2010).

There are other alternatives of contractual agreements to IPD, such as Alliance contracting, but it is not discussed in the present study because it has not been used yet by any of the participants in the sample. Nonetheless, Alliance contracting is an alternative of IPD successfully implemented in Australia.

To conclude, the common pattern between the AIA IPD and the AGC ConsensusDOCS300 are: (a) tri-party agreements (owner, designer and constructor); (b) the active participation of the owner (leadership) in the whole process; (c) open information sharing; (d) an integrated project team based upon high qualifications from the participants (CURT, 2006); (e) sharing risks and rewards; (f) liability waivers; (g) unanimous decision making during the design process; (h) processes modified to improve communication (BIM, web-based sharing information, etc.); and (i) early involvement of all stakeholders.

As revealed, the process of design is changing for sustainability. The adoption of multidisciplinary design teams often includes revisions of the design by specialists to assure maximum performance. To respond to ambitious goals like the 2030 Challenge, building performance assessment will play a key role by providing lessons on how to improve designs, as explained in the next section. To continue with the topic, I discuss next the combination of BIM, IPD and BES in a sustainable design environment.

2.7.2 Combination of IPD, BIM and BES in a Design Process

The literature suggests that any of the three concepts of IPD, BIM and BES have helped significantly the design of high performance buildings (Torcellini et al., 2006; Tupper & Fluhrer 2010).

Schlueter & Thesseling developed an Autodesk Revit API program to link Revit parametric modeling capability and energy performance testing, with a mathematical model for the calculation derived from the German Energy Conservation Regulation and the Swiss regulations. Utilizing BIM to realize fast energy and exergy simulation leads to a more integrated view of building performance in earlier stages of design, improving the interdisciplinary quality of the process. They used a prototype tool called DPV (Design Performance Viewer) for mathematical models of calculation of energy and exergy (Schlueter & Thesseling, 2008).

Integrating BES with BIM is an area of interest for researchers. The complexity of BIM requires simplification in order to effortlessly form thermal envelopes and zones for thermal simulation (Bazjanac & Kiviniemi, 2007, and Bazjanac 2001). These papers explain the problems faced in data exchange from a BIM tool to an energy simulation tool. For example, windows are modeled with detailed frames in the BIM, although the frames may not contribute significantly to accuracy of thermal simulation. The articles also include a comprehensive background on BIM and data exchange issues, and some of the tools currently used for that translation/reduction/simplification process.

Ali (2010), analyzed the workflow for conducting energy analysis from BIM tools (Autodesk Revit MEP) to Trace 700 V.6.2.4 (Trane, 1972), and suggests best practices to minimize the time spent in the whole procedure. From Revit, the user is able to export a gbXML file, which is then imported into Trace, but it is important to notice that shading elements will not be transferred into Trace. Time to construct a model, time to create the analysis, time to run parametric analyses and time to process the results between different computers (network or stand-alone machines, different processors and memory RAM) are discussed. The author recommends the architectural team to be well-versed in Revit to understand how their components will be interpreted in the Trace model, and energy modelers should also be well-versed in Trace. The experience using the programs from both sides (architectural team and energy modelers) is highly important in order to get a satisfactory level of productivity. High-end workstations reduced processing time by 64% over a conventional desktop. This paper addresses the workflow from a BIM tool to a thermal model tool from an individual user viewpoint, but does not address the strategies regarding computer equipment and information management from a design firm prospective.

Tupper and Fluhrer (2010), state that in the typical design process, design teams use energy modeling as an accounting or code compliance tool, while in an IPD process the energy modeling should inform the design and facilitate a comprehensive LCC analysis. Delivering modeling outputs in a timely manner in easily understandable metrics (such as currency) is important to aid the decision-making process and final selection among the design alternatives. This paper presents strategies to help energy modelers to provide critical information that will impact the decision-making process during each design phase. The key ingredients for a successful design process of an energy efficient building are:

- An educated, motivated and committed building owner;
- A talented, innovative and committed design team; and
- An Integrated Design Process (IDP).

Other important steps to follow in the integrated design approach are:

1. Define needs or service required;
2. Identify appropriate measures for a specific building and climate;
3. Reduce loads through passive design strategies;
4. Plan system layouts to reduce pump and fan power;
5. Select appropriate and efficient technology for system types;
6. Optimize operation (control and demand response measures);
7. Seek synergies to assess water streams and other resources; and
8. Explore alternative power (renewable energy, purchase green power or carbon offsets).

The authors suggest the use of baseline models (e.g. ASHRAE 90.1 2007 Appendix G model as a base case) to project overall energy saving goals (e.g. 40%). According to the authors, in the Schematic Design phase of an integrated process, the energy modeler should focus on:

1. Building siting and orientation;
2. Exterior envelope constructions;
3. Glazing size and location;
4. Thermal zone and space configuration;
5. Shading and daylighting strategies;
6. System features that impact floor or ceiling space (bigger ducts); and
7. HVAC system options.

For Design Development phase, the energy modeler should pay attention to:

1. Evaluating specific design options and decisions by updating the energy and LCCA models;
2. Periodically reviewing the design for variations from recommendations and continuously referring back to the original goals;
3. Evaluating and suggesting specific products/manufacturers to achieve the recommendations from schematic design;
4. Optimizing control strategies;
5. Ensuring that all thermal comfort and IAQ criteria are being satisfied; and
6. Revisiting how measures are modeled to improve accuracy.

This paper is important because it suggests the use of baseline models according to the ASHRAE 90.1 Standard, which represents a metric system or protocol to evaluate building performance from the beginning of an IPD process. However, it falls into a prescriptive category, rather than performance-based, where the last seems to be a better approach to sustainability and to pursue innovation.

At Autodesk University 2011, Levring and Nielsen (2011) presented Schematic Strategies and Workflow for Sustainable Design Development, with proposed workflows for different software suggested for a particular design stage, optimizing interoperability and the overall design process. The idea is to put these processes and knowledge into a schematic overview through awareness of design themes in relations to design phases, linked to the use of simulation, modeling detailing and capabilities in different software applications. The authors stressed the importance of having a clear strategy in different aspects of the design workflow, such as business, management, organization within the firm and communication. Also the infrastructure plays a key role by providing design phase specific workflows, libraries for materials and templates for translations from different software applications. However, the authors explicitly claimed that this proposed workflow is not enough to make an efficient design process. To make it adoptable as an efficient business and implementation strategy for multiple companies and projects, it is required to have a basic understanding of design methodologies to create value as individuals and as a design firm.

Vallero and Brasier (2008) described the transformations in the design process for sustainable design, and indentified two models: the linear model and the transitional model. The main difference in the goals of both approaches is that in the integrated (green) design process, the environment, comfort, safety and health of occupants is the priority. The other difference is the technological advance of integration that is available with BIM. The book clearly explains the changes in the design process after the introduction of digital technologies and the aim for high performance/sustainable buildings. Nevertheless, it does not distinguish between two different warrants for decision in the design process to sustainable design: tacit knowledge and explicit knowledge, and how the use of technology can differs in both cases. Moreover, it fails to discuss the problems of the transitional model, where some LEED Platinum certified buildings consume more energy than “code compliant” buildings of an equivalent type (Torcellini et al., 2006). This exemplifies failures to the prescriptive approach to sustainability of older versions of LEED.

(Krygiel & Nies, 2008) describes the experience at BNIM Architects and how BIM adoption was successfully implemented in their first trial under the tutelage of BIM experts, delivering the project seven months ahead of the original schedule. Inspired the great success, BNIM decided to depend entirely on internal expertise on a second project, but that trial resulted in a failure. The explanation was that the company was excited and confident about the possibilities of BIM, so for the second project they tried to do too much with BIM too soon, with no backup support from other companies or experts. BIM learning curve is steep, so it is recommended a well-planned step-by-step process while transitioning.

Contemporary tools for BIM and simulation are being continuously integrated with the IPD process. The combination of design data, fabrication data, construction management data, and clash detection in a single database makes BIM a catalyst for collaboration during the IPD process. Moreover, after the project is built, the owner can keep using the model for Facility Management purposes (planning, furnishing, monitoring energy performance, maintenance, etc.). BIM tools can improve communication between different stakeholders accelerating the design process and reducing waste in the construction process (Eckblad, 2009). Without BIM, the chances of having errors during the process will be increased significantly, which could delay the delivery time, add cost to the process of design and construction, generate burden into the design team, etc. The phases of a construction project can be closely related, and even overlapped. The process parameters section, as seen in Figure 2, are a good fit for BIM and simulation capabilities; and in the project deliverables, BIM and simulation overlap.;

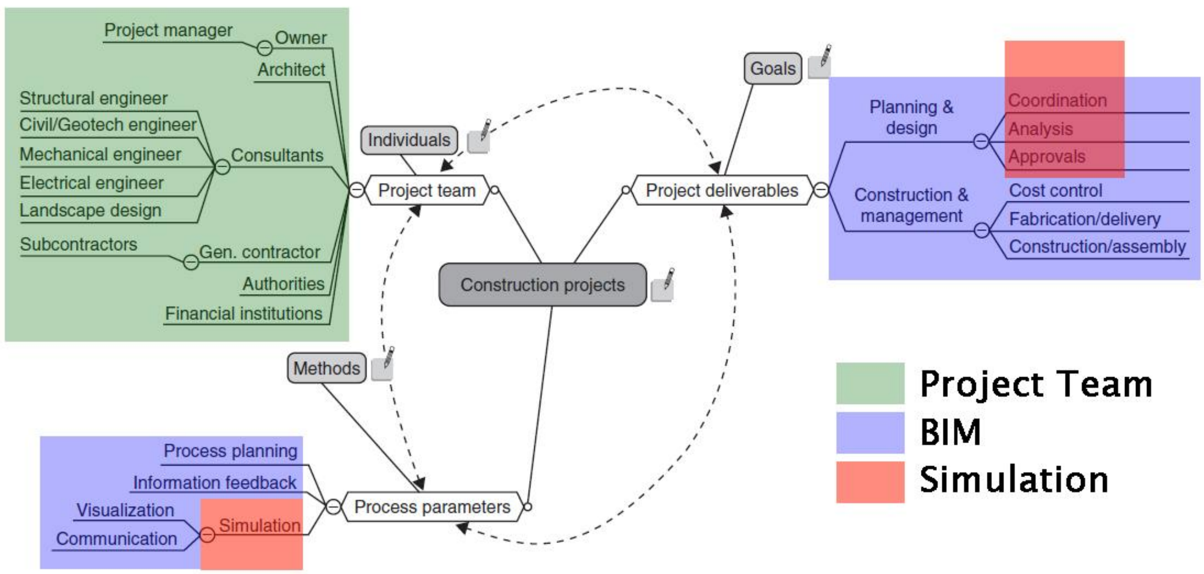

Figure 2: Relationships among the components of a construction project (adapted from Kymmell (2008)).

According to Torcellini (1999), the inclusion of energy simulation is highly recommended in an IPD process, as well as the inclusion of BIM. The idea of whole-building design approach is to enable the multidisciplinary design team to interact throughout the design process. The process relies significantly on energy simulation and includes a design charrette involving all members of the design team establishing energy goals early in the process. According to the author, the best time to define performance goals is at the beginning, before any design concepts have been developed. (Torcellini, 1999)

Following the author, energy simulation in pre-design helps to quantify goals and identify areas with high potential for energy savings/peak reductions. The author states that energy simulation is crucial to understand the impact of design decisions regarding building performance, where the ability to affect the design decrease rapidly as the design proceeds.

According to Erin McConahey from Arup Engineers, their use of multiple tools is a must in order to get a comprehensive understanding of all the variables that could make a design perform better, and to better engage the client into the sustainability issues of a project:

> *Our experience at Arup is that the use of multiple tools is usually required to achieve a holistic view of key design decisions… For each alternative we were able to list:*
>
> *-the statistically probable percentage of daytime hours that natural ventilation could be used,*
>
> *-the first cost investment,*
>
> *-the energy saved,*
>
> *-the total 25 year life cycle cost,*

-the anticipated range of internal temperatures experienced,

-the annual hours of maintenance,

-the relative amount of water used, and

-the number of LEED points achieved.

This allowed all of the stakeholders to have an informed discussion of the project goals with sufficient information for each party to understand the compromises that they might experience… The synergistic interactions of disciplines that could formerly act independently is becoming crucial in our ability to deliver high-performance building designs that move towards reduced use of natural resources. (E. McConahey, A note on tools – e-mail, 2011, April 14)

Several case studies developed in combination with the three concepts have reported great success, which validates the significance of them in different grades, according to individual situations (Cohen, 2010). In the next section we will see through a series of cases how a combination of IPD and BIM generated optimum results. The use of simulation is not mentioned, but was likely a part of the process.

2.7.3 Cases of Combining IPD and BIM

This section presents a selection of case studies to show the performance of an IPD process combined with BI , and the final outcome according to the stakeholder's experience.

The **Autodesk AEC Solutions Division Headquarters** is an office building project near Boston that incorporated early involvement of all key participants in the project (Cohen, J., 2010; cCrarey, E. 2009). The RFP clearly explained the owner's sustainability goals, budget, and the type of agreement. Three major subcontractors were selected to be involved in the risk and rewards structure through creation of an Incentive Compensation ayer (IC). In the IC (with adjustments of ± 20%), architects' and builders' anticipated profits were put at risk but incentives for high performance were also established. If the delivered project exceeds expectations, both firms are eligible for some compensation. Otherwise, if the goals are just met according to the original expectations, then designers and builders will receive the normal profit. A multi-party agreement was set up with clear distinctions in roles and responsibilities. A project implementation team was set up to manage the daily issues of the project, while a project management team (represented by the owner, architect and builder) managed the overall project by consensus. If a problem arose with no solution or consensus, a senior management team with representation of the three major parties would find a higher resolution of the problem. The parties waived all dispute against each other, with the exception of fraud, willful misconduct or gross negligence. In case of a dispute, mediation or arbitration (in the worst scenario) would resolve the issue. A building advisory team was set up to provide programming input from occupants, which revealed conflict of interests (privacy in offices) between certain groups of users. However, that was finally resolved following the originals goals of sustainability (daylighting) and collaboration in the work environment, which led to an open space configuration. A criterion to judge success was developed, including schedule, budget, sustainability, quality of design and craftsmanship, and functionality. The three parties jointly selected three comparable buildings in the Boston area to define a benchmark, so the evaluation could be made by an external agent or person. The design and build team was given an overall and established budget, but they had freedom to move the money among line items. For example, if the cleanup could be achieved by lower wage workers at night, instead of paying higher rates for other workers to do the same task, the savings could be placed back into another area of the project. A BIM execution plan set rules for who modeled what and when, as well as agreements for data storage. The design was dramatically changed during the design process, and three design alternatives were evaluated by the parties to comply with the desired changes. Virtual walk-through helped the team to make decisions. Design fabrication was implemented using Computer Numerical Control (CNC) machines. The lessons learned in the process were that interoperability with BIM was still an issue (MEP and millwork subcontractors did not use Revit), and that the use of the BIM model for use in operations was not mature yet (real time monitoring and maintenance scheduling was not possible). Close collaboration with builders reduced detailing work, which gave architects more freedom to spend more time on site, rather than reviewing Request for Information (RFI) and submittals. Final design/construction cost was lower than the contract target. Architectural, Engineering and Construction (AEC) profits exceeded typical values, as did the final construction quality.

The **Cronkite School** is a build-to-suit venture by the City of Phoenix for Arizona State University (ASU). The six-story, 230,000 square foot project consists of academic classrooms and offices for the School of Journalism and Mass Communication. The City of Arizona had been using CM-at-Risk exclusively for several years and released a public Request For Qualifications to select an architect and builder together, based on qualifications and with no price attached. Both the City and the owner desired LEED certification (Silver or higher). The builder (Sundt) brought in their preferred mechanical, electrical, and glazing subcontractors to the selection committee and started working simultaneously with Ehrlich/HDR (design and executive architects). HDR provided mechanical, electrical, and plumbing engineering in house, while Sundt chose its subcontractors in a qualifications-based process, with fixed fees but with open book accounting of costs. The City of Phoenix had an obligated and inflexible design-build contract, which did not permit a shared "pain and gain" strategy, and budget/schedule were absolute. Also, the tight schedule and the lengthy review process of the model imposed by the City required many aspects of the design to be fast tracked. Subcontractors were required to use BIM, but there was no standardization of software platforms, which led to problems in translating models back and forth between Autodesk Architectural Desktop and Autodesk Revit. There was no time to train staff on new software. In addition, full BIM coordination was not possible until the 3rd floor was erected. The design team developed alternative schemes and takeoffs in 3D, testing the cost of different design ideas with input from all of builders in a big room provided for the meetings. Money savings from efficiencies in the design/construction were returned to the project for value-add items. Nonetheless, many IPD characteristics were added in place on a non-contractual basis. The contract was a two-way owner/designer-builder multi-party contract as required by City procurement regulations, but the team made a conscious decision to sign the contract without letting it dictate their behavior. An Executive Committee had meetings every week with the presence of all participants and stakeholders. Decisions were made by consensus to achieve such a forceful schedule. The standard City of Phoenix inflexible contract included a limitation of consequential damages provision but also a “no-sue” clause. Owner, architects, and builder decided how to spend the funds for maximum gain. Early in design, the budget would not suffice for the entire program the University asked, but ASU was able to find an additional $2 million budget to fill the gap. However, the efficiencies achieved during construction and buyout permitted the entire program to be achieved without spending the extra $2 million (Cohen, J., 2010).

The **Sutter Health Fairfield Medical Office Building** is a three-story, 70,000 sq. ft. medical office, built in Fairfield, California. Sutter Health is the owner, Boldt is the builder and HGA is the architecture and engineering firm. A three-way agreement was made to bond the owner, builder and designer very early in the process. The Integrated Form of Agreement (IFOA - another IPD type of contract that includes a “no sue” clause) created a shared risk system with the objective of reducing overall project risks. Sutter IPD projects used incentives from project savings and pooled profits to reward designers and builders, along with subcontractors and sub consultants. Smaller subtrades were bid with lump sum prices. All books were open and designer/constructors were responsible for construction errors or omissions. An Integrated Project Team (IPT) met weekly throughout the process, while a higher level Core Team met monthly to check for issues passed up from the IPT. If any decisions could not be unanimous, they were referred to an Executive Level committee represented by the three partners. Despite a three month delay for reprogramming and the addition of extra scope at the beginning of the project, the building process achieved successful delivery in 25 months as planned. BIM was used extensively together with clash detection, and provided significant cost savings due to improved field productivity, tighter schedule, less redesign, and more pre-fabricated work. BIM was also used with GPS measurement to drop ductwork hangers. This layout task usually would take 2 or 3 weeks to be completed, but the use of technology allowed it to be completed with great accuracy in 2 or 3 days. The ability to work interactively between the design team and subcontractors was highly appreciated, and much less detailing work was required. More than 50% of the submittals were processed paper-less. Sutter was very pleased with the building and the overall process being under budget and within schedule. Change orders were almost nonexistent. According to participants, preconstruction design assistance was vital in earlier stages of design through coordination of MEP and fire protection. Additionally, Boldt perceived that exterior glazing and skin should also be one of the early selected subtrades that fully engages in early design (Cohen, J., 2010).

The **New York Times Building**, designed by Renzo Piano Building Workshop in conjunction with FXFOWLE was a collaborative effort during the whole process. Piano was not familiar with the local practices, and consequently FXFOWLE was included on the team to provide the additional expertise. It was necessary to establish a team of 30 to 40 different consultants, and a consensus was made about having monthly meetings with Piano's crew, alternating locations between Paris and New York. In the early stages, some staff from Piano's office stayed in New York full time, and occasionally, some members of the US consultant team were in Paris for extended periods. The engineers were brought into the process right at the start and participated in all of the weekly team meetings with the owners (Yudelson, 2009).

Bedrick, Eckblad & Rubel (2009) states that according to the Construction Industry Institute, the total project cost reduction under an IPD process can be up to 10% overall. If the individual aspects of a project are analyzed, the cost reductions in construction administration can be 24%, value engineering can have a 337% increase, profitability can increase by 25%, the number of Request for Information (RFI)reduced by 83%, and finally, the number of projects with RFI decreased by 68%. Although the different forms of IPD includes a comprehensive set of guidelines on the overall process of an integrated design, they do not define standard procedures for the assessment and verification of building performance. To address that issue, the U.S. Department of Energy created the *Building Cost and Performance Metrics: Data Collection Protocol* (Fowler et al., 2009), and the ASHRAE created the *Performance Measurement Protocols for Commercial Buildings* (2010).

Although there is a large and growing literature to describe design methods for sustainable buildings, there is yet no well-documented or standard process. Most of the literature shows that the three concepts of BIM, BES and IPD are related, or that one can provide leverage to another. Researchers seem to agree about the holistic approach necessary for sustainable design, fostering a multidisciplinary effort and embracing a radical change through the implementation of high technology. Building energy performance assessment methods are currently not fully adopted, although some versions of GBRS are requiring them. BIM interoperability problems are a concern to facilitate BIM adoption and to realize the full potential of the technology. Simulation is being increasingly adopted in a design process to predict and improve a building's performance. IPD and IDP are considered critical aspects of the transitional design model and seem to have a synergetic effect on BIM and simulation. Case studies have shown the benefits of combining IPD with BIM.

The next section will present the research methodology and the theoretical framework for implementing it in my research, as well as data collection procedures and delivery methods.

3. METHODS

In this section, I explain the theoretical framework for qualitative research and the overall methodology, including the interview methods employed, delivery methods, data analysis techniques and a discussion about reliability and validity issues with qualitative research. I also discuss the challenges of a qualitative exploratory research approach in relation to the Architecture, Engineering and Construction industry.

3.1 Overview of Methods for Qualitative Research

This research relies upon a largely qualitative research method and case studies to explore complex interrelationships among behavior in relation to technology in architectural firms. In built environment research, researchers use the real-world context of the AEC industry as a site for developing research questions and to conduct empirical work to examine hypotheses (Harty & Leiringer, 2007). Philosophers such as Popper (1972) demonstrated the structural problems of induction and theory of independent observation. It is arguable that in social science, the appearance of the various schools of interpretivism such as phenomenology and hermeneutics were legitimized. Similar trends emerged in management science with soft systems methodology (SSM) and other soft operations research (OR) approaches. The new perspective of 'methodological pluralism' attempts to achieve greater validity through the use of multiple research methods (Knight & Ruddock, 2008).

The basic principle of methodological pluralism is the legitimate and desirable use of multiple theoretical models and methodological approaches (Knight & Ruddock, 2008). Some scholars argue that quantitative and qualitative methods should be combined, since theory building requires 'hard' data for uncovering relationships and 'soft' data for explaining them (oosemore et al., 1996).

Questionnaires are research instruments to be used in different settings (survey, phone, interviews) and are intended to measure something, including people's attitudes. If the measurement is looking for association or causality, then the survey is said to be analytical (Oppenheim, 1992).

According to common research practice, each question in the survey generates a variable, which is usually coded with a number assigned to each possible response. It is vitally important to be aware of the type (or level of measurement) of each variable. Another type of variable commonly used in surveys is ordinal, which is created by ordered categories, such as attitude scales (Likert, 1932). Levels of measurement are important to be distinguished when applying appropriate statistical analysis techniques to the data gathered by the questionnaire (Knight & Ruddock, 2008).

In summary, researchers need to avoid subjectiveness and bias, whether using qualitative or quantitative methods. However, qualitative research can sometimes be quantified if the sample size is large.

3.2 Alternative Methods Employed

First, I conducted a literature review to identify gaps in the state of the art in design methods for sustainable design. Then, I developed research questions and research objectives to guide my interview schedule, avoiding a priori hypothesis that could preclude unexpected findings of an exploratory approach. Throughout the course of the study I investigated theories of BIM, BES, IPD/IDP and sustainable design, to enable me to reconcile and to relate all the concepts holistically.

Second, I identified firms to include in my sample, based on accessibility to personnel and an extensive analysis of credentials with respect to sustainability. From that tentative list, Texas offices appeared as representative of leaders in sustainability within the U.S. firms and London firms as representative of acclaimed U.K. firms. After that, I started to develop a questionnaire flow-chart that would guide the interviews in a flexible but comprehensive way.

Third, I prepared invitations and consent forms to obtain Institutional Review Board (IRB) approval for conducting research with human subjects. I considered basic ethical issues, as outlined by Willig (2001) and as shown in the Consent Form (Appendix 2). I ran a pilot interview with a local architectural firm to test the efficacy of the questionnaire and to improve its formulation. After receiving IRB approval, I contacted the targeted firms and invited them to participate in my research, following the protocols approved by the IRB. I scheduled interviews with the informants and conducted interviews to discover their insights into the concepts of BIM, IPD (or integrated design) and simulation, and how they use these technologies in the design process for sustainable designs.

Fourth, after the interviews were conducted, I analyzed the raw data by repeatedly reading the transcripts and coding the data for emerging concepts using Thematic Analysis. The a priori categories were used, but additional themes emerged from the data and were used as the basic for additional exploratory analysis. I also used case study methods to analyze the individual characteristics of the participant's offices.

Finally I compiled the research into this dissertation. Figure 3 summarizes the steps and actions required to conclude this research.

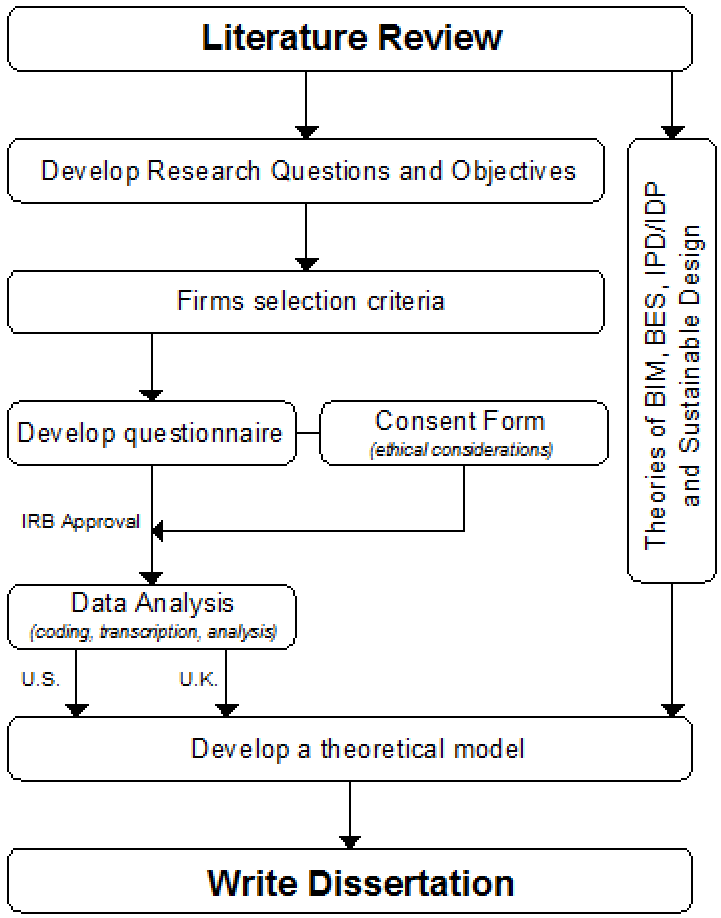

Figure 3: Sequence of the steps for the methodology.

3.3 Data Collection and Procedures

The data were collected using semi-standardized interviews and one focus group aimed at understanding the design workflow of acclaimed designers. I collected qualitative data from design professionals to acquire insight into the interaction of BIM, IPD, and simulation in the production of sustainable design. In addition, a questionnaire was used to collect demographic and contextual information from each participant.

An exploratory qualitative research approach permits the investigation of a research topic with few preconceptions so that the researcher may uncover unanticipated topics and avoid missing important concepts due to too much a priori structure (Knight & Ruddock, 2008). A limitation of post-positivist viewpoints about research is that the subject and the object should be independent, a situation that may be difficult or impossible to achieve in research into social phenomena (Lincoln & Guba, 1985). Due to the nature of my research, which tries to capture experiences and attitudes on sustainable design and the use of technology to aid designers, a qualitative method is a reasonable choice. This study used critical literature reviews, case study analysis and interviews.

Due to the broad topics to be covered in my research, a research design employing multiple participant interviews consisting of guided group discussions of selected topics is an appropriate choice. Advocates of the focus group state that the social interaction between participants allows for a dynamic and insightful exchange of information that would not be possible under traditional one-on-one interviews (Ruane, 2005). Generally speaking, lower levels of moderation are better suited for exploratory research, while higher levels of involvement are indicated when the research seeks answers to specific questions or to test specific research hypotheses

(Morgan, 1996). The problem of the focus group is that it takes longer periods of time to gather the required information for the research. Moreover, it requires more preparation in setting up the appointments (larger number of people to coordinate for a simultaneous meeting) and also it is considered to be the most expensive of all the available methods.

I also used **semi-standardized interviews**, which involve a number of predetermined questions in a systematic sequence, but the interviewer has freedom to use additional questions, called "probes," to gather extra information. This method can still be aided by a set of structured questions. This method is well suited to examine the experiences and attitudes of the designers regarding the improvement or not of design methods using technology. The interaction and use of probes generated under this method provided a deeper insight into the informant's experience and attitudes (Berg, 2001).

Considering that my research analyzes the interactions of diverse tools and technologies that are usually assigned to different members in a design team, a single informant per firm or project would not have been able to answer all of the questions. To address that issue, I tried to involve at least one person in each firm knowledgeable of BIM, sustainability and contractual processes (ideally, one person for each domain). Because there are many areas of expertise involved in my topic, the interview questions were divided into different sections, and each section was presented to a particular individual with expertise in the area. When possible, participants were interviewed simultaneously (multiple participants) to generate a more fluid discussion. This modality also improves reliability of data, so whenever a participant reveals erroneous information, another participant might provide corrections. The interview consisted of open-ended questions for gathering the informants' own experience and perceptions, while being open to unanticipated findings. In one case, a focus group was feasible while in others I conducted one-on-one interviews.

In summary, my research topic was addressed using a combination of interview methods. Fitzgerald and Cox, (1987) only mention two methods –formal and informal– while others refer to interviews as either structured or unstructured (Fontana & Frey 1994; Leedy 1993), even when they follow the same format, respectively. Scholars such as Babbie (2004), Frankfort-Nachmias & Nachmias (1996) extended those definitions to three types: the standardized (formal or structured) interview, the unstandardized (informal or non-directive), and the semi standardized (guided-semistructured or focused) interview.

3.4 Interview Process

For the interviews methods I used seven one-on-one interviews, one interview with four participants with the same background (architecture), one interview with four participants with different backgrounds and e-mail exchanges with two participants. In two cases I used a phone call interview using Skype and recorded the audio. The Skype method was used when either the interviewer or the interviewee could not meet face to face due to budget, travel or schedule constraints. The reason for using different methods was to improve the quality of data collection when feasible. Once the interview was approved by the IRB, I ran a pilot to pre-test the questionnaire study, as recommended by other researchers (Knight & Ruddock, 2008; Ruane, 2005). The piloting process by itself was conducted with experts in a local architectural firm, and was key to correct the formulation of the questions.

Before each interview, I sent an invitation with a brief description of my thesis topic to the informants, so they understood my goals, limitations, strategies and the time required for the interviews. They were given enough detail in the Consent Form so they would understand the purpose of the study, but not enough to influence or prejudice their responses. The possible informants were identified and selected by their involvement with sustainable design, BIM, IPD/IDP and BES. The informants included designers from different hierarchical levels, from founders and partners to more technically oriented positions, such as BIM managers and information technology experts. However, the inclusion of such variety depended on their availability and willingness to participate which was not equal across the offices, so a comparison of roles across the different offices was not possible from this study. The interviews took place in the informant's offices. The number of informants in total was 15 as summarized in Table 3:

Table 3: Summary of Interview and Archival Data.

	Foster + Partners	HKS - Dallas	HKS-London	HOK - Houston	Lake|Flato	TR Hamzah and Yeang	Total
Number of interviews	1	1	1	1	3	1	8
Number of informants	2	1	4	4	3	1	15
Number of pages of transcription	29	15	22	30	26	17	139

All interviews aimed to address sustainable design process in the firms, including the challenges and technical problems faced. In general (with some exceptions based on the conversation flow), I began each interview by asking their familiarity with any of the concepts of sustainable design, BIM, IPD and IDP, and simulation, to avoid asking questions that the interview could not answer. Next, I asked general questions about the hierarchical structure and organization of the firm, such as divisions or departments related to specific building types or design support teams, to see if that affects their design workflow. Finally, I asked about the overall design process for high performance buildings and their use of BIM, IPD and BES.

Each interview was audio recorded (some were video recorded as a backup) with a professional digital recorder with the informant's signed permission (Appendix 2). In case of date clashes where we were not able to meet personally, I used video-conference (Skype) and written responses for specific issues. While the digital recorder was running, I was free to take notes about the names of other people involved with the designs, names of projects that exemplify their achievements, issues they faced, names of people I should contact for further information or questions that remained unanswered. The interviews lasted in general one hour and the participation was voluntary –no compensation was provided. The busy schedule of some participants probably prevented some participants from answering follow-up questions that remained unanswered in initial interviews. All recorded interviews were later transcribed verbatim and used as raw data for analysis and coding.

3.5 Structural and Demographic Aspects of the Firms

I began with a comparison of the structural and demographic aspects of each firm, such as its size, types of professional services provided, organization and personnel. This step was done by treating each firm as a separate case study. Since each firm has its own hierarchical structure, that organizational framework can affect the design process, and their designers can have a different perception about issues in their design workflow. Table 4 details the key actors involved from each office and their respective backgrounds (names were deleted for privacy purpose). Some function titles are equivalent, such as Chief Sustainability Officer, Sustainability Manager, Sustainability Chief and Sustainability Coordinator, as well as BIM Manager and Design Systems Manager:

Table 4: Key actors involved and their position in their respective firms.

Offices	Key actors function	Background
HOK-Houston	Sustainability Manager Associate Architect BIM Manager Simulation/Integrated Design	Environment Management Architecture Technology Architecture
Lake|Flato	Sustainability Coordinator Partner, Contract Supervisor BIM Manager	Mechanical Engineering Architecture Architecture
HKS-Dallas	Principal, Chief Sustainability Officer	Architecture
HKS-London	Associate Principal, Senior V.P. Sustainability Officer Associate Architect Architectural Assistant	Architecture Architecture Architecture Architecture
TR Hamzah & Yeang	Principal, Sustainability Chief	Architecture
Foster and Partners-London	Partner, AR&D Associate Partner, Design Systems Manager	Aeronautic Engineering CAD Management

Information for the structural organization of the firms was partially collected from the interviews and supplemented by information on each firm's website:

HOK: http:// www.hok.com

Lake|Flato: http://www.lakeflato.com/people

HKS: http://hksinc.com/#/about-hks/services/

TR Hamzah and Yeang: http://www.trhamzahyeang.com/features/staff.html

Foster + Partners: http://www.fosterandpartners.com/Team/DesignGroups/1.aspx

The calendar of the interviews follows:

September 20th 2011: HKS-Dallas, from 04:00 pm to 05:00 pm

September 21st 2011: Lake|Flato-San Antonio, from 12:00 to 12:30 pm

September 26st 2011: Lake|Flato-San Antonio (Skype follow-up) from 08:00 to 08:30 am

September 29th 2011: Lake|Flato-San Antonio (Skype call with partner) from 04:00 to 05:00 pm

October 3rd 2011: Lake|Flato-San Antonio (e-mail exchange with Technical BIM)

November 4th 2011: HOK-Houston, from 12:00 to 2:00 pm

November 10th 2011: TR Hamzah and Yeang-London, from 11:00 am to 12:00

November 11th 2011: Foster + Partners-London, from 5:30 pm to 7:00 pm

November 14th 2011: HKS-London, from 12:00 to 1:00 pm

November 23rd 2011: Lake|Flato-San Antonio (e-mail exchange)

3.6 Description of Data Analysis Techniques

After all the interviews were conducted, the data was analyzed using the following techniques:

1. Transcription;
2. Coding;
3. Thematic analysis;
4. Exploratory Analysis.

This coding and analysis led to the formulation of a set of conclusions that are claimed to be of general interest. The conclusions are supported by references to specific comments in the transcripts and are correlated to published literature. The following sections discussed these techniques and how they were executed.

3.6.1 Transcription

Recorded material (interviews) were transformed into text. Three out of the seven interviews were transcribed by the researcher, and the remaining interviews were transcribed by a professional service. Special attention was paid to recording quality and "tidying up" transcribed speech, where inaudible words were marked in brackets with the time of the recorded audio, so I could go back, double check and correct it according to the context. When correction to the transcribed talk was not possible, it was left within the brackets and timeline. The transcription produced 49,979 words of data, provided in Appendix 1.

3.6.2 Coding

To code the transcripts, a number was allocated to the responses according to the following a priori codes:

1. Impact of Hierarchical Firm Organization;
2. Use of BIM;
3. Use of BES;
4. Use of IPD/IDP;
5. Sustainable Design Workflow;
6. Other findings.

Wherever I found a positive or negative perception about any of the concepts from 1 through 5, I classified them as (+) and (-) respectively. Every answer can have several numbers since it can relate to different codes simultaneously. Additionally to the numbers and signs (+ and -), I followed Bijker's (1995) recommendation to focus on four constitutive elements associated with all coding:

a. the goals of the firm;
b. the key problems they have encountered while trying to achieve those goals;
c. the strategies used to solve those issues; and
d. the requirements that have to be met for a solution to work.

Using these four categories, I coded the raw interview data from the sample to reveal how each firm approaches advanced sustainable design methods using technology. According to the coding, a response could have several numbers, letters and signs associated. Example of the coding is shown between brackets:

> *We've had a few clients bring a project, saying they wanted us to use IPD or BIM, but either the project did not move forward or the client changed their mind [2b+-, 4b+-] ... As for the contracts (which I handle within the office), I've reviewed the AIA and ConsensusDocs contracts (have not seen one from EJCDC and don't know that one exists, but expect it does). In general (and in my opinion), the contracts need some work, as they seem short on reality as to the way the construction industry (as we've experienced it) really works [4b-]. Logistically, sharing the model with the Contractor is not an issue [2+], but*

the shared responsibility/liability between the three parties will have to be more clearly spelled out [4d].

We have things like our own materials research library [6c], which literally is a room full of materials. It's like books on shelves but different materials, as well as having a specialist team [6d] who researches materials and will look at all the new materials coming through [6c].

After coding all transcripts, I reviewed them and started thematic analysis.

3.6.3 Thematic Analysis

Thematic analysis was set up in advance, before data collection. Thematic analysis has three stages: descriptive coding, interpretative coding, and defining overarching themes, being successive levels of increasing abstraction respectively (King & Horrocks, 2010). Descriptive coding consisted of identifying those parts of the transcript that help in addressing my research questions. In this step, I highlighted participant views, experiences and perceptions towards sustainable design, firm's organization, BI , IPD and simulation, and took notes about it. These notes helped defining my descriptive codes, which are relatively close to the data, without speculation of any kind. This process required some refinement while I moved into the second stage and so on (quality checks at any stage of the process). The final descriptive coding in this study was identified in groups as detailed in the coding section as:

- **Firm Organization**: horizontal organization, vertical organization, division of departments and/or leadership.
- **Use of BIM**: internal use only, multidisciplinary/coordination/operations, multidisciplinary/coordination/operations, LCC and LCA assessment, use of formal standards, creation of alternative standards, design process affected by data exchange.
- **Use of BES**: in-house simulation for sustainable design, outsource simulation, use of high-end simulation, design process affected by data exchange
- **Use of IPD/IDP**: in-house multidisciplinary team, outsource multidisciplinary team, requirement of a sophisticated three-party/project, liability issues, design process affected by data exchange.
- **Sustainable Design Workflow**: add rigor to the process, benchmark, roadmap, toolkit.
- **Other findings**: internal research, participation/attendance in conferences, membership on sustainability- related organizations, creation of new leadership positions, sustainability as mandatory, multidisciplinary design, mainstream use of BIM, mainstream use of BES, network support for training and solutions, third-party training, training while designing, documentation, in-house training.

Interpretative coding consisted of clustering the descriptive codes, interpreting the meaning of those clusters in relation to the research questions in the form of abstract concepts. These abstract concepts in this research were identified in groups as described in the coding section as:

- **Firm Organization**: cross-pollination, communications issues, specialties in the firm.
- **Use of BIM**: BIM-A, BIM-B, BIM-I, standards perceived as appropriate, insufficient/inappropriate standards, interoperability issues.
- **Use of BES**: internal explicit knowledge to reduce consultation need, external explicit knowledge, high adoption of explicit knowledge, interoperability issues.
- **Use of IPD/IDP**: perception of exclusivity in IPD, inflexibility in contracts, internal explicit knowledge to reduce consultation need, external explicit knowledge, interoperability issues.
- **Sustainable Design Workflow**: assessment, high performance goals, description of a process
- **Other findings**: creation of research team/lab division, being up-to-date, IDP as mainstream, multi-skilled designers, fluid coordination and communication, strategy for sustaining training, confidence in using the tool (knowledge base monitored), maintain productivity during training sessions, quality control for delivery, knowledge increment as required, promote cross-pollination, high adoption of explicit knowledge.

Overarching themes consisted of deriving key themes for the data set holistically, by considering interpretative themes or common patterns from a theoretical and/or practical stance of the project. At this stage I had a higher level of abstraction from defining overarching themes with the full data set (cross-case). The final overarching themes identified in this research can be seen in the following list:

- **Firm Organization**: organizational impact, potential for IDP
- **Use of BIM**: BIM adoption level, standards, barriers to productivity-mainly identified as interoperability issues, time spent on training and the lack of proficiency.
- **Use of BES**: use of explicit knowledge, detriment of productivity
- **Use of IPD/IDP**: IDP, IPD challenges, detriment of productivity
- **Sustainable Design Workflow**: use of GBRS, standardization of sustainable design
- **Other findings**: strategies to keep the firm at the cutting-edge, changes in the future of sustainable design, training policies.

An example from the transcripts can be used to illustrate the three coding stages:

> *We have things like our own materials research library [6c], which literally is a room full of materials. It's like books on shelves but different materials, as well as having a specialist team [6d] who researches materials and will look at all the new materials coming through [6c].*

This excerpt was coded as follows:

Descriptive coding: internal research.

Interpretative coding: creation of research team/lab division.

Overarching themes: strategies to keep the firm at the cutting edge.

The descriptive codes used are shown in Tables 5, 6, 7, 8 and 9:

Table 5: Impact of Hierarchical Firm Organization - thematic analysis codes.

Impact of Hierarchical Firm Organization		
Descriptive Code	**Interpretative Code**	**Overarching Theme**
Horizontal organization	Cross-pollination	Organizational impact
Vertical organization	Communication issues	
Division of Departments and/or Leadership	Specialties in the firm	Potential for IDP

Table 6: Use of BIM - thematic analysis codes.

Use of BIM		
Descriptive Code	**Interpretative Code**	**Overarching Theme**
Internal use only	BIM-A	BIM Adoption level
multidisciplinary/coordination/ operations	BIM-B	
multidisciplinary/coordination/ operations, LCC and LCA assessment	BIM-I	
Use of formal Standards	Standards perceived as appropriate	Standards
Creation of alternative Standards	Insufficient/inappropriate standards	
Design process affected by data exchange	Interoperability issues	Detriment of productivity

Table 7: Use of BES - thematic analysis codes.

Use of BES		
Descriptive Code	**Interpretative Code**	**Overarching Theme**
In-house simulation for SD	Internal explicit knowledge to reduce consultation need	Use Explicit Knowledge
Outsource simulation	External explicit knowledge	
Use of High-end simulation	High adoption of explicit knowledge	
Design process affected by data exchange	Interoperability issues	Detriment of productivity

Table 8: Use of IDP/IPD - thematic analysis codes.

Use of IDP/IPD		
Descriptive Code	**Interpretative Code**	**Overarching Theme**
In-house multidisciplinary team	Internal explicit knowledge to reduce consultation need	IDP
Outsource multidisciplinary team	External explicit knowledge	
Requirement of a sophisticated three-party/project	Perception of exclusivity in IPD	IPD challenges
Liability issues	Inflexibility in contracts	
Design process affected by data exchange	Interoperability issues	Detriment of productivity

Table 9: Sustainable Design Workflow - thematic analysis codes.

<table>
<tr><th colspan="3">Sustainable Design Workflow</th></tr>
<tr><th>Descriptive Code</th><th>Interpretative Code</th><th>Overarching Theme</th></tr>
<tr><td>Add rigor to the process</td><td>Assessment</td><td rowspan="2">Use of GBRS</td></tr>
<tr><td>Benchmark</td><td>High performance goals</td></tr>
<tr><td>Roadmap</td><td rowspan="2">Description of a process</td><td rowspan="2">Standardization of Sustainable Design</td></tr>
<tr><td>Toolkit</td></tr>
</table>

The first pass through the transcripts used descriptive coding established by a priori themes. By looking at the numbers, letters and signs I was able to quickly understand the context and write brief comments about it. A second pass used interpretative coding with themes that were elaborated from the descriptive coding. A third pass included an abstraction from the interpretative codes that could better relate to the research questions. A cross-case comparison of responses at this level was especially helpful to define overarching themes for the exploratory findings. This process required many revisions until the overarching themes were shared across the data set holistically.

I organized themes and balanced clarity and inclusivity (creating a limit for overlapping issues or relationships between variables) as part of the thematic analysis process.

Another aspect constantly revised was auditability, which measures how thematic structure is organized during the process. Similar answers were grouped with the same code, since no two respondents were likely to give exactly the same answer to such questions. Thematic analysis is a way to overcome natural language issues of synonyms, and contextualized statements. One informant might stress one variable according to his/her particular experience, where another informant might have experienced something different.

Regarding the possibility of inconsistent answers from members of the same firm, I had to double check and ask again to assure that there is no inconsistency in the data collected. For example, at Lake|Flato I was told by the BIM Sustainability Chief that they used IPD in one project, and after I interviewed the person responsible for contracts, I discovered that that particular project was finally not done under an IPD process. Initially, the intention was to use it, but the owner was not fully convinced of the shared risks. This kind of quality control check was used across all informants from the same firm for interviews that were conducted at different times.

3.6.4 Exploratory Analysis

From the multiple readings of the transcripts, additional common themes emerged. In this part of the analysis, I read each participant's answers to follow-up and probe questions that are tangent or do not belong to any of the a priori themes. By reading the transcripts repeatedly, I was able to cluster answers and define commonalities and differences that were later described in the last two sub-sections of Analysis (Human Resources Profile and Training Policies). A coding scheme was created as shown in Table 10 (next page):

Table 10: Other Findings - thematic analysis codes.

Other Findings		
Descriptive Code	**Interpretative Code**	**Overarching Theme**
Internal research	Creation of research team/lab division	Strategies to keep the firm at the cutting-edge
Participation/attendance in conferences	Being up-to-date	
Membership on Sustainability-related organizations		
Creation of new leadership positions	Promote cross-pollination	
Sustainability as mandatory	IDP as mainstream	Changes in the future of sustainable design
Multidisciplinary design	Multi-skilled designers	
Mainstream use of BIM	Fluid coordination and communication	
Mainstream use of simulation	High adoption of explicit knowledge	
Network support for training and solutions	Strategy for sustaining training	Training Policies
Third-party training	Confidence in using the tool (knowledge base monitored)	
Training while designing	Keep productivity	
Documentation	Quality control for delivery	
In-house training	Knowledge increment as required	

3.7 Validity and Reliability

Validity and reliability are concerns in any research and present particular challenges in qualitative studies. In my research, I checked for **internal validity** (verification that the form of measurement actually reflects the variables to be measured) by using **respondent feedback**. Respondent feedback, sometimes referred as "member validation," consists of sending the analysis back to the participants, to see if the interpretation mirrors their own lived experience (Oxtoby et al., 2002). A copy of the transcripts was sent to participants, so they could revise the information provided. The interpretation of the hierarchical structure of the firms was sent back to participants to check for the accuracy of the representation. However, just a few participants responded back: Foster + Partners and HKS responded to the structure diagrams with comments to correct and address, while Lake|Flato agreed with the information provided.

External validity is the issue of whether the research results are generalizable to other settings. Because of the exploratory nature of my research, and the small convenience sample, it is difficult to make a definitive claim of external validity. Reliability in this research is more difficult to address because the informant might be biased by his or her position in the firm. It can be in the participant's best interest to highlight successes and achievements rather than the failures. The replication of this methodology with other participants might reveal different outcomes and findings or might indicate reliability.

4. SELECTION OF THE CONTRIBUTING FIRMS

This section describes the process for selecting the firms. The selection considered personal contacts within some of the most regarded sustainable leaders in architectural design. I used a convenience sample of firms that have a reputation for sustainability and are located in either Texas or London. Another factor considered was to include in the small sample of participants large and medium firms that have adopted BIM, BES and/or IDP/IPD. However, a requisite to be included in the sample was their **Commitment to Sustainability**, as documented through their *Awards or Achievements* (see Appendix 3) for their sustainable design work, buildings with *Green Building Rating Systems certifications,* and *Publications*. Note: italics represent parts of the Appendix 3.

4.1 Commitment to Sustainability

In this section I present some facts justifying the selection of participant offices. *The Architect Magazine* in 2008 for example, listed the Top 100 U.S. firms based on three aspects: profitability (revenue per employee, based on gross revenue), sustainability (with variables such as percentage of LEED projects in that particular year and green policies) and design quality (based on awards given that year). From this rank, HOK was 3^{rd}, HKS was 42^{nd} and Lake|Flato was 96^{th} (Top 100 US Architecture Firms, 2009).
In 2011, HOK was ranked number 1 in size by the *Building Design+Construction* magazine, in the architecture and engineering firms' category, measuring total

revenues (Cassidy & Gregorski, 2012). According to the *Architectural Record* the firm is consistently ranked in the top 10 in revenues in the last decade (Mirviss, 2012). In 2012, the *Building Design + Construction* magazine ranked HOK the number 1 BIM Architecture Firm (Cassidy and Gregorski, 2012). In 2012 HOK was also ranked the top 4 "Green Design Firm" in the U.S by *Engineering News-Record* (The Top 100 Green design Firms, 2012). By late 2009, HOK had 900 LEED accredited designers making sustainable design essential to their work. I selected for my research the HOK-Houston office, where they designed, among others, the LEED Platinum facility *NASA Building 20.*

HKS is another leading architectural design firm ranked among the top five architectural/engineering firms, according to *Building Design+Construction* magazine (Cassidy and Gregorski, 2012). HKS was also among the top 100 (33th) architectural firms in 2011, according to *BD World Architecture* magazine (World's largest practices, 2011). In 2012, the *Building Design + Construction* magazine ranked HKS number.5 in the BIM Architecture Firm category (Cassidy and Gregorski, 2012), while HKS-Dallas was ranked 52 in the sustainability category according to the AIA *The Architect Magazine* (Wills, 2012). Also, in 2012 HKS was ranked the top 10 "Green Design Firm" in the U.S by *Engineering News-Record* (The Top 100 Green design Firms, 2012). HKS adopted the 2030 Challenge in 2007 and officially became a partner in the AIA 2030 Challenge Commitment program in early 2009. As of 2011, HKS employs over 900 people, being one of the largest architectural firms in the

United States. They implemented sustainability policies regarding business travels, reduction in water and energy consumption, waste management, etc., reinforcing their commitment to sustainability.

Lake|Flato is a medium sized firm (51 employees) and was acknowledged for their commitment to the sustainable design community when in 2004 the American Institute of Architects awarded Lake|Flato the National Firm Award (Lubell & Dillion, 2003), the highest honor the AIA bestows on a firm. Five of their projects have been awarded with the American Institute of Architects' Committee on the Environment (COTE) Top Ten Green Projects, and in 2009, the firm was honored with a Texas Medal of Arts. In addition to their awards, Lake|Flato has an AIA 2030 Challenge Commitment, which is reflected in their work towards achieving high performance buildings. In 2011, The ARCHITECT 50 included Lake|Flato within the third-annual ranking of American architecture firms judging profitability, sustainable ethos, and design quality (Hurley, 2011).

TR Hamzah & Yeang was formed in 1975. TR Hamzah and Yeang is another medium firm that has approximately 50 employees. One of the partners of TR Hamzah and Yeang is the author of many books (22 books to this date) on ecological design, such as *Ecodesign Instruction Manual* (2006); *The Skyscraper, Bioclimatically Considered: A Design Primer* (1996) and *The Green Skyscraper: The Basis for Designing Sustainable Intensive Buildings* (1999). Ken Yeang is a pioneer of ecological design and planning starting his work and research around 1971. The *Guardian's Weekend* magazine (Jan 2008) listed him as one of the 50 people in the world who could save the planet.

Foster + Partners was founded by Norman Foster as Foster Associates in 1967. The firm was renamed in the 1990s as consequence of a rapid growth, having as of 2011 more than 1000 employees. Foster + Partners provide services of industrial design and engineering besides architecture, which remains the main focus of the firm. Foster + Partners is constantly voted as one of the most influential designers in the world (Top 12 most admired, 2011), being voted for two consecutive years —2010 and 2011— as the most admired design firm and has multiple awards for their green designs, as shown in Appendix 3. Foster + Partners have anticipated trends in public attitudes towards ecology and energy consumption early on, pioneering design solutions using renewable energy and dramatically reducing carbon dioxide emissions with a strong environmental awareness.

4.2 Projects Designed by the Participants

To support the credentials of the firms in sustainability, I include some projects that exemplify how the participant firms have designed with an emphasis on energy and water conservation, on-site renewable energy production and natural ventilation, among other features. Most projects represented here were designed for climates that often require large and complex mechanical and electrical equipment to produce a comfortable environment. However, these firms managed to reduce energy consumption and the impact on the environment in several ways.

4.2.1 HOK: NASA 20

The building, located in Houston, Texas, was designed as a transitional office space while other buildings within the Johnson Space Center complex undergo upgrades. The new facility departed from the traditional enclosed office spaces widely used in the 1960's and 1970's buildings within the complex and fosters a collaborative working environment. NASA 20 has 83,000 sq. ft. in three stories and is modeled to perform 57% better than an ASHRAE's energy code compliant facility. The building was completed in January 2010. Table 11 shows the services provided by HOK and the area of the building. Table 12 shows the awards and certifications received.

Sustainable Features

The building's HVAC systems include variable frequency drives for fans and pumps, which are controlled to optimize system capacity depending on the varying loads. The building includes an under-floor air system to provide heating and cooling, that consists of pressurized air in a space between the structural floor and an elevated floor. Occupants can individually control the flow of air at outlets near their work areas.

Furthermore, the facility includes carbon dioxide sensors and occupancy sensors that interact directly with a digital control system adjusting temperatures and reducing outdoor air and exhaust during unoccupied periods. The lighting systems include energy-efficient lamps, high power factor ballasts and high-efficiency fixtures. A low-voltage lighting control system also uses occupancy sensors, daytime harvesting, timer sensor switches, photoelectric sensors and override switches. Plumbing systems incorporate water-saving strategies, cooling coil condensate collection for irrigation and solar-assisted water heaters to reduce energy. Flat-panel solar collectors are located on the roof accounting for 18 percent of hot water use in the building, together with an indoor solar water storage tank, solar hot water circulating pump and heat exchanger.

Table 11: NASA 20 project overview.

Project Overview
Size: 83,000 sq. ft. / 7,700 sq. m.
Services provided by HOK:
Architecture
Construction Administration
Facility Programming
Interior Design
Landscape Architecture
Mechanical/Electrical/Plumbing
Engineering
Sustainable Consulting

Table 12: NASA 20 awards and certifications.

Awards and Certifications
Design Award, Architecture Greater than 50,000 sq. ft. – AIA Houston
Judges Award Best Green Building Project – Engineering News-Record Texas and Louisiana
LEED Certification: LEED Platinum

Figure 4 shows the entrance of the building from the street (Southeast), where the building orientation optimizes daylighting avoiding excessive exposition to the West and East.

Figure 4: NASA Building 20. Photo: Joe Aker, Courtesy of HOK.

Figure 5 shows the exterior shading device that protects the building from excessive sun radiation and passive solar gains from Southwest, where that part of the building is oriented.

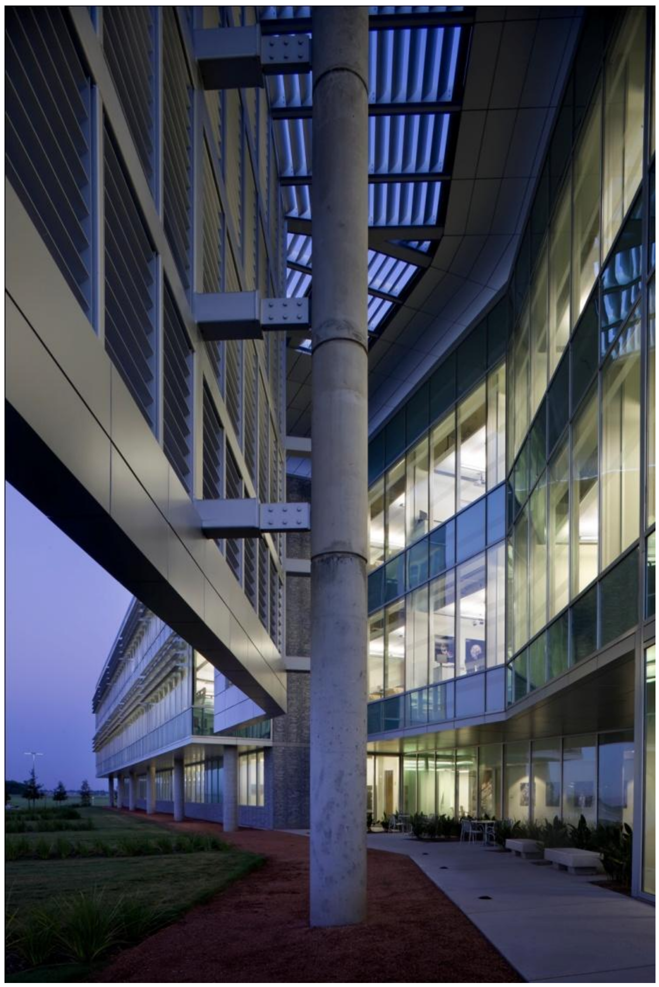

Figure 5: NASA Building 20, exterior corridor and shading. Photo: Joe Aker, Courtesy of HOK.

Figure 6 below shows the South façade of the NASA 20 building with louvers to control glare and excessive sun radiation.

Figure 6: NASA Building 20, exterior view. Photo: Joe Aker, Courtesy of HOK.

4.2.2 Lake|Flato: Arizona State University Polytechnic Academic

This project is located in Mesa, 30 miles southeast of downtown Phoenix (Central Texas-Balcones Chapter, 2009). The campus was formed in 1996 with 1,000 students and faculty occupying very old repurposed buildings that had been abandoned when Williams Air Force base was closed in 1993. By 2006, the school had grown to over 6,500 students and was expected to reach 10,000 students with 40 degree-granting programs before the end of the decade. The campus required an expansion project with its own identity. The design for the ASU Polytechnic transformed the old airbase into an inviting pedestrian campus that celebrates the desert landscape and creates a new identity for the program. Lake|Flato segmented the 245,000 sq.ft. building program into five buildings with classrooms, forming four landscaped courtyards linked by a series of portals and arcades, creating a cohesive pedestrian campus. The campus was finished in 2009.

Sustainable Features

Fourteen acres of asphalt and concrete were removed to create a desert landscaped mall. Storm water is slowed and captured in smaller detention basins throughout the new mall, which is used to irrigate the desert landscaping. Apart from minimizing the load on the existing storm water detention basin, this strategy creates a beautiful indigenous landscape as the heart of the new campus. The three largest buildings have their long sides facing east and west, protecting the courtyards and open-air atria from the monsoon driven rain and desert dust. Flexibility and growth were central considerations, so the design relies on simple well-lit classrooms configured around a repetitive 30' x 30' module. Utilities and duct chases are located within the atria allowing the interior space to remain unobstructed and facilitating future reconfiguration. The uses of local materials resistant to the desert, together with the expressed building systems are both cost effective and responsive to the desert context. Narrow building sections, shading devices and solar orientation allow 90% of the spaces to be effectively naturally illuminated, reducing thermal loads and contributing to its LEED gold rating.

Table 13 shows the credentials of the participants and a summary of the building's total cost and area. Table 14 shows the list of awards received for excellence in sustainable design and the GBRS certification obtained.

Table 13: ASU Polytechnic Academic project overview.

Project Overview
Gross area: 245,000 sq. ft.
Architect: Lake | Flato architects; RSP architects
Civil engineer: Wood/Patel
Commissioning agent: Engineering Economics
Contractor: DPR construction
Landscape architect: Ten Eyck Landscape Architects
LEED consultant: Green Ideas
MEP engineer: Energy Systems Design
Structural engineer: Paragon structural design
Total project cost: $75.7 million ($78.5 million including landscape)
Cost per square foot: $309

Table 14: ASU Polytechnic Academic awards and certifications.

Awards and Certifications
2012 - AIA Committee on the Environment, Top Ten Green Project
2011 - Texas Society of Architects / AIA Design Award
2009 - AIA Committee of Architecture for Education
2009 - American Institute of Steel Construction Design Award
2009 - Architect Magazine Design Award
2009 - McGraw-Hill Construction's Best of the Best: Green Building
LEED Certification: LEED-NC Gold

Figure 7 bellow shows a general view of the Campus and the desert landscape, while Figure 8 (next page) shows the entrance of one of the buildings on Campus.

Figure 7: Landscape and Campus view, Arizona State University Polytechnic Campus, photo by Bill Timmerman.

Figure 8: Access to Arizona State University Polytechnic Campus, photo by Bill Timmerman.

Figure 9 shows the steel structure and screens designed to protect from sun exposition. That design strategy was implemented in different buildings on Campus.

Figure 9: Arizona State University Polytechnic Campus, photo by Bill Timmerman.

Figure 10 shows the Campus on its daily activity and highlights one of the metallic screens for the balconies.

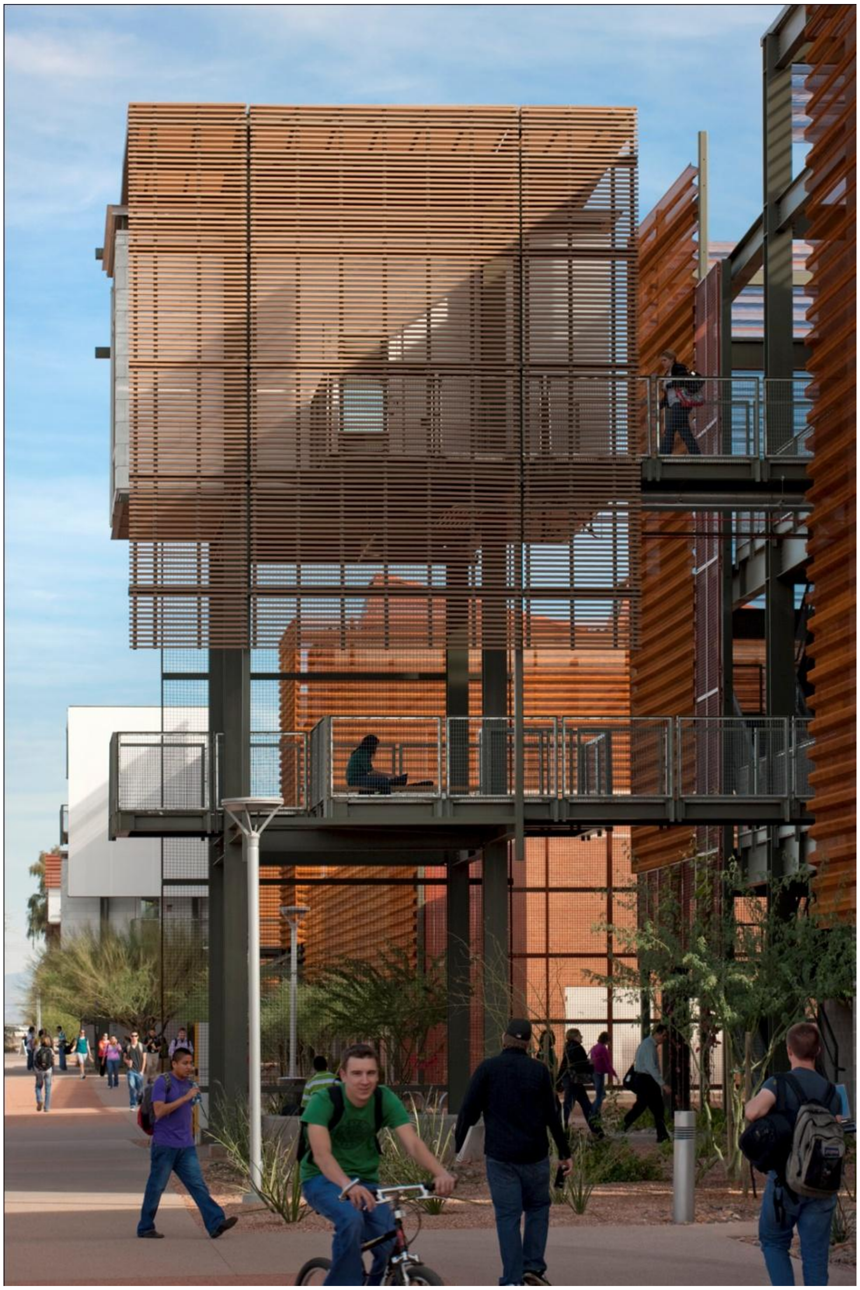

Figure 10: Daily activity, Arizona State University Polytechnic Campus, photo by Bill Timmerman.

4.2.3 HKS: MGM City Center – Aria Resort and Casino

The Aria Resort & Casino is Phase 1 (or Block A) of MGM's three-phase project, where HKS collaborated with Pelli Clarke Pelli Architects. When completed it was the largest LEED Gold building in the world. Above the 24th floor the building bifurcates into two separate towers curving in opposite directions. The towers accommodate over 4,000 hotel rooms and luxury condominiums, a 165,000 sq.ft. casino, a 300,000 sq.ft. three-story convention center, a 70,000 sq.ft. spa, a 2,000-seat theater and a three-story lobby.

Sustainable Features

To accommodate the solar control performance requirements, all exterior wall systems incorporate an integrated sunshade system with projecting fins that range from two feet to eight inches deep as a function of location. The CityCenter – complex where the Aria is a part of – is the first complex able to generate energy on the Las Vegas Strip with an 8.5-megawatt natural gas co-generation plant, providing efficient electricity production on site (10% of overall CityCenter use). The strategy reduces emissions and also uses "waste heat" to supply all domestic hot water at CityCenter, including its numerous swimming pools. The exterior design of each tower has energy-efficient exterior features such as reflective rooftops, specially coated windows and high-performance glass. HKS worked with manufacturers to design water fixtures that deliver pressurized showers while using a third less water. Outdoor landscaping includes native desert plant life, nurtured by a highly efficient irrigation system equipped with moisture controls, providing watering only when necessary. Water conservation technology and programs save approximately 40% of water within the buildings and 60% in outdoor landscaping, saving overall approximately 50 million gallons every year. Other initiatives include the world’s first fleet of stretch limos powered by clean-burning compressed natural gas (CNG), as well as displacement of ventilation units in the ground. The combination of energy-efficiency measures will provide savings equivalent to powering 8,800 households per year. The CityCenter is located where the Boardwalk Hotel was before its implosion. Eighty percent of the previous structure has been recycled into the building materials or sent elsewhere for reuse, while 95% of all construction waste was recycled. CityCenter used Forest Stewardship Council (FSC) wood extracted from forests with responsible management practices. Carpets with sustainable certification were used as well as low volatile organic compound (VOC) paints. The neighbor building “ ont e Carlo Resort & Casino” offered its reclaimed water to be used for dust control in place of drinking water, contributing to savings of 2.4-million gallons of potable water. A concrete batch plant allowed concrete to be generated on site saving gas and energy. Table 15 shows the gross area and a list of stakeholders, while Table 16 shows the LEED certification obtained.

Table 15: MGM City Center project overview.

Project Overview
Gross area: 4,000,000 sq.ft.
Architect: Pelli Clarke Pelli Architects / HKS
Owner: MGM Resorts International / Dubai World
Facade Consultant: Israel Berger & Associates / Curtainwall Design Consulting
General Contractor: Perini Building Company
Completion: 2009
Contract Value: $150 million

Table 16: MGM CityCenter certification

Certification
LEED certification: LEED-NC Gold

Figure 11 shows a general view of the complex at night, where connoted designers created different buildings to be a part of the complex. The two towers of the Aria Resort and Casino are seen further away, in the center of the photo.

Figure 11: MGM Center aerial view, photo by Blake Marvin, HKS INC.

Figure 12 shows the two towers of the MGM City Center Aria Resort and Casino, as seen from the plaza.

Figure 12: MGM Center from the plaza, photo by Blake Marvin, HKS INC.

Figure 13 shows a daily view of the towers. Notice the integrated sunshade system with projecting fins and the specially coated windows and high-performance glass designed for the façade.

Figure 13: Aria Resort & Casino, photo by Blake Marvin, HKS INC.

4.2.4 TR Hamzah and Yeang: Solaris Project

This project was designed in the north area of Singapore for SB (Solaris), a subsidiary of SoilBuild Group Holdings LtdTC Corporation. In September 2009, Solaris was awarded a Green Mark Platinum rating, the highest level of certification granted by BCA's Green Mark, Singapore's sustainable building benchmark. The building is a Media and Science Research and Development Center containing several ecological design features, which are described in the next paragraphs.

Sustainable Features (Large Building, 2008).

An uninterrupted 1.5 km long ramp three meters wide connects the adjacent *one-north Park* at ground level and the basement *Eco-cell* with the cascading sequence of roof-gardens at the building's highest levels. A parallel pathway allows maintenance of the continuous planters without requiring access from internal tenanted spaces. The pathway is also designed to provide a linear park connecting the ground plane to the top roof areas. That continuity of the landscaping is a key component of the project's ecological design concept, enabling fluid movement of organisms and plant species between all vegetated areas within the building, enhancing biodiversity and contributing to the existent ecosystem. The ramp, with its deep overhangs and large concentrations of shade plants, helps provide ambient cooling to the building facade. This eco-infrastructure provides social, interactive and creative environments for the occupants of the building's upper floors and also helps balance the inorganic/organic content of the building.

A diagonal shaft cuts through the upper floors of Tower A allowing day-light to penetrate into the building's interior. A system of sensors reduces energy use by turning-off electrical lighting system if adequate lighting is provided. The solar shaft also includes landscaped terraces, enhancing views up into the building from the street. The eco-cells are located at the building's north-east corner where the spiral ramp meets the ground. Their function is to allow vegetation, daylight and natural ventilation to extend into the car-park levels below. The lowest level of the *Eco-cell* system contains the storage tank and pump room for the rainwater harvesting system. The two tower blocks have a public plaza in between providing space for communal activities and creative performances. The naturally-ventilated ground floor of the plaza operates as a mixed-mode (non-air conditioned) zone with an operable glass-louvered roof over the atrium to allow ventilation. CFD (Computational Fluid Dynamics) simulations were used to analyze thermal conditions and wind-speed inside the atrium. Ground level landscaping, linking to the park across the street, allows for cross ventilation of the ground-floor plaza and provides a venue for social/interactive events. The project's climate-responsive façade was designed with an analysis of the local sun-path. Solar-path studies determined the shape and depth of the sunshade louvers, which also double as light-shelves. This solar shading strategy reduces heat transfer across the building's low-e double-glazed perimeter facade. Combined with the spiral landscaped ramp, sky gardens and deep overhangs, the sunshade louvers also assist in establishing comfortable micro-climates in habitable spaces along the building's exterior. The combined linear length of the building's sun-shade louvers exceeds 10 kilometers. Upon completion, the sum of the building vegetated areas will exceed the footprint of the site on which the building sits. ore over, 95% of the project's total landscaped area is above ground level, which serves as an example of the potentials for sky-rise vegetation.

The extensive landscaped areas are irrigated with a large-scale rainwater recycling system. Rainwater is harvested from the drainage downpipes of the perimeter landscaped ramp and from the roof of tower B. It is stored in rooftop tanks and at the lowest basement level, beneath the *Eco-cell*. The combined storage capacity allows the vegetated areas to be irrigated almost exclusively with harvested rainwater. Table 17 summarizes the total areas of the building and the designers involved with the project. Table 18 shows the award and certification obtained.

Table 17: Solaris project overview.

Project Overview
Site Area: Total GFA: 51,282 m2
Site Area: 7,734 m2
Total Landscaped Area: 8,363 m2
Principal architect: Dr. Ken Yeang
Project Leader: Mitchell Gelber
Senior Designer: Esther Klausen
Designer: Jan Rehders
Assistant Designer: Faizah Rahmat
3D Visualization: Vijai Kumar

Table 18: Solaris awards.

Awards and Certifications
First Prize - Skyrise Greenery Awards 2009
BCA GreenMark: Platinum Rating (GBRS certification)

Figure 14 and Figure 15 show exterior views of the building, highlighting the corners of the building with its double and triple height balconies and the integration of vegetation.

Figure 14: Solaris façade (Copyright T. R. Hamzah & Yeang Sdn. Bhd. 2012).

Figure 15: Solaris exterior view (Copyright T. R. Hamzah & Yeang Sdn. Bhd. 2012).

Figure 16 shows the eco-cell ramps and vegetation accompanying it. Figure 17 shows the glazed and eco roof.

Figure 16: Solaris eco-cell (Copyright T. R. Hamzah & Yeang Sdn. Bhd. 2012).

Figure 17: Solaris glazed roof and eco-roof (Copyright T. R. Hamzah & Yeang Sdn. Bhd. 2012).

4.2.5 Foster + Partners: The Masdar Initiative (Masdar, 2007)

The Masdar Initiative (2007) is an emerging global clean-technology group that attempts to be one of the world's most sustainable urban developments powered by renewable energy. Located about 17km from downtown Abu Dhabi, Masdar was inspired by the architecture and urban planning of traditional Arab cities. The incorporation of narrow streets, shading of windows, exterior walls and walkways, thick-walled buildings, courtyards and wind towers, vegetation and a generally walkable city resembles ancient Arab urban environments. The design provides the highest quality living and working environment with the lowest possible carbon dioxide emissions. Its northeast-southwest orientation makes best use of the cooling night breezes and diminishes the effect of hot daytime winds. All buildings contained in Masdar will surpass the highest sustainable building standards currently set by internationally recognized organizations. Table 19 shows the designers of the Masdar City, while Table 20 shows the awards obtained. Figure 18 shows an aerial view of the project in its desert environment.

Table 19: Masdar City project overview.

Project Overview
Abu Dhabi, UAE 2007-
Client: Masdar-Abu Dhabi Future Energy Company
Mubadala Development Company
Business Plan: Ernst and Young
Architect: Urban Design Foster + Partners
Renewable Energy: E.T.A.
Climate Engineering: Transsolar
Sustainability-Infrastructure: WSP Energy
HVAC Engineer: WSP
Transportation: Systematica
Quantity Surveyor: Cyril Sweet Limited

Table 20: Masdar City awards.

Awards
Best Sustainable Development, Cityscape Abu Dhabi (Masdar Development)
Condé Nast Traveler Innovation & Design Award – Sustainability (Masdar Development)
AJ100 Sustainability Initiative of the Year (Masdar Development)
Cityscape Real Estate Awards - Best Environmental Real Estate Project (Masdar Development)
Best Sustainable Development, Cityscape Abu Dhabi (Masdar Development)
Condé Nast Traveler Innovation & Design Award – Sustainability (Masdar Development)

Figure 18: Aerial view of Masdar city. Image courtesy of Foster + Partners.

The Masdar Institute is the first part of the larger Masdar City masterplan to be built and serves as an educational focus for the entire project. The Institute embraces the principles and goals of Masdar to create a prototypical and sustainable city. It is also the first building of its kind to be powered entirely by renewable solar energy. A variety of passive and active environmental strategies are incorporated and used to serve as a test-bed for the sustainable technologies that will be explored for implementation in future asda r City buildings. The Institute's residences and laboratories are oriented in such a way to shade adjacent buildings and the pedestrian streets below, and the facades are also self-shading. The roof has over 5,000 square meters of photovoltaic installations to provide power and further protection from the direct sun. A 10-megawatt solar field inside the masterplan site provides 60% more energy than the Masdar Institute actually consumes, all of which can be fed back to the Abu Dhabi grid. The laboratories are shaded by horizontal and vertical fins and brises soleil. The laboratory facades remain cool to the touch under the intense desert sun. Public spaces are naturally cooled with air currents that are directed through the spaces using a contemporary interpretation of the region's traditional wind towers. Additionally, green landscaping and water provide evaporative cooling. The laboratories and residential accommodations support a variety of social spaces, including a gymnasium, canteen, café, knowledge centre, majlis – or meeting place – and landscaped areas that extend the civic realm. Apartments of one, two and three-bedroom are housed in low-rise, high-density blocks, providing a social counterpoint to the research environment. Windows in the residential buildings are protected by a contemporary reinterpretation of mashrabiya, a type of latticed projecting oriel window, constructed with sustainably developed, glass-reinforced concrete and colored with local sand to integrate with its desert context and to minimize maintenance. The perforations for light and shade for the mashrabiya are based on the patterns found in the traditional architecture of Islam.

The green linear park adjacent to part of the buildings will capture cool nighttime winds, while wind gates will control hot winds. The development of sustainable concrete helped reduce the carbon dioxide footprint by 37% by replacing the amount of cement with GGBS (Ground Granulated Blasted Slag). There are 255 square meters of evacuated thermal collectors and 3,156 photovoltaic panels installed on the roof and also shade pedestrian streets and facades. The aluminum sheeting used on the residential buildings has 6.7kg of embedded carbon/m^2 of 2mm-thick sheeting, compared to conventional aluminum sheeting, which has 56kg of embedded carbon/m^2. Compared to UAE baseline performance and ASHRAE 90.1 2004, the building has 54% reduction in water demand; 30% of Phase 1A's energy use is covered by the solar panels located on the roof; and 75% of Phase 1A's water is heated by the sun through evacuated thermal collectors. Table 20 lists the participants in the design of the Masdar Institute shown in the next figures.

Table 21: Masdar Institute project overview.

Project Overview
Client: Abu Dhabi Future Energy Company - Masdar
Architect: Foster + Partners
Sustainability MEP Engineer: PHA Consult
Structural Engineer: Adams Kara Taylor
Laboratory Design: Research Facilities Design (RFD)
Collaborating Architect/Engineer: RW Armstrong
Facade Engineering: Mott MacDonald
Landscape: Gillespies
Lighting: Claude Engle
Facilities Management: Key Facilities Management / Design FM
Vertical Transport: Lerch Bates
Logistics: Arup
Fire Safety: Arup
Acoustic/Vibration: Sandy Brown
Security: WS Atkins
Transport Infrastructure: Systematica
Audio Visual: Acentech
Sustainability Analysis: Decarbon8
Wind: RWDI
Quantity Surveyor: Faithful and Gould
Food & Beverage: Cini Little
ICT/iBMS: PB ICT
Project Managers: Parsons Brinckerhoff
Contractor (Phase 1A only): Al Ahmadiah – Hip Hing JV

Figure 19 shows an exterior view of the Masdar Institute, where the contemporary reinterpretation of mashrabiya for the dorms is shown in the sand tinted glass-reinforced concrete.

Figure 19: Exterior view of Masdar Institute. Image courtesy of Foster + Partners.

Figure 20 shows another exterior view where the scale of the public space is designed in such a way that the perimeter buildings provide adequate shade.

Figure 20: Exterior view of Masdar Institute at night. Image courtesy of Foster + Partners.

Figure 21 shows the wind tower and the proportion of the exterior space that enables adequate natural ventilation and shade.

Figure 21: Exterior view of the wind tower. Image courtesy of Foster + Partners.

5. DATA ANALYSIS

This section includes the analysis of the data gathered from the literature, from the case studies represented by each office or firm involved as participants and the data from the interviews including an exploratory analysis. A synthesis of the findings at the end of this section will guide the reader towards the conclusions and contributions of this study.

The data analysis substantiate the importance of implementing BIM, BES, GBRS and a multidisciplinary design team when pursuing sustainable design. The complexity or the size of the building types designed by a firm or office seems to have an influence on the firm organizational and hierarchical structure. Advanced sustainable architecture designers are incorporating specialist support teams with specific job titles that affect the hierarchical structure of the firm. Most participants in this sample presented commonalities in their design processes that were collected as best practices and generalized into a single process. The exploratory analysis revealed the impact of training policies in the performance of the design team and how the professionals involved in sustainability have changed to adapt to the new challenges.

This section includes the analysis from the raw data and it is divided into:

1. Analysis of the organizational structure of the participants;
    - (a) Impact of Hierarchical Firm Organization;
    - (b) Large Firms: HOK, HKS, Foster + Partners

(c) Medium Firms: Lake|Flato, TR Hamzah and Yeang

2. Analysis of the interviews;

   (a) Use of BIM

   (b) Use of BES

   (c) Use of IPD/IDP

   (d) Use of GBRS

3. Commonalities in Sustainable Design Processes;

   (a) Standardization of Sustainable Design

   (b) How the contributing Offices create sustainable Designs

   (c) Detailed Description of Sustainable Design Processes

   (d) AIA Best Practices and Contractual Forms

4. Exploratory Analysis;

   (a) Training Policies

   (b) Human Resources Profile has evolved

5. Synthesis of the Findings

The analysis is accompanied by descriptions gathered from both the interviews and information provided on each firm's website, as well as the literature.

5.1 Analysis of the Organizational Structure of the Participants

In this subsection I analyzed the organizational structure of the participants. I identified commonalities in size of the firms and offices, as well as the creation of specific groups or departments that reflect logistic aspects of their design workflow. If a vertical or horizontal organization can affect the design workflow for sustainability is a topic for further research.

5.1.1 Impact of Hierarchical Firm Organization

I analyzed the organizational structure of each firm to establish a context for comparison of the firms and see whether the organization affects the design workflow. The basic information was provided in the interviews, and additional information was collected from each firm's website. The organizational structure diagrams were sent back to the participants to confirm reliability. HKS, Lake|Flato and Foster + Partners replied with corrections or confirmation. I separated the firms into two groups: large firms and medium firms. The different building types and architectural services these firms provide to their clients determined the creation of specific divisions or departments.

Some of the larger firms have offices distributed in different parts of the world, making the direct interaction between designers a challenge, which is sometimes overcome with the use of high-end communications technology. In general, leadership groups presented a vertical organization while the design teams presented a horizontal organization facilitating interaction between designers. This sub-section acknowledges the differences among the firms. Further research on the impact of design firms' organization is encouraged.

5.1.2 Large Firms

The large firms in my sample are HOK, HKS, and Foster + Partners.

HOK has more than 1600 employees as of 2012 and is the largest architectural-engineering firm based in the United States. Its organizational structure reflects its size by being divided into different leadership levels and specialty departments, as illustrated in Figure 22. The top level leadership is shared between the CEO in San Francisco, the Vice-chairman in St. ouis and HOK's President in Washington D.C., followed by the Executive Committee that provides advice on overall directions and leadership decisions. HOK has a Board of Directors, Marketing Core Board, Project Delivery Core Board and a Design Board. Below the Boards, they have Leadership Groups that assure quality and strategic advantage across all operations. The Design Studios are focused upon different Marketing Business Units (MBU), which are related to the primary building types or specialties in design. Some offices have more expertise in their B U's than other offices; hence their specialty Design Studios are distributed geographically according by demand. HOK also provides services of engineering, landscape architecture, urban planning, sustainable design and construction, and others, allowing the firm to undertake in-house integrated design across these disciplines.

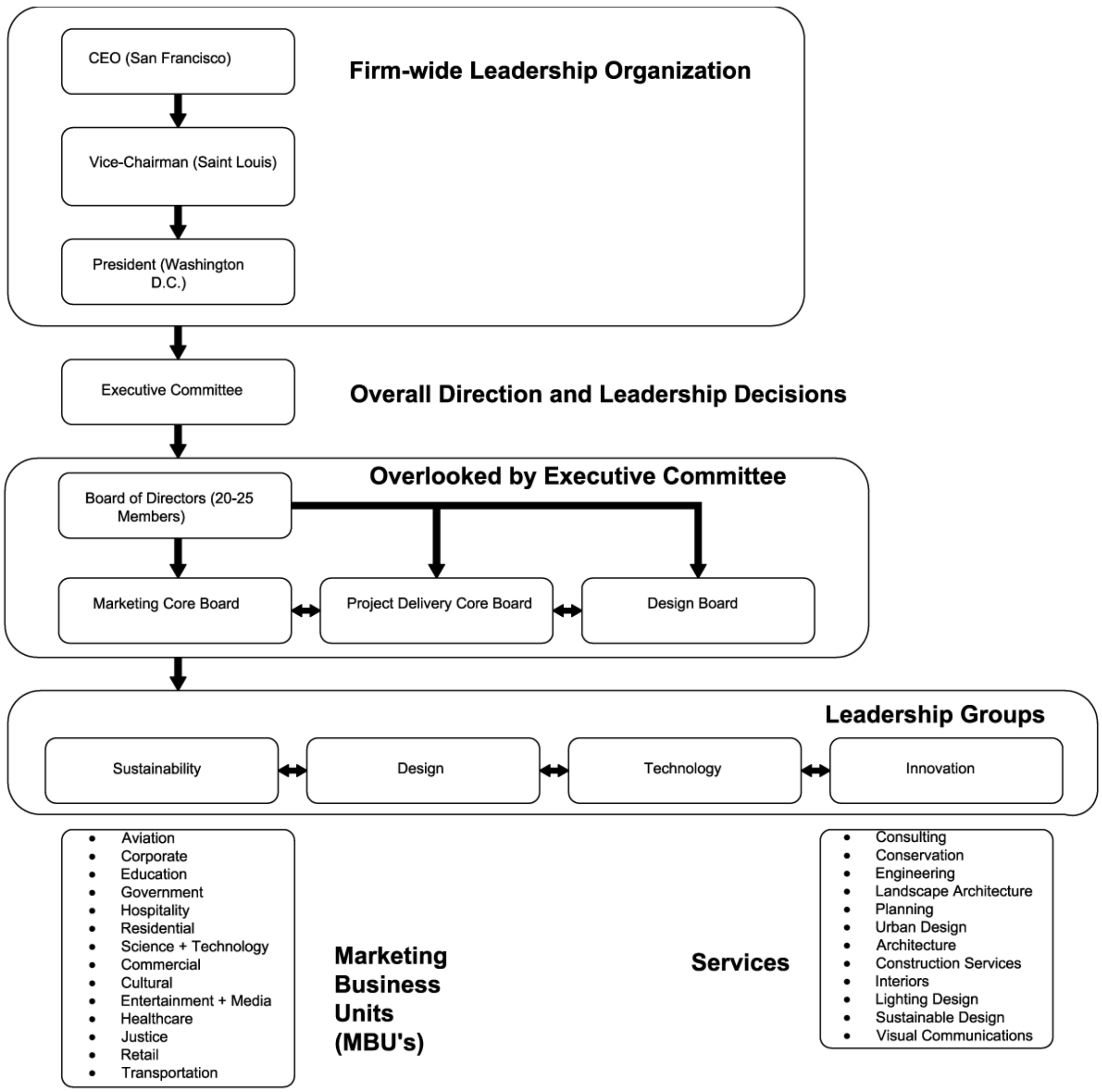

Figure 22: HOK's hierarchical organization.

The leadership groups (Sustainability, Design, Technology and Innovation) are intended to provide advice to sustain innovation in design, and the adoption and implementation of BIM with their buildingSMART initiative is an example of that. The leadership structure is explained bellow by the Sustainability Leadership Leader:

> *Firm-wide, it is a de-structured leadership. Our CEO and chairman sit in the San Francisco office. Our vice chairman is in the St. Louis office. Our president is in the Washington, D.C. office. The strategy is that they want those leadership positions spread around the firm so it's not in one concentrated location. Historically, HOK was founded in St. Louis, where our corporate office is. There's a corporate St. Louis and there's the St. Louis business unit, which is part of the north central region... That's sort of a strategic alliance between St. Louis and the Chicago office. Texas is organized as a region, so Houston and Dallas are the Texas region… The way the offices work, there's kind of a managing principle, it's like the PIC, principle in charge of that office. In our office, it's Jay Tatum. There's a director of operations who is in charge of personnel and staffing and day-to-day functioning of a project. The way the firm is organized is there are different MBUs, they are market-based business units. It's around different broad areas… Within each of those business units, there is a leadership team. There are some knowledge experts that are firm-wide resources. (HOK-Houston's Sustainability Leader)*

By having a multidisciplinary team of architects, engineers, environmental scientists, landscape architects and urban designers, the firm can provide expertise and feedback for a comprehensive analysis early in the process. The leadership organization of Design Studios becomes more horizontal at this point. This recent change is explained by their Sustainability Leader:

> *I would say the way it traditionally worked is there are a few of those kind of experts scattered throughout the firm. There wasn't much of an organization to leverage them. A lot of offices would use consultants. They'd bring in a special consultant to work with Arup or work with one of the big firms or small kind of local environmental consulting firm that specializes in daylight analysis or modeling or whatever. Now the way it's moving is we're focusing on bringing all that talent and expertise in-house. (HOK-Houston's Sustainability Leader)*

The distributed location of representatives of the Leadership Groups produces an indirect involvement with some HOK designs, creating a distant presence and role. To foster a consistent quality delivery, the firm has developed a rigorous process for documenting the design workflow (Mendler, Odell, and Lazarus, 2005).

Similar to HOK, HKS is another large US firm with offices around the globe. It has a vertical leadership organization that becomes more horizontal at the level of Design Studios (Figure 23). According to their Principal and Sustainability Chief Officer:

We have four individuals that serve as our executive committee, and three executive vice-presidents and our president and CEO. They are predominantly responsible for the business side of the company. We also have a management council that is comprised of various individuals throughout the firm that serve as an advisory group to the executive committee. And that kind of takes care from a business organization. From a project, marketing and delivery standpoint we are broken up into multiple different market sectors, and then in some cases, in multiple studios within a market sector. (HKS-Dallas' Sustainability Chief Officer)

HKS has a more traditional architectural design team consisting largely of professionals with a similar background (architecture). However, they promote a multidisciplinary approach to design supported by internal research, external consulting, structural in-house engineering services. They have recently created an internal research group called *Center for Advanced Design Research & Evaluation* (CADRE). CADRE's mission is to improve the design industry's understanding of the built environment and to explore new ideas to inform design. HKS also provides design expertise and design services to other firms, having experience with complex building's construction processes, including BI management and 4D coordination. HKS's a rketing Business Units (BUs) a re similar to those at HOK with the exception of including Sports. (HOK separated their sports division into a distinct company).

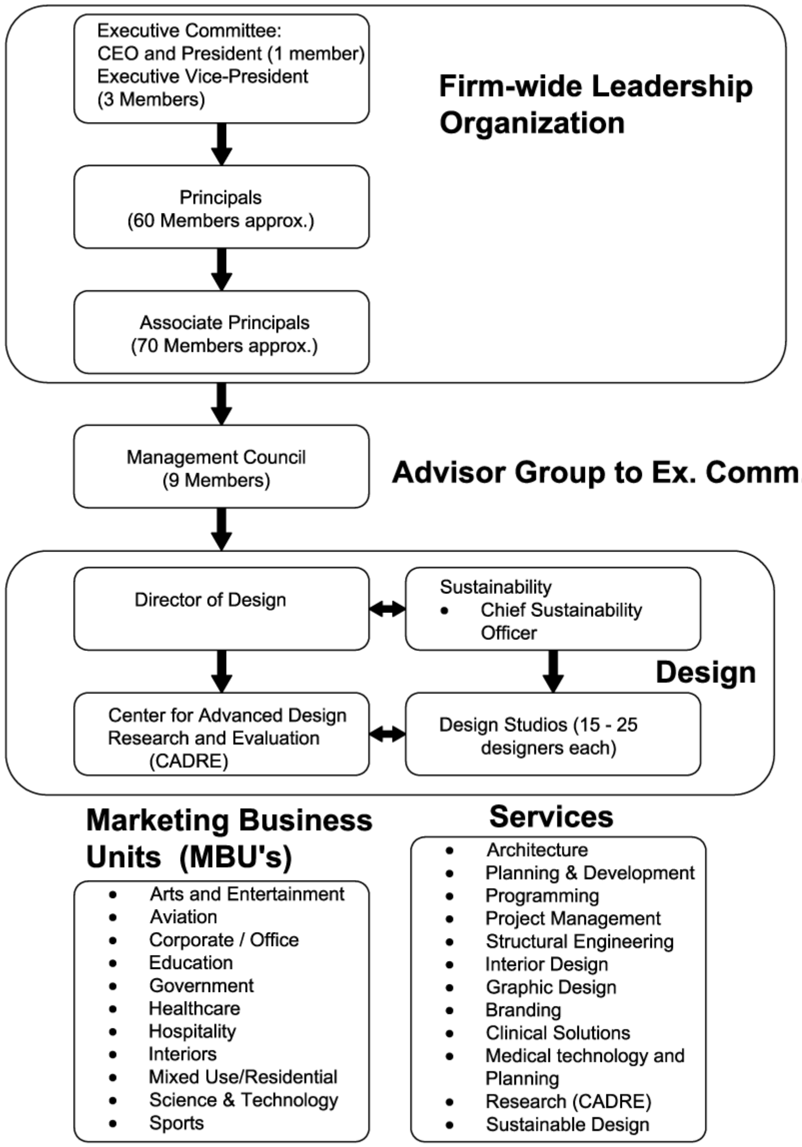

Figure 23: HKS's hierarchical organization.

Foster + Partners are able to concentrate their main design leaders in one physical location (London), facilitating a horizontal organization. Each Design Studio has the presence of at least one Partner and one Associate Partner, besides a Group Leader and an Associate (Figure 24). All design teams and support teams share the same physical space, and that closeness helps providing a dynamic design workflow, facilitating the decision making process:

> *We are split into six design groups, which each is almost a small architecture practice on its own right. Obviously we have the board on top of that, heads of the design groups. As well as those six design groups, we then have specialist support teams around high-end visualization, high-end graphics communication, high-end modeling and complex geometry modeling. We've got programmers and mathematicians as well as model makers. (Foster + Partners' Design System Manager)*

Among the various resources they use to aid their design workflow, their Applied Research + Development team and Material Research Library play a special role, with employees whose specific function is to continuously build up their lab content:

> *We would work with manufacturers sometimes as well as just researching new materials, looking at how they can potentially be utilized in our designs and buildings. (Foster + Partners' Design System Manager)*

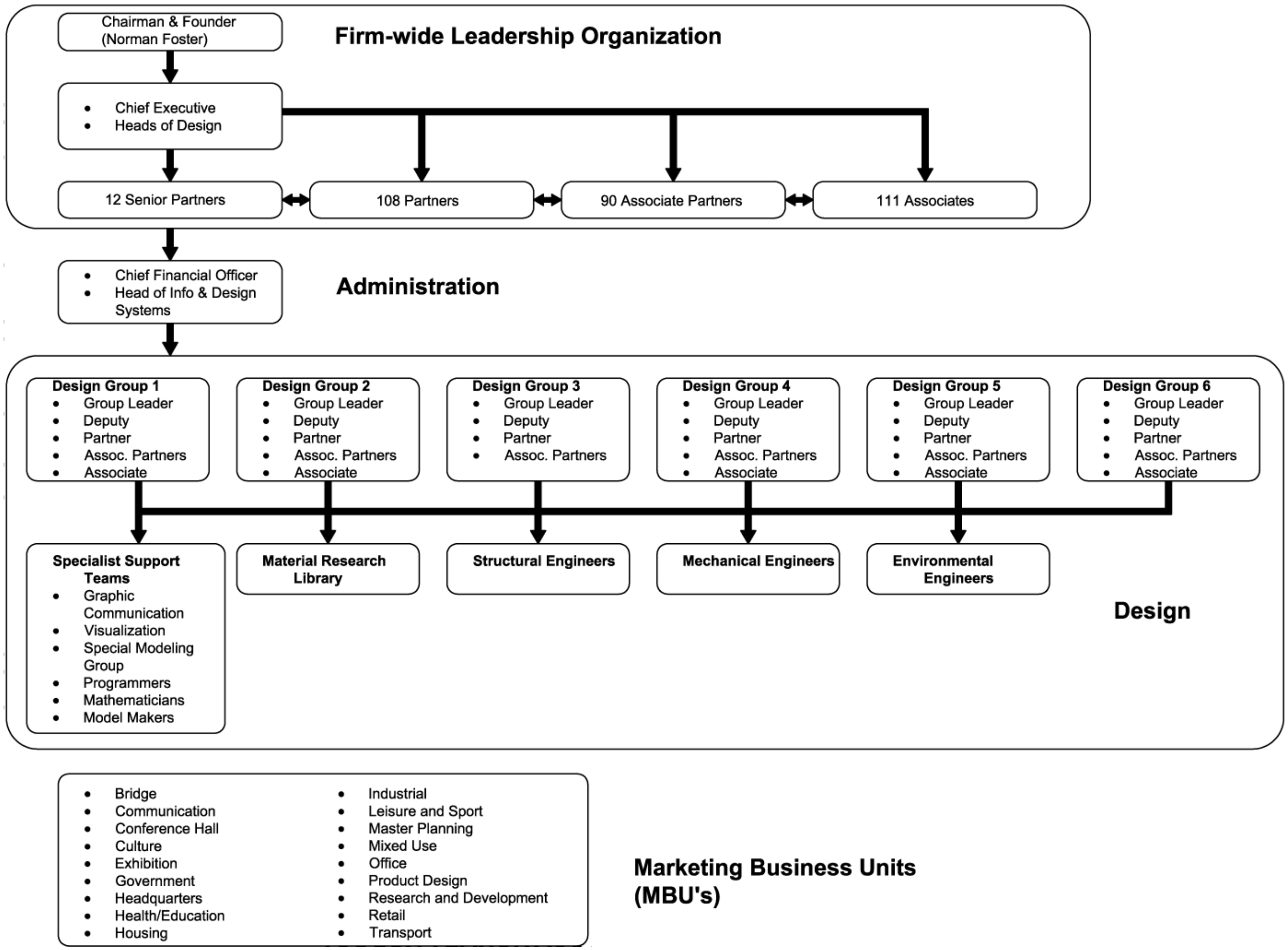

Figure 24: Foster + Partners' hierarchical organization.

5.1.3 Medium Firms

Lake|Flato is an example of a medium architectural firm –less than 100 employees- that has achieved a significant impact in the sustainable design community. Lake|Flato has two principals and founders: David Lake and Ted Flato. Below that top level they have had six partners almost since the inception of the firm, and four associates. Further down the hierarchy, they have the main architectural staff comprised of project managers, project captains. They also have technical managers to provide services to all projects grouped as Design BIM, Technical BIM and Green BIM. In a separate hierarchy there is an administration group and the Marketing Core Board. Several special ventures establish collaborations with design firms that are specialized in healthcare. The organizational structure is illustrated in Figure 25. The architectural staff reflects a horizontal organization, where Design Studios are established by area of expertise. Backgrounds different from architecture are being incorporated into the design support teams (Design BIM, Technical BIM and Green BIM), transforming the Design Studio into a multidisciplinary team capable of providing expertise on simulation and other areas as required. Constant internal feedback between the technical managers, the support team and the Design Studios foster sustained innovation. In addition, being an active participant of external organizations, such as United States Green Building Council (USGBC), American Institute of Architects (AIA) Committee on the Environment (COTE) and Sustainable Design Leaders, helps them to be aware of and incorporate cutting-edge strategies, techniques and materials for sustainable design.

The firm has experimented with significant changes in the last few years, where they moved from a more vertical and traditional organization to a more horizontal structure in the design teams. ake|Flato's Sustainability Coordinator explains:

> *The structure I told you about earlier with the principals, partners and associates, it's very vertical, so we had a consultant come in a few years ago and talked to us about marketing and our structure here. One of the really useful things they gave us was that we needed some horizontal cross-cutting entrance groups, and they called "BIM"... So we have a Technology BIM that looks at computer issues, software and things like that. We have a Design BIM that gets really into detailing, and then Green BIM that does sustainability around the office and projects. (Lake|Flato's Sustainability Coordinator)*

Due to their small size, they frequently join forces with larger firms for more technically oriented and large size projects, such as hospital facilities.

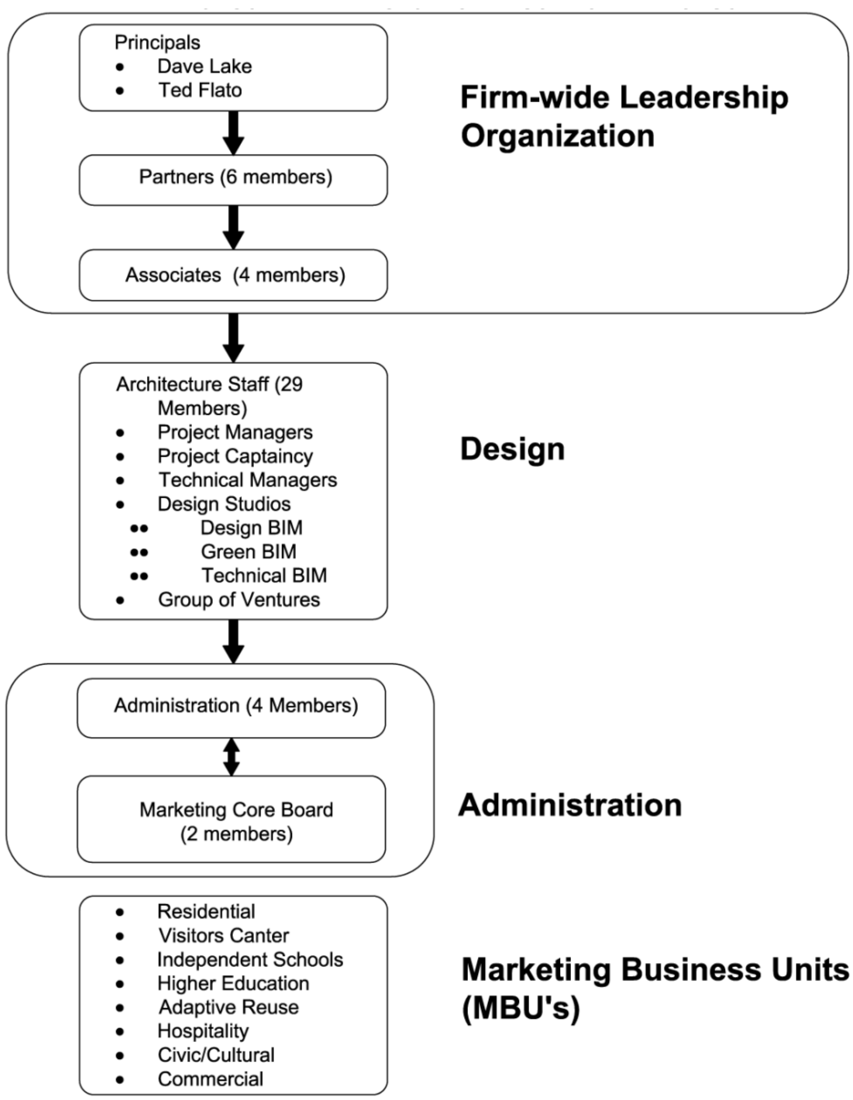

Figure 25: Lake|Flato's hierarchical organization.

TR Hamzah and Yeang leadership group is comprised of the two principal/founders, followed immediately by their design team, comprised of a Director of Design, a Director of Contracts and the architects (Figure 26). They have the administration group (finances and administrative assistant). The organizational structure does not specify a department or unit focused on innovation and research. Their acclaimed and innovative designs in sustainability seem to depend on the knowledge and talent of a champion, who tries to transmit his knowledge through his books and manuals for ecological design. The following diagram (Figure 26) has not been confirmed by the firm.

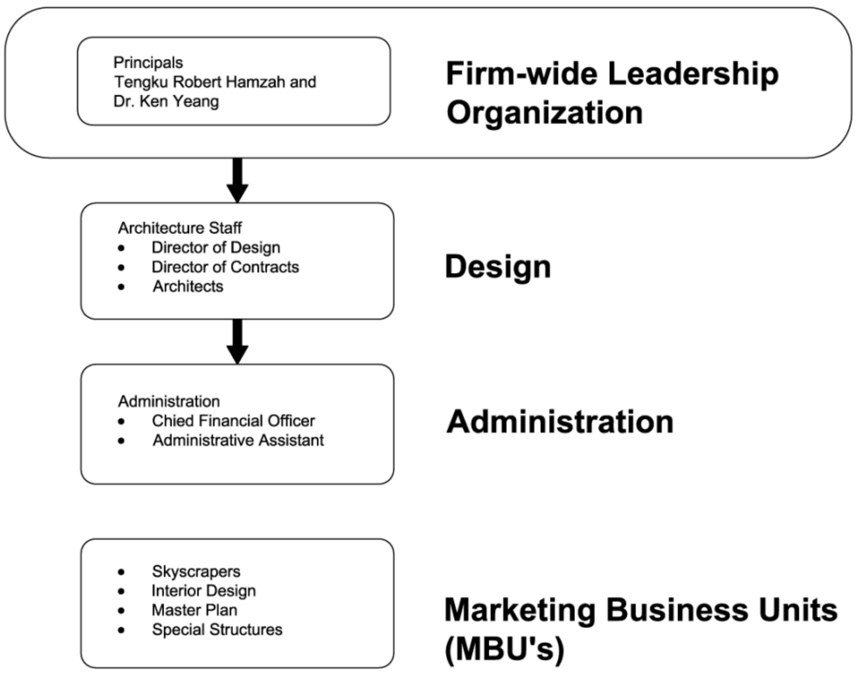

Figure 26: TR Hamzah and Yeang' hierarchical organization.

As a conclusion from the organizational structure, it is clear that larger firms have created different technical groups to support project teams. HKS created a research group with a focus on improving operational performance, streamlining business practices and to enhance sustainability. Foster + Partners created a material research lab with a particular focus on new materials to enhance building energy performance and sustainability. HOK has specialty groups such as lighting and daylighting, advanced use of BIM and other sub-specialties related to specific building types scattered in different offices.

5.2 Analysis of the Interviews

This subsection presents the perceptions and opinions of the participants on the impact of BIM, BES and IPD/IDP in the design process for sustainable architecture. These opinions should not be interpreted as facts, but illustrate some of the challenges and issues these designers have to deal with daily.

5.2.1 Use of BIM

All offices, with the exception of TR Hamzah and Yeang have used BIM-A or BIM-B level at most (repository of cross-disciplinary information, clash detection, coordination, and operations). Some firms like HOK and HKS are recognized leaders in the advanced use of BIM in the US (Cassidy & Gregorski, 2012), while Foster + Partners is in the UK. TR Hamzah and Yeang have not successfully implemented BIM yet. For that reason, in this subsection of the analysis TR Hamzah and Yeang will be excluded. They are currently studying the use of BIM as part of an openness to continuous advances in their design workflow by taking advantage of technology.

Lake|Flato has a strong commitment to implement BIM, although its full potential is not currently being implemented. A principal from Lake|Flato said that his firm does most of their architectural drawings in Revit, except for construction details (which are 2D - AutoCAD) but their designers have limited knowledge of the process from concept through construction. The reasons for adopting BIM are explained by their sustainability coordinator:

> *We think that it is one of the greatest values to our clients, and it is a greater value to us. It makes a lot more sense in the way we are modeling, but we believe that is the way the market is going, and if we were not going to adopt it we will just going to be left behind. So we decided to stay on the cutting-edge and become one of the first… I mean, we were one of the smaller firms, but we were one of the first firms to adopt it firm wide and made a 100% commitment to it. (Lake|Flato's Sustainability Coordinator)*

They also value the fact that BI i s a repository for a project's information, so it becomes easier and faster to search for specific information in the course of time (a single file, instead of multiple CAD files), and to provide more value to the client by having integral information at once.

HOK has a commitment to use BIM worldwide, and also has its own HOK BuildingS ART Initiative, as well as a complete documentation standard. HOK's CEO, Patrick MacLeamy, was a founder of the IAI (International Alliance for

Interoperability)/ buildingS ART International, and also created the "shifting the effort" graphic, otherwise known as the a c eamy Curve, shown at the beginning of this study.

HOK's approach to BI is publicly available as a resource on David ight's blog hokbimsolutions.com (Light, 2011):

> *BIM is not a software solution; it is a process, underpinned by technology and collaborative working. In many instances the use and reuse of data throughout the lifecycle of a construction project is not used efficiently. Much information is wasted due to mistrust, information not being complete, lack of process and standards, as well as a lack of understanding of what data is available. The BIM process attempts to maximize the return on investment by defining a fluid flow of data use... This more complete information stands to improve the quality, efficiency and sustainability of buildings delivered to clients. (Light, 2011)*

HOK's buildingS ART is an attempt to leverage 3D modeling, analysis and integrated delivery practices, based on the buildingSMART alliance™ (NIBS, 2012). It allows project teams to collaborate on virtual models, test design schemes, and optimize building performance and coordination before the building is constructed. HOK describes HOK buildingSMART as:

An innovative way of working in a virtual environment using intelligent objects in a model server so that design, construction, operation and sustainability are tested and optimized before work commences on site. (Light, 2011)

Basically, HOK is organizing their Autodesk Revit models to include information about:

- Model Input;
- Design Parametrics;
- Performance based design;
- Quality and Delivery;
- Specification;
- Fabrication Workflows;
- Integrated Project Delivery;
- Facilities Management.

One of the objectives of this HOK buildingSMART initiative is to be able to comply with a new BIM certification from the buildingSMART alliance™, which certifies a model as being useful for conceptual design, simulation and facilities management (Vandezande, 2011).

One of the unforeseen difficulties most firms have found in using the full potential of BIM happens after construction:

It needs to find its way to the contract and the deliverable, because the model that is for the constructability of the building is not the same as the operations and maintenance model. There may be a different data set associated to that. As an architect, we're not necessarily obligated to put in the information that the client would need to use in the future. The question is do we put it in for them? Do the engineers put it in for them? Does the client get into the model during the design process and put that information in? Do we hand off the model and the client's responsibility is to put in the information of the manufacturers and specifications of the materials that they've used, installation times and so forth. A lot of that can fall on the contractor because they're the ones doing the installations. (HOK-Houston's BIM Manager)

A similar thought comes from Foster + Partners, where the specifications and standards for BIM are not well documented in contract agreements:

A lot of contracts we have say, "You will deliver BIM." They don't actually specify what we're delivering or what that content should be, what that level of detail should be in the model, what should be in that model, what attributes are required in the model, what the purpose of that model is going to be. Is it going through to facility manage the building in its life cycle, to energy manage the building in the future through its operational life cycle? Are we just doing BIM for coordination, basic site? How far are we taking this model? How far do we have to invest in that design? Particularly if we're only engaged, for example *to go up to detail design stage, and then we're handing over to a local architect or something like that, what's our incentive to put all that information, all those hooks in early on, into a BIM model, for them to be filled in later or reused? Do we leave it open and let them do that? That's very rarely specified in a contract in terms of, particularly if we're effectively engaged to design the concept of the building and not actually go through to construction. That depends on our level of agreement and level of service that we have as part of the contract with the client. (Foster + Partners' System Design Manager)*

Regarding BIM standards, Foster + Partners use General Arrangements (GA) Drawings, which is an U.K. standard for BIM modeling. Similar to the LOD used in some U.S. practices, Foster + Partners create models to generate the GA level drawings but then they do separate detail models and drawings if needed. That strategy helps them to keep models small and consequently more flexible and faster to navigate. Also, the details can potentially be reused for analysis in other situations.

Additionally, HOK's BI ma nager complains about the lack of standardization of BI components and data offered by manufacturers that are used in their models. Furniture, systems, lighting and equipment can have parameters of materials, energy consumption, reflectivity, etc., that if standardized could accelerate the design process and data analysis considerably:

> *Right now, there is no real industry standard as far as the content and the parameters that are provided by manufacturers. When we download content directly from a manufacturer resource, we aren't necessarily able to use it at all until we translate it or apply our HOK standards to it before we can adopt it into our model. (HOK-Houston's BIM Manager)*

Lake|Flato works with an adapted version of a BIM Standard, based on NBIMS or the GSA Standard if required, in order to have a more flexible standard based on its current operations, as explained by their technical BIM specialist:

> *We are in the process of re-ramping some of the standard within Lake|Flato that are similar to many other architectural firms as well as NBIM Standard. It really comes down to the project type of our building. The big picture is to have a similar standard that is close to what everyone is familiar with. (Lake|Flato's Technical BIM)*

A problem is that currently, many firms are creating alternative BIM standards, so their models could probably work well in their own environment but not so well in another. As described by the participants, the interoperable BIM is shared within the multidisciplinary team, and different simulation and analyses are performed through the model. A few examples from larger firms have used partial features of BIM-I implementation (digital fabrication, operations and FM). However, regardless of the firm size or scale, most designers in this sample have a strong desire for other consultants to adopt BIM to improve communication, minimize errors and to provide more feedback into the design workflow, adding more value to the project.

The use of parametric modeling is a powerful tool that not only accelerates documentation, but also improves communication, accelerates the design workflow with all its dynamic changes, and provides a better value to the design when delivered to the owner for commissioning and Facilities Management (Eastman, 2008).

When asked about parametric design capabilities developed within HOK, he responded:

> *Parametric design is our ability to respond to the changes, whether they be from the designers, architect, owner or the simulation or energy analysis. How quickly and how readily can we respond to those changes? (HOK-Houston's BIM Manager)*

HKS started its migration to BIM about six years ago. They decided to use Autodesk Revit as their main tool, working to make it the standard delivery format for their projects. An associate principal from HKS-London explains their approach to clients regarding the use of BIM tools as follows:

> *When we write our proposals, we tell the client we work in Revit. Everybody knows what that is now… We go a step further and we advise them that they should appoint other consultants that work in Revit as well, for the reasons we've all just been talking about… When you start to get into pulling the project together and the delivery of it and coordination with other consultants*

is one thing, but then when you get into cost plans, quantities, bills of whatever, then you can take that a step further. You can take that model and send it directly to a manufacturer… We're trying to advise the clients that you shouldn't just use Revit because clash detection is much better and it's easier for us to coordinate the model. Yeah, that's a benefit, but you should make it part of the project as a standard because of all these reasons. (HKS-London's Associate Partner)

HKS is currently promoting the extensive use of BIM in all stages of design, and also researching new ways to take advantage of the technology. However, many projects, especially overseas projects, are currently not using BIM authoring tools *due to the lack of training of staff. This is one of the major drawbacks in their design workflow, because it means wasting time frequently translating from Revit to AutoCAD. That situation happens frequently with projects done in China, for instance.* The associate principal from HKS-London also explains their challenges of trying to use a common BIM tool with other design consultants:

Fundamentally as a firm, we have made the decision that we're a Revit firm. All new projects that come through the door, since two years ago, start in Revit… Originally, the intent was that we aligned ourselves with other consultant design team members that were also working Revit, and we would all share the model and it would be nice and easy. (HKS-London's Associate Partner)

But they face problems in the process:

> *That's not the reality of how it's actually happening... A lot of other design consultants don't use Revit. (HKS-London's Associate Partner)*

And their strategy to overcome that problem is:

> *So we've changed how we do things. We do everything in Revit. We endeavor to do everything in Revit. We may save things back as an AutoCAD drawing and send it off to the lighting designer who has no desire to work in Revit or may ever work in Revit. But as a tool, when it comes to those design team meetings and that whole process, we get to a point where we get the model to a good level, and then we hand it off to the engineers and they use that model and do whatever they do, and that model becomes "the" model. (HKS-London's Associate Partner)*

So the full potential of using BIM is limited mostly by other stakeholders, in particular, design consultants. Even if they need to constantly export their models to other formats when exchanging data, they still see more value at the end of the process by finally converging into a single model that contains integral information about the building.

HKS also mentioned how some consultant specialists have not adopted BIM tools, making the integrated design process more cumbersome. According to his experience, some consultants only see BIM as a way to speed up production of construction documentation and are not aware of its full potential. Increasingly, designers are choosing to work with consultants who use BIM tools compatible with their work:

> *For us, it's pretty straightforward because we take the Revit model, export CAD and send it to them, but, if it was the other way around and they were actually using it, they would save themselves time… For example, when structures use it, it works beautifully. Then they actually send us their Revit model and we put it into our model and you can see if there's any structural clash. (HKS-London's Architectural Assistant)*

Understanding the benefits of BIM adoption makes users aware of what opportunities are lost when the design workflow is affected by inadequate interoperability. HKS' perception of BIM interoperability problems is shared by other firms, as explained by HKS-Dallas and their desire to work fluently in a single format:

> *That concerns to me, because I felt that we lose efficiency, that we are losing a lot in that translation. Intuitively to me, we should start in Revit and end in Revit, but that is looking from an efficiency standpoint. (HKS-Dallas' Sustainability Chief Officer)*

Foster + Partners also experienced problems with interoperability, especially regarding exchange formats:

> *It's always a challenge. It means, unfortunately, sometimes you have to rework your models in another package. That is not productive. That's a waste of time.*

> *It's my biggest criticism of the software industry generally, that each company is too insular. Almost every time, you have to at least repurpose a model into another sub-format. That may mean stripping some information out. It might mean adding some content to that model to make it fit for purpose. That limits their functionality, which means we're then limited to export formats like gbXML, IFC, all of which have limitations. (Foster + Partners' System Design Manager)*

His perception of how the industry has faced interoperability problems is not positive, since the problems remained after the introduction of IFC format. Similarly, HOK shares a perception of how IFC has failed in their goal:

> *What we're really waiting for is, and I don't think it's there yet, is one format that Rhino, and Max and Revit and Sketchup and Ecotect can all speak to. IFC format and the XPS format are attempts in that direction. In my experience—actually just before this meeting, we were trying to bring in a mechanical systems model into our Revit model. We just couldn't get it to work. It just doesn't speak the same language right now. (HOK-Houston's BIM Manager)*

Sometimes, these firms will use a middle man to convert the files into a final format, and for that they can use more than one software in the process. In addition, larger firms take advantage of their overseas offices to do that translation, so they can have their models made ready during the night shift, which will be office time in their equivalent oversea office. This strategy is used to overcome interoperability problems as detailed by the HKS-Dallas office:

> *We have an office in India too where our labor [cost] is less, so some of our more tedious translations of… let's say that we get somebody that's developed a really complicated model in SketchUp and it needs to be converted to Revit. We may have somebody in our India office, and we may have decided that we need that tomorrow so we ship it to India, so not only we have the value of someone creating it at a lower cost for us, but also it's done overnight… We get it the next day. (HKS-Dallas' Sustainability Chief Officer)*

At least in HOK and HKS, anything that is designed in Rhino or Sketchup will have to be redesigned at the end in Autodesk Revit, which is their main delivery format.

Similarly, at Foster + Partners, most designs will have to be modeled finally in Bentley Architecture, their BIM authoring tool of choice. One of the strategies implemented by Foster + Partners to overcome communication and data exchange problems is to use a flexible and adaptable tool that has better interoperability, allowing them to work with other design consultants around the globe. Foster + Partners work mainly with Bentley Architecture and use other formats to communicate with their design consultants, such as gbXML or IFC. According to their experience, Bentley Architecture handles big buildings and tends to communicate easier with other tools, despite not being the most powerful tool for architecture. In some cases, they have faced problems where clients or contractors try to force them to use other BIM tools. They prefer to have a consensus on open formats to foster interoperability and allow them to use the tools they know will help them to design good buildings. They place high importance on using the tools with which they are familiar.

Within HKS, some offices have different degrees of proficiency in using BIM.
A designer from HKS-London explains how their use of BIM tools does not seem as advanced and standardized as it is in the US:

> *I don't think the uptake for BIM is quite as advanced in the UK as it is in the States at the moment. There's a real lack of any guidance, like the AIA level of development documents here in the UK. I think probably quite a lot of Europe hasn't quite gotten to that point. Contractually, the way projects are run here hasn't caught up with the idea of BIM and sharing central model files. They kind of keep talking about public projects in the UK and healthcare projects doing what they did in the States and using BIM as a mandatory approach to it. It's still quite a new thing here, I think. (HKS-London's Associate Architect)*

Despite their attempt to use BIM as their main delivery format, many of their designers still do not feel that Autodesk Revit, in this case, offers the same looseness and freedom to work intuitively as other design tools:

To use Revit during concept (design phase) sometimes can be a little bit, not limiting, but it kills out the looseness that you have with other software. (HKS-London's Architectural Assistant)

Similar to other offices like HOK, HKS makes use of different tools for different design stages, and their use of these tools might vary according to the designer's degree of familiarity with each program, as explained by the HKS-Dallas office:

The use of BIM in the design process is still in a formulation mode… I don't know how we standardize or if we are going to standardize… A lot of guys still use SketchUp, they start with SketchUp and then transition to BIM… Some will start in BIM and stay in BIM but not in Revit… A lot are using Rhino and Grasshopper, so there are quite different ways of designing… Quite a different type of software, but the tools that we use in the earlier phases of design seem to vary a lot from individual to individual. (HKS-Dallas' Sustainability Chief Officer)

Foster + Partners has been a long term user of BIM, even before the term was coined, and its use is considered a mainstream process rather than a software application. As a strategy to improve design workflow, they created the Specialist Modeling Group which helps the Design Studios when facing complex geometry problems, parametric modeling challenges or analytical problems. Historically, the firm has faced many challenges to manage, coordinate and share information with other stakeholders, as explained by a partner in an example from the Swiss Re building in London:

> *We rationalized the geometry further and I did some models in actually Excel and Microstation that would generate all the structural points, to say how the points and panels detail, some of the louvers… It was in the very early days, but it allowed us to generate the building, which was pretty hard to draw back then. It allows us to control the geometry. Also, by defining the whole building as a geometric recipe, it allowed us to exchange the design with our contractors and be sure that they could model the building easily following that recipe and allowed us to check the geometry between sort of their model and our model. At the time it was very bad, outdated interchange to change between Microstation and AutoCAD and the other simulation. So by taking a very simplified mathematical model of the building, we could compare our model with the contractor's model and see if there were any errors. (Foster + Partners' partner)*

This illustrates how designers have to be innovative to overcome problems in their design workflow and coordination with other design consultants and contractors.

The design workflow at Foster + Partners, as well as most of the firms analyzed in this study, always incorporates BIM as part of the process. According to their Design Systems Manager, from their original design concept, environmental engineers might suggest the implementation of a passive system, and then the design concept is adapted to accommodate the suggestion. Using BIM provides good communication and a constant and iterative process of design according to him.

In summary:

- Given six offices, five have adopted BIM and their perception was perceived as positive having a strong commitment to BIM;
- Size and scale of a firm might have an influence on the level of BIM adoption;
- Participants have shown appraisal for BIM capabilities to expedite design production and coordination;
- The appraisal for BIM is increased when used in conjunction with consultants,
- Interoperability remains a challenge, but the participants have implemented different strategies to overcome those issues;
- BIM standards remain a challenge; but the participants have created internal variations from established standards to better fit their needs;
- BIM has supported the implementation of BES;
- BIM delivery specifications in contractual agreements are vague;
- Use of BIM for FM and operations is rare.

Table 22 synthesizes BIM adoption and BIM perception across the participant offices. TR Hamzah and Yeang is shown blank because they have not adopted BIM to this date.

Table 22: BIM adoption.

Offices	BIM
Lake|Flato	Positive
HKS-Dallas	Positive
HKS-London	Positive
TR Hamzah and Yeang	
Foster + Partners	Positive
HOK-Houston	Positive

The next sub-section analyzes the use of simulation and its combination with BIM. Participants discussed the challenges and what they have learned from use of simulation.

5.2.2 Use of BES

The use of BES within the sample firms varies according to the complexity of projects and existence of a fee structure that will allow more or less simulation feedback across more or fewer design iterations. All participant offices are currently using BES in their design processes. For complex buildings or for advanced design stages, most offices rely on external consulting for simulations. Nonetheless, most offices are using in-house simulation to analyze design alternatives early in the design process, using massing schemes to test different orientations, window-to-wall ratio and massing proportions, based on ASHRAE recommendations for internal loads such as equipment and occupancy. The tools of choice in most of the sample are based on the standard DOE-2 engine (eQUEST, Autodesk Green Building Studio and Autodesk Vasari). The BIM tool of choice also affects the choice of the simulation engine. Designers who use Bentley products are inclined to use simulation tools compatible with their BIM authoring tools, such as Hevacomp, and AECOsim, which are based on the EnergyPlus simulation engine. Geographic location can also have an impact on the simulation engine used, where US firms tend to use DOE-2 based engines while in the UK/Europe they might use IES-VE based engines. Other tools such as Autodesk Ecotect create accurate and complex thermal models, which could also be used for advanced daylighting analysis performed by Radiance and Daysim lighting simulation engines.

Structural simulation using finite elements analysis (FEA) or wind analysis using computational fluid dynamics (CFD) are usually used for complex buildings with a high fee structure that makes it affordable. Sometimes some of the firms still rely on wind-tunnels for airflow simulation. The next paragraphs present some of the comments about simulation from the participants in this research.

In HOK-Houston, depending on the local environment or market sector, one design software tool might be best suited for one office and might work better with particular BES tools. Consequently, the design workflow varies widely. For example, if a designer works regularly with Autodesk Revit, the natural sequence will be to use Vasari, Ecotect or GBS as the energy analysis tools, but if the designer uses Sketchup or Rhino, the preferred BES tools may be based on plug-ins for those particular tools. The situation is explained as follows:

To some extent, the preference of the staff in the office is what software they've used preceding the analysis. I think when the technology matures to a certain level, we'll start to see one or two software pull away from the rest of them and that will become more of a corporate emphasis or mandate. Right now, I don't know if there's enough history of projects for us to be able to say for certain that this one or this one. (HOK-Houston's BIM Manager)

Lake|Flato uses BES for assessment at early design stages, but interoperability problems are a concern:

Unfortunately right now, I don't think that any of the Autodesk products export from Revit in an accurate fashion… We found that that export/import process is not very good, you lose a lot of information that you build into your model, so you end up having to rebuild your model anyway, which is kind of frustrating, but I think that's something Autodesk is working on right now, which is great. So at the moment, the software packages that we really enjoy using, I think Green Building Studio is pretty good, we really like that…It's good for comparisons, even when the model that you have imported might not be very accurate, but what you can do is to send a building A and then you remove some glazing and send the building B and see what impact that makes…a percentage difference… (Lake|Flato's Sustainability Coordinator)

Knowing the limitation of different software certainly helped them to choose the appropriate tool for a specific analysis. Another finding is that simulation models can underestimate photovoltaic production, so when they work with a project that has renewable energy installed, usually the PV performs a little bit better than expected as stated by ake|Flato's sustainability coordinator. Here are extracts of our conversation about the matter:

> *It's never exactly as you modeled, but I have actually three projects that have performed a lot better than modeled, so that's great, but yeah, that's usually from a slightly to a lot worse, and that all has to do with how people move into the building. But it is really educational for me every time, because it teaches me something new about an assumption that I should have made in the model but I didn't, and it just makes me that much better on the next models. (Lake|Flato's Sustainability Coordinator)*

Foster + Partners expressed a similar view based on measurements of the constructed buildings:

> *One thing we do as a company, we post-analyze our buildings. We'll be on a thermal imaging team that will go and post-analyze our buildings, to look at the performance. We can learn from our own designs. That's the other thing that's important. Every building will have a different result. What we need to do is learn from those buildings, capture those results and understand them, so*

that we can then develop further with that process and refine it. (Foster + Partners' Design System Manager)

Every building brings a new learning experience for energy modeling, and designers can fine tune their future attempts. During the dynamic design process, energy simulation is often a time-consuming process. How to implement it into the design workflow of a firm is critical. Previous learning experiences from real buildings combined with quick analysis to support certain design decisions seems to be a strategy at Lake|Flato, as their sustainability coordinator explains:

> *I have people come to my desk and ask questions about, you know: "what do you think? Should I do this, and this, and this?" And they want a quick answer, and I try not to make quick guesses like that, because I have been wrong on so many times, but in a situation where I do, I always make the quick answer and then I go back and test it. And I can't tell you how many times I had to come back to their desk and say "you know, what I just told you is inaccurate, and here is why." So it is really important to just keep testing what you think, because (1) while you model, the faster it becomes so it is not really this cumbersome process anymore, but (2) if you just keep designing like you always have, you are not pushing yourself. (Lake|Flato's Sustainability Coordinator)*

HKS-Dallas implements BES for schematic or early design stages only, leaving the more detailed and advanced simulation for external consultants:

> *We don't do full-blown energy modeling; we don't do the complete model… We are focused really on those decisions that happen on the schematic design phase and a little bit on the development design phase. We typically outsource modeling that is more holistic that includes the mechanical systems and detailed analysis of systems and that kind of things. We have key individuals that we have identified in the industry that we think do a good job at those. (HKS-Dallas' Sustainability Chief Officer)*

In order to use BES firm-wide, HKS founded an innovative way to teach fundamentals of energy simulation applied to schematic design by creating a game to motivate the use of building performance analysis early on, as Dallas sustainability chief officer said:

> *We have actually developed a game… It's designed to teach you in a very fun way, just how important architectural decisions are to the energy efficiency of the building... We had about 25 of our engineers consultants that we deal with and for the 2030 challenge we wanted them involved…and one of the guys said "you know, you guys have to do good architecture first", and that really inspired us to bring in the ability to do architectural energy modeling in the house. We have individuals here that are trained to help any of our designers in modeling their buildings in the very earlier stages of form and orientation, sun shading… It's really a fun game because we taught our employees that you*

can reduce the energy consumption of a building by 20% without ever touching the mechanical system. (HKS-Dallas' Sustainability Chief Officer)

Additionally, HKS is aware of the need to understand how a building modeled in BIM affects thermal analysis:

> *We have to learn how to draw in BIM in order to be able to get good energy data back or energy evaluations back. For instance, if we do a BIM model and we don't put a ceiling in, the computer doesn't think it is conditioning more volume that it really is, and then you get false readings back. So you have to know and understand the information that the simulations are based on and make sure that you are providing the information that it needs to print out useful data or reliable data. (HKS-Dallas' Sustainability Chief Officer)*

Knowing what variables affect reliability of BES makes their use an effective design tool.

According to the sustainability officer from HKS-London, the use of BES analysis incorporated into BIM tools is not widespread among engineers. He feels the design workflow could be expedited by using them:

> *I don't know of anyone who's used Revit on a project analysis of energy models or some of the stuff with daylighting. We play around with the IES plug-ins with Revit to see if we can do some of the solar studies from an architectural*

point of view. I haven't seen any engineer using that tool. (HKS-London's Sustainability Officer)

HKS- ondon's associate partner explained that some of the architectural practices are getting a little bit further ahead on simulation and incorporating it into their normal design workflow. HKS, at least in the US are getting more expertise in energy modeling and understanding the effects of solar gain and energy efficiency by working on the building envelope. In addition, their perception of in-house simulation early on is that it saves them time and money compared to working with a MEP engineer. Modeling from MEP engineers is usually a one-time service, providing limited feedback. Currently, the existence of several BES tools that work fluently with Revit (GBS, Vasari) gives them the ability to do BES in-house for earlier design stages. However, one of the problems perceived from energy simulations run by architects at HOK-Houston is how to train the staff to correctly interpret the resulting charts and graphics from the output reports. According to their sustainability leader:

Anybody can go on Ecotect and input some climate variables and put in a little massing scheme and do a quick study. It's easy to draw the wrong conclusion sometimes from the software. We recognize that it's better to have an expert that we've dedicated resources to training, to know the ins and outs of the software, to know what the pitfalls of the software are so we're not drawing the wrong conclusions and going ahead and advocating a solution to our clients *that is wrong because of our lack of understanding of the software. (HOK-Houston's Sustainability Leader)*

Furthermore, knowing how to use the right tool for a specific design stage is another concern. Having that expertise can provide flexibility in the design workflow without having to re-model the building to analyze different design schemes:

From what I understand too, the software the engineers use when they do energy modeling, it's hard to edit that information. Once you run an energy model, once you crank out the output from that and you get a report and you have the model and the graphics and everything that goes with it, you can't just go in and tweak a few things and get a whole new—you have to rebuild what you've done. It seems like it's not very flexible. That might not be the case. I've heard a couple of contractors complain about that. (HKS-London's Associate Partner)

TR Hamzah and Yeang's use of BES is scarce due to the cost, among other reasons:

My biggest problem is really time and cost. Due to the cost, maybe we do it once or twice. If we do it two, three times, several times, they charge a lot for it. We don't always have the time to do this, because once you do one, you can modify the design. But to modify design, to draw it up again, takes time. In practices, you don't have too much time. The most is maybe one, two iterations.

Then we get a CAD view that this is what could work. Then we go and build it. (TR Hamzah and Yeang, partner)

However, their perception of simulation being used during the design workflow is positive in spite of the cost. The possibility to simulate wind flow and analyze air pollution for a master plan is also seen as potentially improving sustainability. Nevertheless, many clients do not realize the cost of BES. Sometimes the client thinks it is included in the design package, as explained:

> *Then we told the client, "Look, can I invite [our simulation specialist] here to present it to you?" so they found it very interesting. Then when they launched for sales, the people by the shops said "It going to be hot. There's no air-conditioning." Then the people who bought the apartment units say, "Why do you need the sun shading? Won't these apartments be hot because it faces west?" So my client comes back to me and says, "Can't you redistribute the figures and diagrams?" So I brought the figures and he showed to his marketing people to say "look at the simulation" to show it was cool. And with those apartments facing west, the sun shading prevented the sun heating up the space. So eventually they used our material for marketing purpose. They still wouldn't pay for it. (TR Hamzah and Yeang's partner)*

Foster + Partners use whatever tools are appropriate for the application or project. They have used Ecotect, Fluent, Radiance, Building Designer, TAS, Hevacomp and now

AECOsim, among others. Because they have multidisciplinary teams, they are able to do in-house BES and afford more iteration to provide more feedback on the design:

> *We're fortunate we can do a lot of it in-house. We don't have to outsource that simulation, so the cost to us is far less. We've invested in that. Given the number of projects, the size of company we are, we have that commercial advantage to be able to offer that internal simulation. But yes, it still comes at a time cost. There is an internal resource cost for us. Occasionally we do outsource, depending on the type of analysis we're doing. It's important that, from that side, we've got to get the right building at the end of the day. If it means we have to pay for ten iterations to get the optimum building, and as a result it saves our client half a million pounds, it's worth doing in terms of heating costs, lighting costs, etc. (Foster + Partners' Design System Manager)*

The scale of their projects and the size of the firm give them the ability to leverage resources. However, BES has to be applied strategically in terms of using the proper detail level at the pertinent design stage. As an example, it is simply not recommended to run complex CFD analysis of a building in early stages of design because its final shape will most likely change several times:

> *What we look at is using different technology to do early stage studies to give us reasonable indicators, to give us an environmental steer to what we think will be the best performance. Having our environmental analysts and engineers in-house also means we can do early stage, you ought to look at this type of*

> *technology for heating the building or where you are in the world or this type of building… Some of it is having the knowledge in-house. Some of it is using earlier stage analysis that is fast and rapid and low cost. Then you can invest the higher-end CFD analysis for specific schemes to come out of it. There's a good workflow there. (Foster + Partners' Design System Manager)*

Foster + Partners also stressed the importance that the analysis of materials performance and the dynamic use of BES will have in an integrated design:

> *I think there will be a lot more information available on performance of materials. I think the analysis (simulation) will become very mainstream and a lot faster than it is now, a lot more fluid. That sort of informed decision can be a lot quicker, a lot more dynamic. It will become far more integrated into the process rather than being a parallel analysis process as it is now. (Foster + Partners' Design System Manager)*

Both TR Hamzah and Yeang and Foster + Partners mentioned detrimental consequences of too much reliance on the emotional aspect of a design. A client may make a decision based on aesthetics or personal taste, rather than through rational analysis, sometimes going against the energy performance goals:

> *The client's decisions, I find are emotion-driven. They say, "Do I like the look of the building?" If they like the look, very often that overcomes everything, supersedes everything. The emotional aspect of it is there… So now, instead of*

showing the perspective at the end of the presentation, first I'll say, "Do you like the design?" Whatever rationality you have is not going to make them like it. The intuition and the emotion aspect of it is extremely powerful. (TR Hamzah and Yeang, 2011)

That's where the client sometimes really weighs in. We can't always deliver an optimum building because they're like, "No, we want something glossy and shiny and it's got to be there because we want it to be part of our corporate branding and corporate image." Sometimes we have to guide our clients, as a good architect, and steer them into a more considered decision at the end of the day. That's what we do as good architects... The client ultimately has an aesthetic influence. (Foster + Partners, 2011)

BES can be used as a strategy to overcome this bias toward appearance as a way to convince the client of the benefits in the full life cycle of the building.

When asked about the most relevant aspects to be improved in order to facilitate the adoption of BES in small firms, Foster + Partners' Design System an ager responded:

Having it online would be the best availability. Then you can just pay for a service… For a small firm to invest in a whole processing grid farm to do analytics, that's just not going to do as a small firm. We have that luxury as a large-scale firm that we can actually invest in that. The amount of analysis we do, we can have them running constantly and justify that investment cost. Even *then, we're still looking at potential outsourcing. We'll be very interested in that technology as it becomes more mainstream, as cloud computing and cloud processing becomes much more of a mainstream application use across all, whether it's design or analysis. It's where the industry is likely to head up over the next five years, well, hopefully. (Foster + Partners' Design System Manager)*

From his words, the use of web services (e.g., Autodesk GreenBuildingStudio) will eventually get better and make use of cloud computing to improve its performance and ability to provide design feedback. Additionally, technology will be cheaper and affordable for smaller firms. High-end simulation such as CFD is currently being validated and used as an alternative to wind tunnels, for example, as explained by the other participant from Foster + Partners, in the analysis of downdrafts created by the bullet shape of the Swiss Re building:

At the time, people still had some concerns about the accuracy (CFD), so people would use CFD to get the design roughly right and they just validated it in the wind tunnel. Nowadays, people are a lot more confident in CFD. We still put some of our projects through wind tunnels, but I think only as a very final check. I think the internal flow was simulated using CFD. The external was wind tunnel. (Foster + Partners' partner)

He expressed his opinion about the use of technology in the firm and the combination of a traditional design process with a transitional process:

> *We will use the technology we can and maybe invent some new stuff, but it's about what you can produce with it. I'm fascinated by the technology, but I'm here to design good buildings, fundamentally. The ends justify the means. If you look at the work of Gaudi, for example, he used some very primitive tools available to him, but he used them very, very well. I think we are not eliminating the traditional process. If you look around, you'll see a lot of physical models. We are trying to extend the design process, trying to augment it, so to speak, allowing us to do things you can't do easily with physical models. I think it allows us to investigate options in more depth and try out things which you couldn't do manually or with physical models or drawings. (Foster + Partners' partner)*

For Foster + Partners, the use of BIM and BES is critical in order to produce advanced designs that would not have been possible without them. Foster + Partners is recognized for its use of high technology in all aspects of design. To nurture that environment and design workflow, a strong and reliable network is required.

In summary:

- Given six offices, six adopted BES in their designs;

- Four out of six are implementing in-house energy simulation for schematic design;
- Six offices outsource BES for advanced design stages;
- BES use varies depending on projects' complexity and/or fee structure;
- Advanced design stages usually outsource simulation;
- The firms are using in-house BES for early design stages;
- The use of a particular BIM tool can affect the choice of the simulation engine;
- High-end simulation such as CFD is usually used for complex buildings with a high fee structure that makes it affordable.
- Interoperability problems between BIM and BES persist, but are not debilitating the design process.

Table 23 synthesizes BES adoption and BES perception across the participant offices.

Table 23: BES adoption.

Firms	BES	In-house BES in SD Phase	Outsource BES
Lake|Flato	Positive	✓	✓
HKS-Dallas	Positive	✓	✓
HKS-London	Positive		✓
TR Hamzah and Yeang	Positive		✓
Foster + Partners	Positive	✓	✓
HOK-Houston	Positive	✓	✓

It is important to notice that BES training and workshops identified in the data only served the purpose of basic simulation for early design stages. Perhaps it is not possible to provide professional expertise in three or four BES tools during workshops that only last a few days. The use of BIM and BES in a design process is also exposed in the next sub-section, where participants discussed the use of IPD, or alternatively, the use of IDP.

5.2.3 Use of IPD/IDP

The use of a formal IPD among these firms is rare. The respondents' perceptions are generally that the intention and spirit behind it is good, but IPD will not take over as the main delivery format. The main reason they cite is the approach to liability (sharing risk and benefits) in IPD is too distant from the expectations of most clients. The way an IPD process is structured tends to benefit large-scale projects and large firms with a recognizable experience in BIM and construction delivery, while smaller design firms and/or contractors and small projects are not a good fit. Some firms are adapting the AIA IPD to provide a more flexible liability arrangement to fit more design situations.

Despite the rarity of the use of IPD, most designers from this sample, regardless of the scale of the project, are using an integrated design or multidisciplinary approach to sustainability (IDP). From the participants, large design firms usually have an in-house multidisciplinary design team comprised of architects, landscape designers, urban designers, structural and MEP engineers and sustainability consultants, while medium firms tend to rely on outsource consulting. By working from conception with external consultants (or in-house, if applicable) and with multiple stakeholders, the firms have been able to achieve higher levels of building performance and satisfaction from clients and occupants. The next paragraphs will detail how each firm approaches IPD/IDP.

HOK as a firm has implemented IPD successfully, and their perception thus far is positive. They perceived it as having improved communication and coordination with all stakeholders. A live webcast explains the process for the relocation of HOK's New York office (Vandezande, 2011). However, HOK-Houston has not to this day implemented an IPD process. Nonetheless, their perception is positive. When asked about sharing benefits and risks with other parties in an IPD process, HOK-Houston's sustainability leader responded:

> *I would think IPD would help facilitate the trust. If I'm not working with an owner or contractor or consultant that I know very well, in the IPD, at least you're contractually bound to hit certain milestones, so everyone is equally incentivized, versus a normal process, where the contractor could be whispering something in the other's ear… It's definitely very interesting; I think it is kind of the future… One of the biggest fears on any project is litigation. If the project doesn't go well, if there's any kind of an issue or delay, lawyers are going to call and you're going to have the threat of litigation. Rather than that threat being a black cloud and the risk of going to court and dealing with lawsuits for years, you're putting all your cards on the table. You're agreeing, "I'm not going to sue you. You're not going to sue me. I'm*

not going to sue him." If you try to limit that liability, people are more up front, because everyone knows the budget… The contractor is not sitting there with the wallet looking at the budget and no one else on the team knows. For me, I think that level of transparency is powerful. (HOK-Houston's Sustainability Leader)

TR Hamzah and Yeang's perception of IPD, as gathered from the interview, is that it can be implemented with elite stakeholders, e.g., a highly sophisticated client, designer and contractor, on a highly sophisticated project.

Similar to TR Hamzah and Yeang, HOK's perception of IPD still is that the major benefits can be obtained from a large scale project because of the bigger incentives. Not everyone is a good candidate to be a party in an IPD contract, as detailed by HOK's project architect:

I think it's more about finding the right project, right client and right partners. I think scale has a whole lot to do with it, too. You try to get people involved as parties who you feel really comfortable about the quality you're able to get from the contractor, and he feels really comfortable about what he can do from the design standpoint, then having that client that embraces that. (HOK-Houston's Project Architect)

HOK-Houston makes use of firm-wide groups, such as BIM and Sustainability, to support offices and studios when required and drive a multidisciplinary and collaborative effort in design. Those leaders have different backgrounds and expertise spread across different offices world-wide, so HOK is currently trying to leverage those resources. As explained by their sustainability leader:

> *I would say the way it traditionally worked is there are a few of those kind of experts scattered throughout the firm. There wasn't much of an organization to leverage them. A lot of offices would use consultants. They'd bring in a special consultant to work with Arup or work with one of the big firms or small kind of local environmental consulting firm that specializes in daylight analysis or modeling or whatever. Now the way it's moving is we're focusing on bringing all that talent and expertise in-house. (HOK-Houston's Sustainability Leader)*

HOK is currently hosting different workshops to leverage those resources, which will be studied later in the Training Policies sub-section. The funding for those workshops comes mainly from their specific MBUs, which devote part of their income to generate expertise within each of their offices, building talent in their local environment.

One of ake|Flato's principals and the main individual responsible for revising their contracts explains that many clients requested an IPD process, but in the end, they decided not to do it. Lake|Flato has not yet implemented an IPD process:

We've had a few clients bring a project, saying they wanted us to use IPD or BIM, but either the project did not move forward or the client changed their mind…As for the contracts (which I handle within the office), I've reviewed the AIA and ConsensusDocs contracts (have not seen one from EJCDC and don't know that one exists, but expect it does). In general (and in my opinion), the contracts need some work, as they seem short on reality as to the way the construction industry (as we've experienced it) really works. Logistically, sharing the model with the Contractor is not an issue, but the shared responsibility/liability between the three parties will have to be more clearly spelled out. (Lake|Flato's partner)

His skepticism is due partly to the belief that for an IPD process to work, it requires a very specific type of project, client, designer and contractor. The lack of trust between designers and the contractor is the main issue. At least with small firms, including Lake|Flato, they rarely do work with the same contractor twice, so it is more difficult to engage in such legal agreements on smaller projects. For larger projects, such as a healthcare facility, Lake|Flato usually work as a design consultant with a larger firm that will deal with the technical infrastructure. The same participant expressed his opinion about contract agreements, and his perception of construction idiosyncrasies:

Actually we use AIA contracts. Most of them are built around AIA contracts, and we prefer them. There are fewer different owner contracts, and the thing I like about those is that those are all governed by another document: the AIA

A201 General Conditions. It lays out the roles of the three parties and their responsibilities. You are working with people… Contracts may define the way the world exists but the world doesn't exist like that because you are dealing with personalities and attitudes. (Lake|Flato's Sustainability Coordinator)

Lake|Flato embraces integrated design and strongly believes that it brings a better solution for the client. However, in its current implementation, the projects have not cost less, as their sustainability coordinator explains:

> *The chart of the EC [MacLeamy curve] about the effort vs. cost and that nice curve where it comes down… we didn't see that on our projects… that's a lot here and doesn't taper down to exactly the low level that everybody would like to think it does, so there are more hours spent working on these projects at the moment while we are getting familiar with them… I just don't think that the argument about costing less in the long run… Again, we don't have as much experience as some other firms do, we just aren't getting much of a demand for it, but at the end, it didn't cost A LOT more but it didn't cost less, but we do think we did a better project. (Lake|Flato's Sustainability Coordinator)*

HKS have a strategy of cross-pollination in their work environment, where the "Sustainability Studio" has work that overlaps with other Studios. This derives from the organizational structure of the firm, as HKS-Dallas' participant explains:

While they are not working together every day, there is a lot of dialog and opportunities for dialogs between studios, so we get that cross-pollination. Unfortunately, for me, I have a sustainability studio that supports all of the market sectors, so I get a lot of overlap with all of them. (HKS-Dallas' Sustainability Chief Officer)

Regarding their overall design workflow, it varies depending on the project. There is no blueprint or standard for their design, although a multidisciplinary design team is always favored:

…What we try to promote is a very integrated design process where we bring all of our project stakeholders together at the start of the project, before any pre-conceived ideas. But not all projects do that… some of them start with a developer and a principal. (HKS-Dallas' Sustainability Chief Officer)

Their use of integrated design preceded the time where the terminology was coined, as well as preceded LEED. They have a few projects done under a formal IPD contract. Their perception is positive on the projects done thus far, especially regarding the strategy of no liability during the development of the project:

Probably the best experience that I had was when we were doing the Sabre Corp Campus on Salt Lake… the client softened the atmosphere and we basically agreed that we will deliver the best project we could… and sent the document saying that we will not sue each other. I think that really opened the

> *door for more creative ideas and the owner was receptive to trying some things that we were not sure for certain that they will succeed. But we did our best diligence to evaluate the pros and cons in some of the ideas, and we had a reasonable assurance that we will not come back to us from a legal perspective if something failed. (HKS-Dallas' Sustainability Chief Officer)*

The project was completed within the budget and on schedule. Their perception of the requirements for a successful IPD process is shared with some of the other firms, in terms of having a carefully selected team. However, HKS-Dallas' sustainability chief officer was skeptical about some values of the IPD contract, and HKS offers a similar alternative without sharing risks:

> *I am a little bit uncertain personally about the value of the IPD contract. It is not that I don't trust contractors, I just think that it is a better arrangement for the owner to have someone that is strictly looking after his interests… We have some that we called "soft IPD agreement" where there are some incentives similar to those you see in an IPD contract, but then the owners are always reluctant to enter into the IPD agreement, because they are equally responsible for the success of the project. Still there is a lot of hesitancy on the owner side… I kind of have doubts if the owner is going to buy into it… On the broad scale, I think it will always be an option of project delivery, I just don't know if it's going to take over as "the" method of project delivery. (HKS-Dallas' Sustainability Chief Officer)*

When a formal IPD is not possible, the use of integrated design has been strongly promoted in the firm:

> *Integrated design will give the client a better product; create a more sustainable project, one that has the input of more than one stakeholder into the design… I know our healthcare department does a really good job at that, getting the input from not only the healthcare department managers, but the nursing staff, interviewing patients, we try to get a really good perspective on what makes a good design. (HKS-Dallas' Sustainability Chief Officer)*

By comparison, their HKS-London office has experienced a different approach to an IPD format, where their perception is more negative than positive. As explained by their associate principal, some particular problems have been encountered:

> *It's similar but it's not set up in the same way as IPD in the States. Contractually, the relationships are similar to that setup. For instance, government work, PFI's and BSF, which is publicly-funded hospital and school projects, it's set up in a pretty similar way. There is a risk sharing agreement between those parties. It moves the project forward the entire way. It's not equally legal… It's probably closer or more akin to a design-build type delivery system than anything else. It's very contractor-driven. As you go through the delivery process, from a negative standpoint, it can be incredibly difficult as a designer to really maintain the standards and level of design, level of things you're trying to achieve throughout the entire thing... How are we*

going to do that piece cheaper, that sort of thing. To me, and this isn't true across all contractors, but in my experience, the contractors who are driving the process, they hold a bit too much power within that relationship. It's not an equal-equal-equal thing. (HKS-London's Associate Partner)

According to their experience in the U.K., there remains reluctance between designers and contractors to work towards a common goal. They tend to follow Design-Build practices rather than shifting the whole model. The sharing of risks and benefits do not work as fluidly as desired and contractors seem to have more power during the delivery process. Managing the budget still remains a contractor's duty, which may affect the quality of the overall building design. Despite some bad experiences with their equivalent IPD process, they appreciate feedback from different consultants and specialists early on in the design process, as part of the integrated design approach.

TR Hamzah and Yeang's approach to design is definitely multidisciplinary, mostly by interacting with external consultants. However, being a smaller firm outside of the US does not expose them as much to the AIA concept of a formal IPD agreement. Nonetheless, their integrated design is widely recognized by the press and their peers as innovative and the firm is also recognized as early adopters of IDP.

Foster + Partners now have a complete suite of specialist support teams to collaborate with their Design Studios in different areas. Those areas are identified as:

- Sustainability Team;
- Specialist Modeling Group;
- Graphics Communication and Visualization;
- Model Makers;
- Material Research Library;
- Applied Research Development; and
- Construction Review.

Additionally, they have structural engineers and MEP engineers. Foster + Partners' perception about contractual agreements like IPD is that it requires many revisions on its liability issues, in particular, the unclear specifications on BIM delivery, which affect an IPD process. Usually, the BIM from designers is rebuilt to fit construction and fabrication purposes, depending on the fabricator's needs. Designers do not always have an influence on the model later on, so the contract should delegate responsibilities for the model's accuracy to be used for F or buildi ng commissioning.

When asked about the impact of integrated design, BIM, and BES in the final outcome of a sustainable design, Foster + Partners' Design Systems Manager responded:

> *Probably the integrated design has the biggest impact. The environmental comes into that in terms of, not necessarily from the analysis, but from the integrated team itself. Particularly if it's an experienced team, the learning they have can have a big steer before the analysis happens anyway. That's your primary influential part. The analysis will then ratify that. Sometimes it informs*

and steers the design, but most of the time we'll ratify it and it will just refine that design. The BIM just joins the two together as the process flow, to get the information flowing cleanly and sharing that model data and the intelligence information coming out of it. (Foster + Partners' Design Systems Manager)

Tacit knowledge is applied by an experienced team within an integrated design, and helps the team to decide how to approach the design problem. Simulation will ratify the design decisions on early schematic designs and also later on, to reassure that the design responds favorably. BIM holds integrated design and BES together being the central repository. BIM and BES combined helps the integrated design team to learn about the design problem and find a more effective solution.

Similarly, HOK has expressed a similar thought about BIM in the integrated design and/or IPD process:

> *I think if IPD is the destination, then BIM is the vehicle. Design/build is probably our training wheels to become familiar with collaborating together at the beginning rather than handing off the project and wiping your hands clean of it. Then you take the BIM model, so you begin to work with the engineers and the energy analysis and simulation while you're designing. What you're left with is IPD. (HOK-Houston's BIM manager)*

HOK-Houston's sustainability leader adds that at present we cannot think about integrated design without BIM. According to him, BIM, BES, and integrated design are all interrelated and interdependent, and for a successful sustainable design, all those components are needed. HOK's sustainable design approach has long depended on integrated design process. Before they adopted BIM, sustainable design was conducted using a charrette format. After the adoption of BIM, the communication was more fluid, efficient, and dynamic. Their BIM manager thinks that BES will have a bigger impact as it matures. He believes simulation tools will be the third component of the equation as soon as the design teams are proficient in using them. According to him, the proficiency in the software plus the technology that allows them to exchange data between experts is truly necessary:

> *I think simulation hasn't had as large as an impact yet because it's not mature enough. Definitely that will be the third component. When the technology and the teams and proficiency all meet will be at the simulation. I think it's an evolution. I don't think it's a ranking. I think it's a timeline. (HOK-Houston's BIM manager)*

A similar perception comes from the HKS-London team, where BES is still not incorporated into their regular design workflow. Lack of proficiency and confidence in using it are seen as the main reasons:

> *We may do it (simulation), but we still may have to point it in the direction of the MEP engineer to take it and say it's correct. I don't see why there's any*

reason the MEP engineer has to be involved in the early design stage. I think if it was fast enough, we could do it all through the use of things like Revit-Vasari. (HKS-London's sustainability leader).

I think, as far as the design process goes, it will evolve as the software evolves and as people learn what they can do with it. From a modeling standpoint, we should know, from an energy standpoint, what we're designing and how it's going to basically perform... Whether that is feeding directly into what the M&E engineers and designs is a whole different story… For us to rely on somebody else for now just to get the basic information, we have a tool already there. We should just be taking advantage of it… The tools are there. It's just what you're willing to incorporate into your process. (HKS-London's associate partner)

The last two insights are presented as outliers of the integrated design approach. Making basic decisions about MEP from using the tools is potentially a radical change of the design process for architects, plus, reducing consultation fees.

After analyzing the participants' perception of IDP and IPD, it is important to prepare the reader to understand the discrepancies found in contract agreements and established workflows. The issues discussed in the next paragraphs do not relate to the data gathered from the interviews, but are a discussion of the existent literature.

Arguably, the AIA's *IPD Guidelines* and the *Architect's Handbook of Professional Practice* are the main references that describe both integrated design practices and IPD, and those documents are used as references by most of the participants. The AIA's *Architect's Handbook of Professional Practice* provides several recommendations for professional practice, including templates of contractual agreements, recommendations for implementing integrated design, adopting BIM and evidence-based design. Along those lines the reader will find important practitioners and researchers' opinions on the subjects of this particular study. In the next paragraphs I will include some of the most relevant observations from the handbook that are supported by this study with additional issues that were discovered through the interview's transcripts. These AIA documents have been widely used in the industry and have been considered standards and best practices for many years; hence it is important to compare them to the reality observed in the practice.

Regarding integrated design, the handbook highly recommends the incorporation of the construction team in the design process as well. For predesign stages, they recommend forming a multidisciplinary design team to conduct a comprehensive site analysis and to prioritize sustainable design goals. For schematic design, they look for ways to reduce demand on MEP systems through passive design strategies. They also suggest creating energy models to adjust the design and/or physical models to test daylighting effects, all through a basecase that serves as a benchmark to be improved. For design development, they refine the design and reevaluate using computer and physical models. Following that stage, construction documentation is started with an emphasis on coordination using BIM. The construction stage starts with sustainable goals for reducing waste and minimizing energy consumption and contamination. Next step is the commissioning of the building prior to occupancy, holding training sessions for owners, operators and occupants (if required). Post-occupancy analysis (one year intervals) is encouraged to provide lessons learned (successes and failures).

The reality observed with the sample of participants is close to that described in the AIA handbook, but there are some issues not fully disclosed. Although the AIA handbook offers the AIA B101-2007 (Standard Form of Agreement Between Owner and Architect) as the main contract form, they also present the AIA IPD as an alternative. The observations suggest that when these firms use IPD, they adapt the B101-2007 to accommodate their own benefits/risk sharing and liability. The first describes a design process very similar to the reality observed for sustainable design, except the liability and benefits/risk sharing which is not widely accepted or adopted yet, preventing its use as a standard agreement. Moreover, despite the recommendation of adopting BIM processes, the delivery specifications and responsibilities for BIM are vaguely described in the AIA IPD agreement, according to the participants. From the interviews, I identified three offices with an advanced use of BIM, but only two of them had BIM experts as interviewees. Both of them agreed about the vague specifications on BIM delivery on most contractual agreements. The second and most common agreement (B101-2007) assumes a linear and orderly process divided in five design phases: schematic design, design development, construction documentation, bid or negotiation and construction administration. The handbook acknowledges that the reality is quite different from this linear process, especially for sustainable design, where many factors require a necessary loop of refinements that go back to the design team even during construction processes.

Second, the handbook, also acknowledged the fact that BIM can break the barriers that define different design phases. Schematic design and design development can have the same level of detail in BIM, with the difference being in the level of design refinement.

Another issue that emerged from the literature is related to training procedures on BIM. The AIA handbook acknowledges that the AEC industry is in a transition period, and that most engineers, contractors and owners do not use BIM yet. Moreover, they acknowledge shortage of both trained staff and trainers (AIA, 2008, pp.238), but there are no suggestions for strategies to implement training. This issue will be discussed in the next section.

The AIA IPD guide refers to seven steps as the initial names appearing in this following list (shown in italics), but the AIA handbook (AIA, 2008) relates them to the best practices design phases (shown in parenthesis):

1. *Conceptualization* (or predesign),

2. *Criteria Design* (or schematic design),
3. *Detailed Design* (or design development),
4. *Implementation Documents* (or construction documentation),
5. *Final buyout* (or bid/negotiation),
6. *Construction* and
7. *Closeout* (post-occupancy).

The *Conceptualization* step includes sustainable goals and programming. *Criteria Design* includes programming as well (form, adjacencies and spatial relationships) and the definition of a basecase (included in **Goals Definition**), initial energy models and considerations for ecology and passive/active systems (included under **Analytics**). *Detailed Design* is a refinement of the design using computer and physical models (included under **Design Refinement**). *Implementation Documents* (or construction documentation) basically refers to the translation of all information for construction purposes (included under **Construction**). *Final Buyout* is a process independent of the design process, so is out of scope for this study. *Construction* includes sustainable goals for reducing waste and minimizing energy consumption and contamination. The next step is the *Closeout* that refers to the commissioning of the building prior to occupancy, holding training sessions for owners, operators and occupants (if required). *Closeout* also includes post-occupancy analysis to provide lessons learned (successes and failures). *Closeout* steps are all included in the **Operations** step.

Overall, the AIA IPD guideline offer valuable information for an integrated design process for sustainable architectural design Nevertheless, the description is still attached to linear phases that belong to a traditional design process. Second, the guideline lacks a clear description of why architectural programming is included in two different phases. Another issue that emerged from the interviews is the perception that the AIA IPD contractual agreements lack clear specification of delivery for BIM. Moreover, the AIA B101-2007 is not representative of the non-linear process of design for contemporary sustainable architecture. Table 23 shows a summary of IPD perception.

While the AIA IPD/handbook and the HOK guidebook have several overlaps, there are critical aspects that require substantial changes to better reflect the reality observed:

1. The definition of steps is still attached to the linear and sequential steps from best practices that rarely happen in the practice of sustainable design.
2. Programming in the AIA IPD is mentioned in two different steps (Conceptualization and Criteria Design) making its implementation confusing.
3. The HOK guidebook is heavily based on LEED checklists that are often descriptive, rather than performance based, despite HOK's encouragement to implement them synergistically.

In summary:

- IPD use in the sample is rare;

- Participants overall perception of IPD is positive, but some were skeptical about its liability agreements;
- IPD is structured to benefit large scale projects and large firms with a recognizable experience in BIM and construction delivery;
- Some firms have adapted the AIA IPD agreements;
- Most firms are using an IDP or multidisciplinary design team;
- Large firms have an in-house multidisciplinary design team; while medium firms tend to rely on outsource consulting,
- Although the AIA IPD guideline offers describes valuable description an integrated design process, it is not entirely accurate as a description of observed practice,
- The AIA B101-2007 contractual agreement does not represent well the dynamics of the design process for sustainability.

Table 24 synthesizes the perception and experience of using IPD.

Table 24: IPD perception.

Offices	IPD	Experience
Lake|Flato	Skeptical	
HKS-Dallas	Skeptical and positive	✓
HKS-London	Negative	
TR Hamzah and Yeang	Exclusive	
Foster + Partners		
HOK-Houston	Positive, Exclusive	

In the next sub-section, the participants were asked about their perceptions of how GBRS can affect their design workflow and the possibility of a standardization of sustainable design.

5.2.4 Use of GBRS

In summary, LEED has been used as a road map for sustainable design by many firms and that is one of its major legacies. However it has limitations, as discussed in the literature review of this study, and the participants agreed that the certification of a project does not guarantee sustainability. They suggested that a more effective implementation of GBRS should be performance-based, rather than descriptive.

The HOK Guidebook to Sustainable Design book (Mendler, Odell & Lazarus, 2005) describes LEED shadowing, a practice that employs LEED as a design guideline but with no desire to actually obtain the certification. HOK-Houston's sustainability leader makes the analogy that LEED shadowing is like auditing a class:

> *You might go to class for the first week. You might read a couple of the readings, but you get busy with your other work. You're not earning a grade on that class. You're not turning anything in. You stop going to class as much, stop doing the reading. All of a sudden you're not there. I've been on a few projects where they initially said, "This needs to be LEED certifiable." I say, "Well, certifiable? What does that mean?" "Well, we need to at least be capable of being certified?" I'm like, "Who's defining that?" The whole*

purpose of certification is that it's a third party defining that… I think they've gotten away from that. The government used to have that language, it has to be certifiable. They've stopped that because they recognize that it's just not really applicable. (HOK-Houston's Sustainability Leader)

According to his vision, the main benefit of pursuing the certification resides in the rigor required to obtain it. If nobody is being accountable for the building not being certifiable, who will make the effort if there is no incentive or punishment for failure?

Similar perception comes from Lake|Flato:

> *A lot of clients and project teams will ask for it to be LEED equivalent instead of actually going through the rigorous process of getting it to be LEED. In my experience without it (LEED)… since they are not held accountable they might not necessarily do everything that is expected from them, so whenever you have the rigorous third party certification system it really holds people's feet to the fire and makes them do what they said they were going to do. I think it just adds an extra level of rigor to the process. (Lake|Flato's Sustainability Coordinator)*

Going back to the rigorous process to obtain a LEED certification, the new versions require a fully documented integrated design process and also metrics from the building's performance for a period of five years. Designers cannot decide for the client to achieve LEED certification, but they may advocate for that rigorous process.

HOK-Houston's Sustainability eader believes EED had a tremendously powerful transformation effect in the industry, especially when used as a marketing tool for commercial buildings.

HKS were also early adopters of LEED, and they are aware of its limitations as a guideline or recipe for a successful sustainable or integrated project:

> *We started using LEED when it was still in the pilot program; it wasn't even published yet… The spirit and intent of the LEED rating system is to promote that integrated design, to promote the input of more and more stakeholders, and we are seeing that. But unfortunately, you can still force the rating system on a project that is not truly integrated. (HKS-Dallas's Sustainability Chief Officer)*

According to TR Hamzah and Yeang, having a GBRS certification does not guarantee a good design, but GBRS can be used as a system for buildings to be measured by, or as design criteria.

The HKS-London office has a slightly different approach when a project needs to be BREEAM certified. A BREEAM third party officer examines their projects, as explained by their sustainability officer:

> *A lot of the projects we do here are public projects, so things like the healthcare or education projects have a requirement as part of their funding to*

take on the BREEAM consultation. In the BREEAM, it's not the architects working, it's the approved professionals. Here, you usually have a party BREEAM consultant working for us to do BREEAM assessment and guide us on credits. We have a design stage checklist which we use similar to what I think maybe in the States with LEED. That is the clearest difference between it being the architects in the States running LEED and the third party doing BREEAM here. (HKS-London's Sustainability Officer)

In addition, the HKS-London office often works with LEED and BREAAM depending on the type of projects. Usually, Healthcare and Education projects are government-funded projects, which are required to be BREEAM certified, while Hospitality and Sports for instance are mostly done outside of the U.K. and tend to be LEED-driven. HKS- ondon's associate partner expresses their commitment to include GBRS into their design workflow as part of their ethos:

We typically will advise the investors early on that we need to decide if it's important for them commercially or ethically to chase the BREEAM or LEED or whatever certification, and if so, how we achieve that. At the same time, as a firm, professionally, it's part of our ethos and strategy to work that into the design regardless. (HKS-London's Associate Partner)

According to the participants, the differences between U.S./LEED and U.K./BREEAM were insignificant in terms of building outcomes/results. Their effects on the design process are seen to be an addition of rigor in documenting goal achievements, making stakeholders accountable for achieving clear levels of performance. Their effects in the AEC industry are perceived as positive for creating higher standards and benchmarks for building performance. Additionally, the use of GBRS is considered by some participants as the closest attempt to standardize design processes when used as a checklist to confirm achievements.

Is it possible for a collection of best practices for sustainable design to be transformed into a standard design procedure? The next sub-section will explore in-depth the attitudes and perceptions gathered from the participants about collecting best practices for sustainable design.

5.3 Commonalities in Sustainable Design Processes

In this section I discuss four topics. First, I discuss about how design processes for sustainable architectural design can be collected as best practices, protocols or standards, according to the data gathered from the interviews. Second, from analyzing their design methods, I present a general description of how the selected contributing firms develop their designs. Third, I present a more detailed description of those processes, including data from the interviews, internal documentation, guidelines and books.

5.3.1 Standardization of Sustainable Design

Standardization of sustainable design in general was seen by the firms as not possible or not recommended, due to the particularities of each project, and also due to the very nature of architecture where multiple solutions are feasible for one particular problem. GBRS was seen as the closest approach to standardizing sustainable design. Despite the disbelief of the participants about a possible standardization of a sustainable design workflow, careful study of their responses in the interviews suggests much commonality in how they approach sustainable design. Five out of six offices described a design process whose commonalities could be collected as best practices regardless of project fee structure, building type or climate, presenting a design process with similarities in terms of their use of analytics and web resources. TR Hamzah and Yeang, Lake|Flato and HOK have made attempts to standardize specific aspects of their sustainable design.

TR Hamzah and Yeang, for example, described a process of holistic analysis to uncover the needs and potentials for the project, beginning with the ecology of the site, and then to the architectural program and design features, with a strong emphasis on the use of passive system design. Their first design alternatives usually do not include BES analysis, but they include simulation to refine or test a specific design when feasible (budget, schedule, etc).

Lake|Flato, another medium sized firm, created a sustainability toolkit (see Appendix 5) to guide designers when considering practical aspects of sustainability, such as the use of natural resources (water, daylighting, materials) and renewable energy. Lake|Flato tends to employ a hybrid approach, being guided by both LEED requirements and their own sustainability toolkit. They try to take maximum advantage of passive systems, in particular, because most of their projects have a small to medium scale and are not heavily dependent on complex and large MEP systems. Their designs usually incorporate BIM at medium level of advancement, and also basic simulation for earlier design stages. Advanced simulation is used if required, and if allowed by budget and schedule.

In the interviews, the representatives from HOK described a team-based organization, and described the ten key steps to provide a roadmap for an integrated multidisciplinary design process. HOK's design process and goals definition is guided by LEED requirements (checklist) and a multidisciplinary team. Their designs are also accompanied by technological advancements, including advanced use of BIM and BES. Mendler, Odell & Lazarus (2005) outlined Ten Key Steps at HOK to enable the design team to fully understand and address the issues of sustainable design. These ten steps are identified as:

1. Project definition, to establish the scope of the project
2. Team building, seeking for experienced design team members committed to sustainability and to collaborate
3. Education and goal setting, engaging the team in discussion of sustainable issues and opportunities and setting the goals and measurable outcomes

4. Site evaluation, analyzing the site and identifying constraints and opportunities
5. Baseline analysis, developing baseline energy and water analysis, exploring potential for renewable energy, etc.
6. Design concept, using an integrated design approach
7. Design optimization, testing and evaluating a broad range of solutions with the multidisciplinary design team
8. Documents and specifications,
9. Bidding and construction and
10. Post occupancy, where the design team and building users discuss ways to improve building operations, maintenance and occupant satisfaction.

HKS is similar to HOK in terms of having a multidisciplinary team and being guided by GBRS requirements, but their design process is also guided by their own "simulation game" to generate design alternatives in early stages. Their use of BIM technology is also advanced compared to medium sized design firms from this sample of participants.

Foster + Partners usually have a highly technological approach to their designs, in addition to incorporating a fully multidisciplinary team within the firm. Their use of advanced materials, active and passive systems and high technology throughout the whole design process allows them to create highly sophisticated designs.

Some firm's design techniques to achieve best performance are documented in manuals or private networks and web resources, such as those maintained by HOK, Foster + Partners and HKS. These documents address how certain design strategies could be successfully implemented and at what design stage they should be used.

The next paragraphs will analyze in detail the evidence found from the interviews:

When asked about the possibility of standardizing sustainable design, TR Hamzah and Yeang responded:

> *I think there are many ways to skin a cat, many ways to get to the end result. It doesn't have to be one way; it can be many ways. Everybody has their own way. Some are faster than others. Some are more appropriate for some of the projects. I try not to be too deterministic about it. That's my view. Some people think there's only one way. (TR Hamzah and Yeang's partner)*

The HKS-Dallas office responded to the question of how sustainable design can be standardized as a collection of best practices, as follows:

> *To a degree it can (standardization of design)… but buildings are so unique, so there are no two buildings alike… The International Green Construction Code (IGCC) is trying to do that, but … Let's say for instance that the intent of the code is that you have good glass in your building… OK? Let's say that you are required by code to put on your building in this particular climate zone a glass*

with the solar heat gain coefficient (SHGC) of 0.23… Well what if I as the designer didn't want to spend the money on that high performance coding on that glass, and I instead want to put some shading devices on it to achieve the same thing or better? I want to have that flexibility, you know what I mean? So I guess: if things get codified, they should be based on a performance base and not a descriptive base. (HKS-Dallas's Sustainability Chief Officer)

A similar thought has been expressed by TR Hamzah and Yeang about GBRS being best suited as a performance based approach, rather than prescriptive:

There are two ways of looking at this. One would be prescriptive. That means you have to design a building that must not consume more than 120 kilo-hours per square meter or your environment will be maybe 23 degrees air change to air change. The other process, the performance-based, says we're not going to tell you 250, just as much non-renewable energy as possible… It's a performance-based approach. Of course, performance-based is more difficult to achieve. It's like a principle. You can never achieve 100 percent. You can never close the water cycle because you lose a lot of water to evaporation and through inefficiencies. The idea is there. The principle is there. So you end up achieving as much as you can. (TR Hamzah and Yeang's partner)

However, some firms have documented a series of steps to follow in certain aspects of the design that are in some sense a standardized process. Lake|Flato, for instance, created a sustainability toolkit to deal with the following categories:

- Solar orientation and shading (climate analysis template and sizing overhangs);
- Energy (2030 Challenge, post-occupation evaluation, among others);
- Wind (natural ventilation strategies and calculation);
- Materials (VOCs, sustainably harvested wood, Living Building Challenge Red List, etc);
- Water (heating and rainwater collection/calculation);
- Glazing (properties, recommended light levels, etc); and
- Renewables (geothermal, PVs, etc).

Each category contains a list of steps and considerations to take while designing, as well as resources for estimations and recommendations for different design stages. The document codifies knowledge and process with empirical data and evidence gathered throughout the years.

It is interest to highlight this strategy as one of the attempts to standardize sustainability analysis during each design phase, using the documentation to inform design decisions. However, when asked about possible ways to standardize sustainable design as a collection of best practices or recommendations, their sustainability coordinator reacted with skepticism. Her reasons were that a sustainable building needs to respond to climate first, and not all passive design strategies work well for all climates. Second, every building type presents different requirements that are unique. According to her, the combination of building type, site requirements and climate makes standardization of design impressive challenging undertaking. She believes that a more flexible framework like GBRS works well enough.

Some firms have specified what to achieve for specific design stages for sustainability, where most are based on GBRS checklists. HOK created *The HOK Guidebook to Sustainable Design* (e ndler, Odell and azarus, 2005), where "Ten Key Steps" attempt to provide a roadmap for an integrated multidisciplinary design process. A series of considerations and recommendations are explained for each design phase, to better inform a design team with sustainability in mind, in a similar fashion to the credit point checklist from LEED. All the responsibilities for each team member are clearly defined for all design stages. The book also presents 18 case studies with several post-occupancy evaluations to showcase the benefits of sustainable design, from an environmental and financial perspective. Additionally, it provides strategies for sustainable design for different building types.

Ken Yeang, principle of TR Hamzah and Yeang, wrote several books where he presents general premises and strategies to approach sustainable design for different purposes. ost notably, "*Manual for Ecodesign*" (Yeang, 2008) explains how design decisions can affect the relation between a building and the environment at different levels. Basically, the manual presents information to consider with sustainability in mind. However, it does not attempt to present a rigorous step by step process that can be implemented for all designs, since the conditions of site and climate are unique to each project. The book also considers practical issues for building envelope design, such as optimum aspect ratios of massing and passive/active comfort measures according to specific climate zones.

According to Foster + Partners' design systems manager, different GBRS and performance standard protocols have started to converge in terms of building performance requirements (ASHRAE Standards, LEED, Part L (U.K.), etc.), which might be one way to standardize design in a prescriptive form. Every building is different, and Foster + Partner designs do not follow templates of any kind. Because they are often trying to push the limits in terms of building performance, new materials and techniques are used for every particular project. However, depending on the building type, it might be possible in case of a specialty, e.g., housing or retail, to create a standardized design process.

The only strategy on the design workflow that is shared across all participants in this sample is the use of weather and performance analysis. Some participants will also analyze the local impact the new building will have in the site before construction. Nevertheless, not all buildings have the same need for analysis because it will depend on each building's complexity and design team capacity. From this sample, there is no suggested workflow in terms of software use and design consultants' participation in the timeline of a project.

The sample of participants is moving from a traditional and linear method using tacit knowledge to an explicit approach using BES to ratify their design decisions. In summary, five out of the six firms have presented, implied or suggested the possibility of a standardized method or workflow for sustainable design, as shown in Table 25.

Table 25: Standardization of Sustainable Design and Design Workflow.

Offices	Standardization of Sustainable Design?	Sustainable Design Workflow
Lake|Flato	Undecided	✓
HKS-Dallas	Yes	✓
HKS-London		
TR Hamzah and Yeang	No	✓
Foster + Partners	Undecided	✓
HOK-Houston	Yes	✓

5.3.2 How the Contributing Offices Create Sustainable Designs

The participants were asked to describe their overall sustainable design workflow, in terms of site and climate analysis, material selection, implementation of passive design strategies, and other factors.

In general, the participants start with an analysis of the orientation, site and climate, as well as the urban or rural conditions. That information orients designers to choose specific passive design strategies. The architectural program can dictate the space configuration and the connection between different zones/spaces that might affect the decision of what passive design strategy can be implemented. Simple massing simulation analysis is performed to compare design alternatives for schematic design and to refine building shape. When the design approaches the design development stage, most of the simulation is already done and the design is refined. Then, the next step is for coordination using BIM and 4D CAD if applicable (clash detection). BIM can be used for commissioning and FM, providing new information about the building's performance and new lessons. The next paragraphs highlight some thoughts from the participants.

As described by TR Hamzah and Yeang, the design workflow usually starts with a holistic analysis of the site, its ecology, climate and all the possible passive strategies for a climate responsive design. This is followed by an analysis of the program with the goal of reducing carbon dioxide footprint, as explained in this excerpt:

> *We start by looking at the site. A couple of factors: we look at the climate… So if it is a temperate zone, we try and see what climate responsive devices we could use. If it's a cold climate, that's different, so passive mode design is the starting point for our building form. Then we look at the ecology and find out the ecology of that location. More important, we look at the type of site. Is it an*

urban site, rural site? Existing ecology on that site determines how much information you need to collect as a basis for this design. Those are the starting points. Then from there we look at the built-up area on the design program. We look at the uses and try to find out whether we can create an internal life that's sustainable, reduce the covered area, reduce the enclosed area. We see if we can create in-between areas, interstitial areas or transition areas where activities can take place without being in a full energy consumption mode. (TR Hamzah and Yeang's partner)

One of the strategies implemented is to incorporate unconditioned spaces to transition between conditioned spaces, as a way to reduce loads and energy consumption. However, TR Hamzah and Yeang recognize that is not always plausible, since occupants often do not want to reduce their level of comfort. In their words, a good architect is capable of finding the best compromise with all the factors that interact with buildings, and also the best compromise between time, money and effort.

Foster + Partners' Design System ana ger explains their design workflow:

Where we're doing skyscrapers in China, we'll look at a site and do analytics on just the massing form to make sure we're getting the optimal angle for the building on the site for the solar gain on it, at very early stages in the design… What we look at is using different technology to do early stage studies to give *us reasonable indicators, to give us an environmental steer to what we think will be the best performance. (Foster + Partner's Design System Manager)*

When asked about the design workflow and the decision making process, he expressed:

It's a constant iteration and it's a constant discussion. We, typically on a project, will every fortnight review the design, review where we are, or review the options that have been developed in the last week. (Foster + Partner's Design System Manager)

The HKS-Dallas office describes their design workflow as follows:

It varies so much between different clients, different market sectors, it just varies tremendously…but usually our principals and our marketing guys, those guys still design and they will sit down with the client at the very first opportunity and brainstorm ideas… We try to promote a very integrated design process bringing all stakeholders at the beginning. (HKS-Dallas' Sustainability Chief Officer)

A more in depth analysis of their design workflow is described in the next paragraphs, separated in different steps.

5.3.3 Detailed Description of Sustainable Design Processes

In this section of the analysis, I will present in depth the design methods of the participant offices. Since I found many commonalities in the design processes of the sample of participants, I analyzed them as a part of a single group rather than individually to avoid repetition of topics. When necessary, I referred to specific offices individually to explain where and how they differ from the rest. Basically, a design process for sustainability involves a series of steps that I clustered as: (a) programming, (b) site, (c) goals definition, (d) analytics, (e) design refinement, (f) construction and (g) operations.

Programming

In this step, a detailed description of the function requirements for the design is done by specialists. In the highly accepted *problem seeking* method, Peña and Parshall (2001) distinguish between the architectural programmers and design architects. Architectural programmers are responsible for developing a detailed description of needs and requirements, while design architects synthesize the proposed solution into a form to be evaluated. According to the authors, design architects are too permissive towards modifying the program to match the shapes created by them. The argument is that programmers should have enough authority to develop a complete, thoughtful, and relatively fixed program for design architects to comply with. An alternative approach was created by *The Whole Building Design Guide* which proposes a six step for programming, defined as follows (Cherry & Petronis, 2009):

1. Research the project type: the types of spaces, the space criteria, typical relationships of spaces for these functions, typical ratios of net assignable square footage to gross square footage, typical costs per square foot, typical site requirements, regional issues that might alter the accuracy of the data above in the case of this project, and technical, mechanical, electrical, security, or other issues unique to the project type.
2. Establish goals and objectives: Organizational Goals, Form and Image Goals, Function Goals, Economic Goals, Time Goals and Management Goals.
3. Gather relevant information: in this step they analyze site conditions, topography, etc.
4. Identify strategies: By using "bubble" diagrams, you can indicate what functions should be near each other in order for the project to function smoothly. Relationship diagrams can also indicate the desired circulation connections between spaces or other aspects of special relationships. Some examples of common categories of programmatic strategies include:
    a. Centralization and decentralization
    b. Flexibility
    c. Priorities and phasing
    d. Levels of access
5. Determine quantitative requirements
6. Summarize the program

For automated processes, there are several software that helps organizing and evaluating programs, such as Trelligence Affinity™ (http://www.trelligence.com/) and dRofus™ (http://www.drofus.no/en/index.html), the later used by HOK.

Site

In this step, TR Hamzah and Yeang considered sieve-mapping as an adequate technique that visualizes parts of the holistic ecological analysis of the site, e.g. the disposition of the access roads, water management, drainage patterns and shaping of the built form(s), etc. by adding consecutive layers of information (Yeang, 2008). This can be done with transparent sheets of paper where each is a specific layer; or digitally, managing layers in a CAD file. Climate will dictate fundamental characteristics of the site to be considered, such as:

- Heating degree days (HDD) and cooling degree days (CDD) to determine if the design will need more heating or cooling throughout the year, www.degreedays.net
- Solar orientation, to determine passive heating and cooling strategies,
- Operational system (Yeang, 2008), defined as:
    - Passive mode – bioclimatic design, no mechanical/electrical (M&E) systems required;
    - Mixed mode – combination of passive systems with M&E systems (ceiling fans, double facades, flue atriums and evaporative cooling);
    - Full mode – M&E systems extensively throughout the year;
    - Productive mode – the design can produce energy/food;

- Composite mode – a combination of all the above.

To help analyzing climate and possible passive strategies, some firms use a software called Climate Consultant (Milne et al., 2010), along with psychrometric charts and wind rose charts for the site. Blank psychrometric charts can be obtained at http://www.uigi.com/UIGI_IP.PDF, or you can find loaded charts on software like ECOTECT/Weather Tool. Normally, a mechanical engineer is responsible for working with these charts, but an architect/designer can easily understand them with a little effort. Wind rose charts can be obtained from http://www.weblakes.com/products/wrplot/index.html, as well from ECOTECT/Weather Tool, where the comfort zone is already delimited on every weather file, and Green Building Studio.

Topography can have an impact in the site and design. Mountains and hills can provide shade and block sun radiation during specific hours and seasons of a day. Topography can also block or enable free wind circulation. Hence it can also affect the climate by creating a micro-climate. Geology can have an impact in terms of the quality of the soil for construction and economical feasibility, as well as possible energy sources (geothermal).

The site can be rural or urban. If it is rural, designers should look at the ecosystem of plants and the habitat of animals and species, to see how the building will affect that existent eco-system. If it is urban, they analyze the existent network of transportation, such as private and public, and conditions of the site, to determine if the site is a greenfield or a brownfield. Other aspects to be considered are the network of water, natural gas and electricity, including generation, processes and treatment. The proximity of the site to green areas such as parks and forests should be considered. From formal and legal aspects, requirements from building codes also affect in the analysis of site.

Energy consumption is related to climate, topography and site. Renewable energy sources can be classified as geothermal, wind and solar. Climate would dictate solar and wind potential for renewable energy, which by sub-product can define operational systems. Topography might provide obstacles to the generation of renewable energy. Geology dictates the geothermal qualities of the site. Buildings and trees can also present obstacles to the generation of renewable energy by casting shadows or disrupting wind patterns.

ake|Flato's sustainability toolkit provides a summary and tips about renewable energy that are fully described in Appendix 5. The toolkit discusses the cost of photovoltaic panels, as well as the available sizes, batteries and recommended angles. The toolkit also discuss other renewable energy devices, such as evacuated tubes, wind power and ground-source heat pump (geothermal).

Other aspects to be considered in the site are:

- Food sources, in case of the possibility of the site to generate food (seafood, agriculture, livestock, food waste management, etc.).
- Water sources**,** in case of the possibility to provide water from rainwater, lake/river, and also manage waste water.

If using rainwater tanks, ake|Flato’s sustainability toolkit provides useful installation tips (see Appendix 5).

The site can provide materials for the building, and designers should also consider waste management, recycling/disassembly, embodied energy, LCC, LCA, organic/inorganic material’s content. Designers can consult extensive database with all the materials commonly used in buildings and their correspondent harmful effects, as well as providing healthier alternatives to those.

Goals definition

In this step, stakeholders define the goals in terms of sustainability and design performance (Performance Goals and Measurement Criteria), and also establish the design team with an up-front loaded multidisciplinary work. They might decide to pursue a GBRS certification (LEED, BREEAM, Green Globes, etc.) and a third party to account for achievements. For the measurement criteria, several protocols or standards such as ASHRAE, ISO, IESNA, EPA, DOE, Part L (U.K.), third party certification consultants and verification methods (post-occupancy analysis, building commissioning, energy simulation) can serve to confirm that the goals were reached. The team building is arguably the most critical aspects of this step, where all design consultants are selected and the design atmosphere is set.

Analytics

This step represents one instance of an iterative loop where all stakeholders and design consultants work together to specify design strategies. BIM adoption is highly recommended for a fluid communication among design consultants, being the central repository of data. In several loops of discussion and analysis the design team defines the following:

- Choice of MEP systems,
- Passive technology (renewable energy production, passive cooling/heating, etc.),
- The environmental steer provided by design experts from their previous experience (tacit knowledge) and/or normative calculations, and
- Several design alternatives represented by basic massing analyzed with energy-simulation tools to inform decision making.

This process derives the final envelope design and the shape of the building, including solar shades, construction assembly, glazing construction/qualities, orientation, insulation, etc. The main BES tools used in the sample were identified as Autodesk's Project Vasari®, Ecotect®, Green Building Studio® and eQUEST® due to its friendly and interactive GUI (Attia et al., 2009), and RADIANCE® and DAYSIM® for advanced daylighting analysis. The main BIM tools identified were Autodesk Revit® Architecture and Bentley® Architecture.

An advanced use of BIM authoring tools should produce the following consequences, among others:

- Guarantee appropriate modeling efforts for each design
- Reduce setup time for BIM projects (prepare settings and templates to standardize family naming, font and text height, etc.)
- Facilitate efficient delivery of design models for construction and fabrication
- Meet client requirements for BIM
- Provide a structured framework to learn from designs
- Virtually eliminate redundant design efforts
- Test and/or help assessing building performance

Design Refinement

This step accounts for the many iterations of analytics where design consultants' feedback enhances and refines the design. It can include a detailed and/or advanced simulation. BIM is again critical for a fluid communication and a seamless loop dynamic. This step is finished whenever all stakeholders are satisfied with the design or when budget/timeline constraints allow them to continue design refinement.

Construction

This process includes construction documentation, bidding and negotiation, update of design if required, e.g., changes in material's selection, the construction process itself where BIM plays a key role in coordination and digital fabrication (optional). For this step, the use of BIM is highly recommended for coordination (clash detection) and the possibility of using digital fabrication to streamline the construction process. Software such as Navisworks is widely used for clash detection.

Operations

In this step, the building construction is finished and the facility goes through a process of commissioning. It is recommended that owners conduct post-occupancy analysis to verify final performance of the building. Finally, Facilities Management (FM) starts during normal operation of the building. BIM can also play a key role in FM.

In summary, the literature suggests the use of roadmaps to guide sustainable design, in particular, the use of GBRS (Vallero & Brasier, 2008; Mendler, Odell & Lazarus, 2005). Additionally, the literature also presents guides to integrated design and best practices (AIA, 2008). The various firms exhibit a high degree of common steps and activities in their sustainable design processes.

5.3.4 DEPROSU

The commonality found in the design processes from the participants has been synthesized into what I have named Design Process for Sustainability (DEPROSU) that could be validated and perhaps standardized across firms. The DEPROSU is a prescriptive and flexible model that conceives a multidisciplinary design team using BIM and BES proficiently. DEPROSU is a revised and updated model based on existent methods in the literature, such as the HOK Guidebook for Sustainable Design (Mendler, Odell & Lazarus, 2005), the AIA Integrated Design Guidelines (AIA, 2007), the Manual for Eco-Design (Yeang, 2008). DEPROSU also recommends the use of Eco-Balance principles (Fisk, 2009) as shown in Appendix 4 and the sustainability toolkit from Lake|Flato (see Appendix 5). Not all steps and sub-processes are mandatory in DEPROSU, but they are recommended for a holistic analysis and assessment of the design. Also, the design process itself is not a fixed and linear design process or development, as suggested by traditional design methods and the AIA best practices design phases. Furthermore, there are overlaps between the DEPROSU and some of the existing methods. For example, HOK also have a prescriptive method described in their HOK Guideline for Sustainable Design (Mendler, Odell & Lazarus, 2005), following ten steps for an integrated design. Their ten steps have overlaps with the description of processes from section 5.3.3., which are shown in Figure 27:

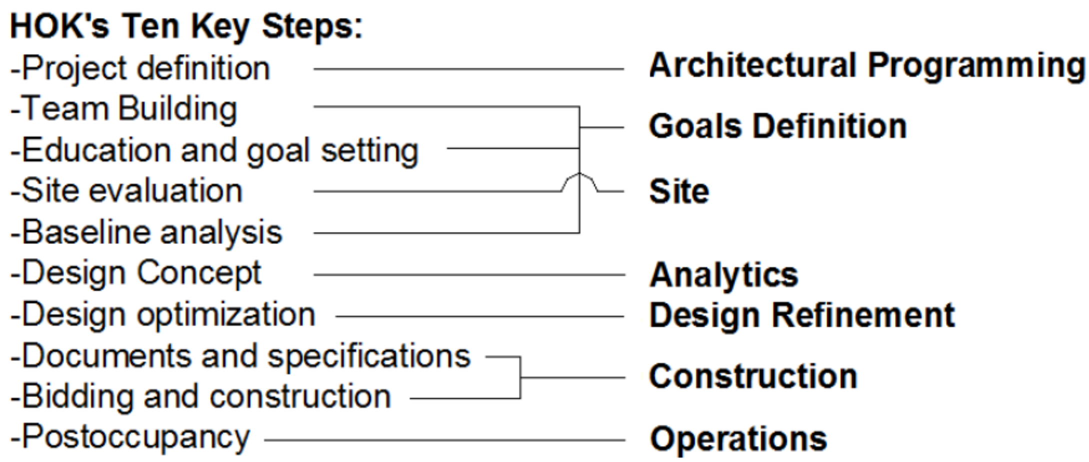

Figure 27: HOK's ten steps overlap with DEPROSU's steps.

In addition to the different emphasis a firm can have, there are multiple covariant variables that affect the design output, such as:

- Designers and/or consultant's talent/skills,
- Project's fee structure,
- Design firm infrastructure, including human resources and Information Technology,
- Building type, and
- Site.

All of the above can have multiple levels of complexity. The effects these covariant variables can have in the design output are out of scope for this research, so I am focusing on defining the design process holistically.

The DEPROSU model contains a series of steps that better reflect the state of the art in sustainable design methods. These steps, based on the processes described in section 5.3.3., are grouped in three main phases; each containing two sub-phases A & B. Every phase A represents an information gathering process for the process to be done in phase B (synthesis and invention). Phase 1A cluster all the necessary steps (or information) to start the actual design such as architectural programming, site and climate analysis, and goals definitions. Phase 1B includes the Design Refinement Loop where the building envelope takes place using simulation and design refinement. Hence, the Analytics step identified in the sample using tacit knowledge combined with explicit knowledge becomes exclusively a simulation task. Phase 2A cluster all the necessary information to start the construction process (construction documentation, sustainable goals, etc.). Phase 2B is the construction process itself. Phase 3A gathers all information required to start the building commissioning process (manuals for systems operations, cleaning, inspection duties, etc.). This is a result of a thorough BIM-enabled process that accelerates phases through automated drafting, energy modeling (BES), quantity take-offs, and form explorations. The consequence of adopting this process is the elimination of the three levels of hierarchical refinement described by AIA design stages (schematic design, design development and construction documents). As described earlier in the literature review, all forms of IPD recommend an effective use of BIM processes and an iterative analysis of design alternatives through BES. The ConsensusDOCS300 format includes a BIM Addendum and the AIA IPD also suggests the adoption of BIM throughout the design process. Although most of the participants of this study have not designed under a formal IPD format, their design methods suggest a close approximation to the principles of IPD, excluding sharing liability and savings (not included in DEPROSU).

Phase 3B includes all the steps recommended when the construction is finished and building operations begin (post-occupancy evaluations, facilities management, etc.), so it can provide valuable insight and information to refine future designs. With Phase 3B concluded, the DEPROSU cycle is closed.

It is important to emphasize that the construction process for sustainability is distinct from a regular construction process. With sustainability in mind, the process includes an additional level of rigor to manage waste, to control contamination and to reduce energy consumption, among other issues. The planning of such an endeavor requires careful study of accesses and exits, connection with the existent urban grid (electricity, gas, water and communications), recycling, etc. The documentation of the construction process when targeting a GBRS is also critical. These phases include all other steps found in documented processes from the sample of participants and also the literature, with different kinds of overlaps.

The DEPROSU differentiate from existent methods in two ways: (1) some steps can have no particular order within a phase; and (2) some steps can go back and forth emphasizing the real dynamic of the design process for sustainable architectural design, represented by double arrows in the next figures. A simplification of the DEPROSU model is defined in Figure 28.

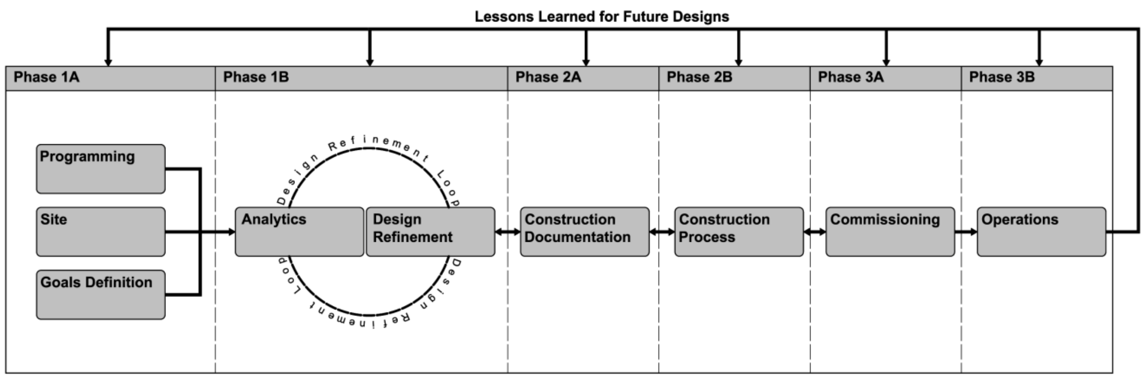

Figure 28: Simplified DEPROSU model.

A detailed DEPROSU model is shown in Figure 29, including the breakdown of all sub-processes/steps that should be included, as discussed in section 5.3.3. Some items have strong connections or influences on other items; e.g. *climate* has a strong connection with *orientation* (some orientations are desirable for passive design) and *energy* (potential for solar renewable energy, or wind). Weaker connections are identified, e.g. *geology* can have an influence on the potential for for renewable energy, although is very rare that geology will influence that decision. Some arrows have double direction, which means that the steps can go back if necessary. One example is that during construction processes, the design might have an error so the design team goes back to the design refinement loop to correct it. Some choices are optional, such as the adoption of a GBRS, building commissioning or advanced BES for the design refinement, but their implementation is important to achieve higher levels of reliability in the overall design process.

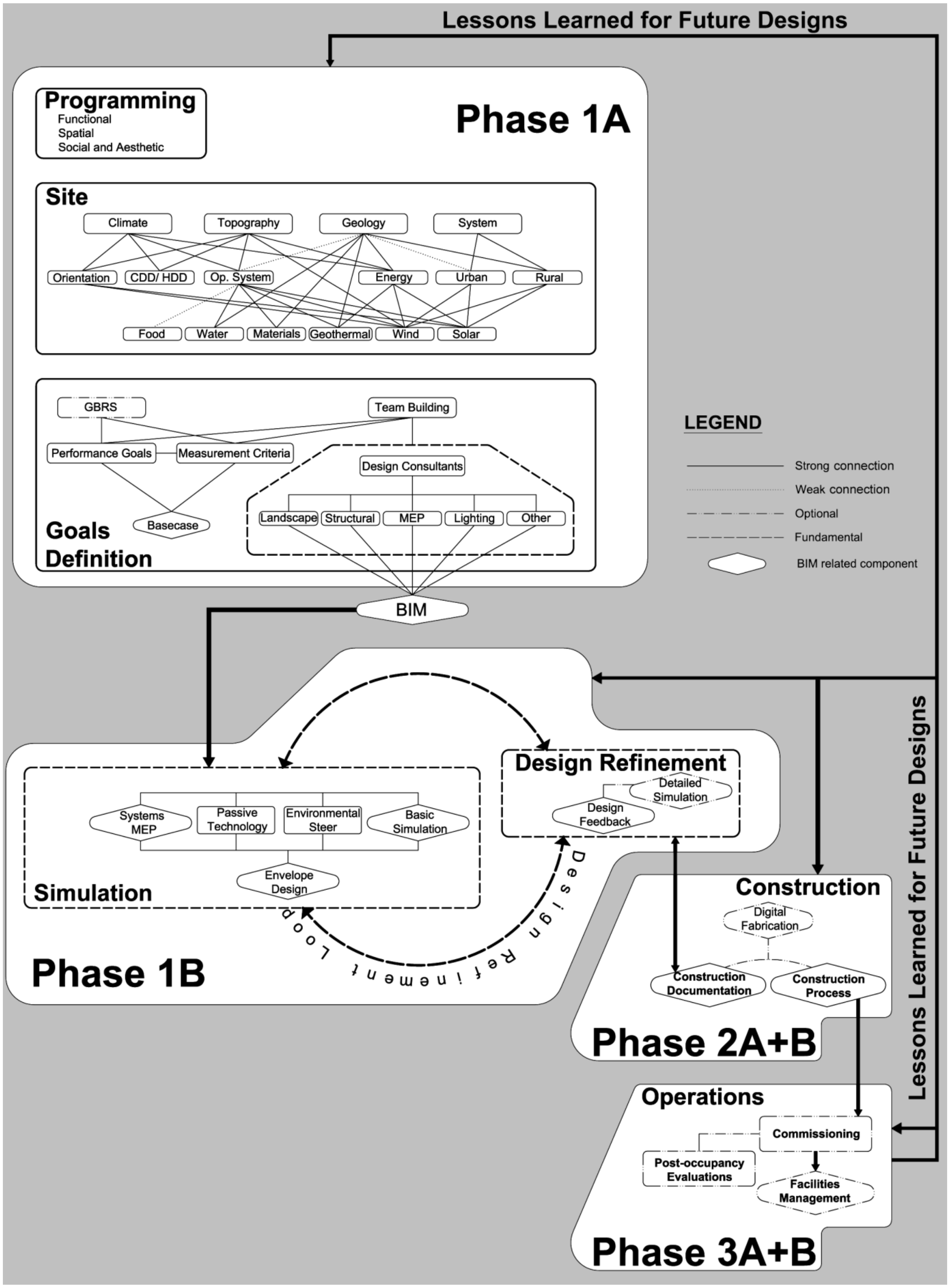

Figure 29: Detailed DEPROSU model.

For Phase 1A (Architectural Programming, Site and Goals Definition), the order is interchangeable without affecting the final output significantly. For example, an owner can have a site and a clear definition of goals in terms of sustainability/performance, but the function of the future design is not well defined (what the design will be). Another example is that the function is clearly defined as well as the basic requirements, but there are several alternatives of site for the design to be built. Site analysis should implement an exhaustive study of the ecological impact of the design into the environment, so the priorities and strategies can be clearly understood and addressed. The implementation of a quick assessment tool to calculate eco-balance (Fisk, 2009) is highly recommended, so designers can rapidly visualize the full impact of the building, establishing ambitious performance goals as a result (performance-based). Goals Definition is also critical because the design atmosphere is set, as well as the ambitious goals that will drive innovative solutions. The creation of a team of capable designers and consultants that is also knowledgeable with new technologies (including BIM and BES) will have an ultimate impact on the overall outcome of design.

The next step is the iterative Design Refinement Loop (Phase 1B), where simulation tests the proposed design schemes and their consequent refinement will result in the final design (BIM model), which will generate construction documentation (phase 2A) and facilitate coordination for the next phase. For this step, it is highly recommended the use of additional resources that combined can guide and make the design process more effective and efficient in DEPROSU. These resources can be found in the *Manual for*

EcoDesign (Yeang, 2008), and in Appendix 4 and Appendix 5. Appendix 4 shows facts to be considered when designing with sustainability in mind, and I provided spreadsheets that enable quick estimations of eco-balance in different categories. Appendix 5 is a summary of ake|Flato's sustainability toolkit providing several recommendations to normative calculations of daylighting, the use of specific software, reference to databases, etc.

In the Construction step (phase 2B), BIM still plays a key role and the design could still experience some changes, which brings the Design Refinement Loop back again. Digital Fabrication can be facilitated with BIM, as demonstrated by Foster + Partners and Lake|Flato in their projects (Swiss Re tower and Porch houses, respectively)

In the Operations step (Phase 3A & B), commissioning of building's design will bring lessons learned that will help to improve future designs and share new knowledge (Beltrán & Farías, 2009; Hensen & Ulukavak, 2006). Finally, Facilities Management could be facilitated by using BIM.

The next paragraphs will disclose findings from the exploratory approach, related to sustainable design.

5.4 Exploratory Analysis

In this section, I discuss the unanticipated topics resulting from the exploratory research. The two themes presented are "Training Policies", discussing the challenges, strategies and efforts made to educate professionals in the field of sustainable design, and "Changing Human Resources Profile", as the resulting advantage of having multi-skilled professionals in-house.

5.4.1 Training Policies

There are a variety of training policies for BIM, BES and/or how to apply the internal standards for documentation. Training policies can affect the design workflow because the staff is usually busy working to comply with deadlines and training may be perceived as a distraction or delay. Staff often has no time to isolate themselves in training. Nonetheless, the staff needs training to improve their design workflow and to adapt to new technologies and strategies. One challenge is how to provide training without getting behind on their regular work.

In general terms, staff is trained while working on a project with supervision from specialized actors, allowing the staff to train but keep working on their regular projects. Most of the firms rely on certified third parties when first adopting a new technology (BIM, mostly) until they feel confident while using it. From then on, they rely on their internal resources and online help to keep progressing. Most large firms have invested in high technology to overcome accessibility and communication problems. Additionally, intranet resources are used as internal library references. The content of their internal library is usually created following their own standards (if applicable). Quality delivery is regularly checked while working on the project, especially when exchanging information with other design consultants. The next paragraphs will provide evidence for the aforementioned assertions.

As mentioned in the “Use of BES” sub-section, HOK is hosting different workshops as an attempt to leverage resources. Those workshops will review software applications such as Ecotect and Daysim with the goal of generating content experts in every office. An example of those workshops and the feasibility to host them in a world-wide firm is shown:

> *With daylighting, we do have a group in the St. Louis office. We have several projects active in this office right now who consulted with our St. Louis lighting group for our lighting analysis… The direction we’re moving in is breaking down the technology barriers so that whether we’re working with San Francisco or Tampa or the London office, the transition between sharing drawings and information is seamless. The infrastructure and the network that we’ve built up and the technology that allows us to share our BIM models and drawings or design intent is something more readily available to all of our staff. (HOK-Houston’s BIM Manager)*

HOK, as well as other large firms have invested in high-end communications technology to overcome problems with the staff scheduling, plus decreasing travelling, energy consumption and cost. HOK's Advanced Collaboration Room has a Cisco telepresence screen where they can share drawings, do live sketching (digital whiteboard) and take pictures simulating an environment where all participants are in the same room. The use of technology helps staff training when their specialists are scattered in different offices. BIM and technology support goes hand in hand and helps to improve confidence in the use of tools, allowing designers to push the envelope with more ambition.

Almost all designers at HOK pass through a crash course to learn strategies for sustainable design. Some of them are workshops where they learn how to use simulation or BIM software, or in some cases, they get familiar with a multidisciplinary environment, as enthusiastically described by an architect from HOK:

> *I got a really neat crash course in how to use and where sustainable design fits into a project… Prior to any design work, we had three workshops regarding sustainable design. One of those workshops was sort of coordinated by HOK, which went really, really well. We talked about large-scale objective versus local objective, where we agreed with the university, our client, which we would work with them and with the city to change certain code requirements to allow simple things like waterless urinals and so on and so forth... Just the tone the client set about what the goals were kind of set the tone for the project. Then the client had RMI, Rocky Mountain Institute, do another workshop. We*

also consulted the White Group through the process. You had HOK, the big think tank RMI, and then you had the White Group, who were the guys who could really get in there and tell you what the numbers are. We were able to work with these guys at different scales and understand where in the process we can engage our engineers, start to engage our consultants, like the White Group. Really, we started early on with the mechanical engineers. Before we even put building, starting things on massing, there was a strategy about how the systems, the attitude one should take towards what systems they're specifying for the building. Then we started working with iterations of concepts. We were able to take simple massing, the program and give that information to the White Group and start, early on in the process, to sort of compare different options. We were able to, at that early phase, sort of put all the schemes into the same playing field and determine, from a sustainable standpoint, what the metrics are. (HOK-Houston, Project Architect)

HOK invests in training for their staff to be able to work efficiently under an IDP process, interacting with specialists and understanding when and how to apply different sustainability strategies. In addition, understanding how to interpret results from BES tools requires special training combined with experience. HOK tries to address these issues with special training and workshops.

Another detailed description of the simulation training comes from the designer and simulation expert at HOK-Houston:

> *Recently, there's this HOK recharged effort where we are mandating the energy analysis on every project. One person from each of the North America offices convened in New York. We had a four-day workshop with Atelier 10 who are consultants that the New York offices typically use. They basically hosted and led this workshop in which they taught the basics of several software, including the obvious one, Ecotect, then Vasari, which is an Autodesk software as well, soon to be integrated into Revit. There were a couple more where it was a Climate Consultant software, which basically input the weather data. It spits out everything from diurnal swings, thermal comfort levels, psychometric charts and things like that. Some other tools like Daysim, Diva for Rhino. Diva and Daysim both are also integrated into Ecotect. (HOK-Houston's simulation expert)*

The goal for these workshops is to train designers so they feel confident in using these tools. Being true experts in all of the tools is an ambitious challenge, so they try to understand the limitations and strengths of some of the tools and to be proficient with them in order to gather the required analysis data. Following that, interpreting the results is also another task so that the use of BES is seamless within a design workflow and can provide useful feedback for the Design Studio. The benefits of this training were seen in different ways:

- Sell a design scheme to a client based on science or evidence;
- Engage engineers early on in a fluid conversation about the impact of design decisions on the building envelope and its effects on loads and mechanical systems;
- Accelerate the decision-making process in a multidisciplinary/integrated design team.

Regarding BIM training, the BIM Manager at HOK-Houston is the current staff's support. When HOK adopted BIM about six years ago, they had experts from a consulting firm do classroom presentations and work on the projects with the project teams, for a period of approximately six months. Since then, the general knowledge of the HOK community has achieved a certain baseline and confidence to use the tool (Autodesk Revit). Now, HOK has an internal support network with email lists and support requests where their world-wide staff can provide feedback and support. Additionally, they have an internal training website with video tutorials and documentation to show the process step by step. Having that internal support system also helps to avoid re-creating solutions: when a problem arises and someone finds a solution, the steps to solve it will then be a resource already available to the firm worldwide.

A similar approach to training support is being used at Foster + Partners and HKS. Their use of technology and IT infrastructure allows them to take advantage of their resources for internal support. Lake|Flato implements training internally while the designers are working on a project, with the supervision of their sustainability coordinator (simulation) and their technical BIM support.

Similar to HOK, HKS-Dallas has formal training from expert users within the firm that work as resources firm-wide. The training is oriented according to the needs of a project or the position of the employees, in order to provide good communication with their clients and to understand the scope of work:

> *We have a formal training. We have a classroom over here that is setup for BIM training that we use pretty regularly… There is a lot of intensive training going on though… And then we will have training for just like project managers, who are not necessarily been taught exactly "hands on details" or how to draw, but they understand the capabilities and the limitations so that they don't overpromise or under promise to a client. (HKS-Dallas' Sustainability Chief Officer)*

Additionally, HKS attempts to leverage knowledge by hosting boot camps for their staff, where they are exposed to new techniques to improve their design workflow. HKS also takes advantage of their technological resources to help the dissemination of these new findings:

> *We always have certain individuals that will really excel in learning better, more efficient ways of doing things, and then they end up being a "go to" person for other people… And then they end up being a resource and the way*

that we kind of address that is that we periodically have something called our "Revit boot camp", even if is not specifically Revit… We bring together the individuals that excel in some capacity, like one guy that is really good at Grasshopper, and he figured out this software that connects Grasshopper to Ecotect and he can dynamically get Ecotect feedback instead of exporting it out and then getting data. So people come up with these more efficient ways of doing things and then we try to get them all together periodically. (HKS-Dallas' Sustainability Chief Officer)

Another interesting finding relates to the use of BIM tools to teach young designers such as interns how to understand construction problems. Because the 3D model of a BIM includes diverse aspects of structure and construction, the user has to understand how the building is put together in reality. In comparison, a CAD drawing is just a group of lines that can be completely disconnected from reality. However, the complexity of some BIM tools could also be counterproductive if the staff is not well trained:

It could lock you in very quickly. If you're a daily Revit user and you're part of the team and you're constantly in Revit, you suddenly start to ask questions that are geared from the use of the program, the use of the software, and not necessarily what's driving the project… You just have to be very conscious about why you're modeling things in a certain way. Is it driven by the project or by limitations of the software? (HKS-London, Architectural Assistant)

There are different ways to achieve the same objective in BIM, so different modeling techniques can be a distraction to designers, while trying to represent their projects. The leverage of expertise across different HKS offices is somehow affected, especially regarding training for staff:

> *We have a facility available to us to be able to find information. On our intranet site, there is a BIM area where you can ask questions and see the tip of the day, stuff like that. There are people we can call that are part of this core group who will help us with problems. These guys kind of work as a traveling road show: they will go from office to office and give little training seminars. We sometimes don't benefit from that because geographically we're farther away. The offices in the States tend to benefit from that more than we do. I know that's an issue that they understand at the corporate level. (HKS*-London, *Associate Partner)*

In addition, similar to other participants of this sample, their training is usually implemented parallel to the design of a project, because that way, designers can immediately implement their knowledge and retain all the information while doing it:

> *In the Revit training, if you don't use it, it's not an effective use of time. At the same time, as a business, we try to hold off on that training until we have a critical mass that can take advantage of the training. We don't want to have just one person sitting in training for three days. There is some frustration sometimes with people not feeling like they're getting the training that they*

should get. That's the basic entry-level training… On one occasion where we needed some sort of follow-up help, we had a guy come in and do some Revit training for some specific issues we were having. (HKS-London, Associate Partner)

An architectural assistant from HKS-London also perceives training as an important aspect for designers to use the tools efficiently:

> *I think you also have to be quite careful that not all these tools suddenly run the project instead of you controlling. It's like having a toolkit but knowing when you want to use what. If you get sucked into running this and this and this, you're no longer in the driving seat. (HKS-London, Architectural Assistant)*

One particular advantage of being a large firm is the ability to be more flexible, to incorporate training without affecting delivery and to incorporate technology to help their designs:

> *We will grow and shrink teams quite rapidly depending on development cycles, scale of projects. We have to be very flexible these days and very dynamic. Having tools that are very integrated helps us do that, having good workflows, having it well documented, and having well-trained teams so that they are proficient. Knowing when it's appropriate to hand over to a more specialist team or having the support network so they can hook into that special team and*

feed in. That's constantly evolving. The technology is adapting all the time. (Foster + Partners' Design System Manager)

Documentation policies play an important role at Foster + Partners and have several functions. One is to describe a design evolution and process including BES, construction challenges, material selection criteria and other relevant issues; and another to help potential new design team members to speed up their adaptation:

> *Our whole design [team], very often these days do geometry statements that describe technically how the building is put together and how the design process is, as well as having environmental feed into that, describing the environmental design process and analytical process as a workflow. Very often we'll have a project setup that will describe how the project process is evolved, as well as developing obviously all the documentation for the building itself. The two go hand in hand, which helps as well when a project suddenly expands and we need another 20 people on a project. Then we can say, "Read this lot." Then you'll learn how this project has been put together so far. (Foster + Partners' Design System Manager)*

Similarly, HOK created their buildingSMART Initiative based on buildingSMART alliance^{TM}, that describes the documentation policy for different aspects of design, including parametric design, how to import manufacturer's models and others. This is an attempt to standardize their digital files to have more integral information firm-wide.

To implement correctly, all documentation policies require training and/or experience, which is given during the supervised design process.

When asked about what aspects of training the staff have found more difficult to address, Foster + Partners expressed a similar thought as the other firms:

> *Probably BIM training. It is a shift in process in culture. It's something that you can't just do in a classroom. You have to do it with a working project and actually mentor them through a project… We're all under immense pressure to deliver projects to deadlines. So getting users out of their projects into classrooms is always a challenge. It's much easier to have bite-size training and do it in small chunks of time and actually do it specific to that project and mentor them. (Foster + Partners' Design System Manager)*

To conclude, training is done using multiple channels, and usually simultaneously with design. One of the challenges is to organize groups without losing productivity, and also select the appropriate tools for the job, considering the large variety especially in simulation tools. Documentation policies can be a helpful resource for staff to get familiar with the design workflow. Some firms are trying to leverage resources by taking advantage of technology. By hosting webinars and teleconferences, specialists from one office can help designers in other offices. Proficiency in using BIM and BES is becoming paramount for sustainable design. Firms appear to be protective of their own design processes, including their own standards for BIM use.

5.4.2 Changing Human Resources Profile

The participants were asked about the specific qualities or characteristics that a sustainable designer should have. One desirable characteristic of a contemporary sustainable designer was identified as the ability to multitask. Proficiency in using multiple software and ability to communicate effectively with diverse disciplines in an IDP have become the human resource profile for sustainable designers.

Because architecture is becoming more and more interdisciplinary, Yeang speculated on how future designers will be able to grasp so many disciplines and be able to incorporate them into their own design workflow:

> *Yes… I think the human mind is capable of handling it… Talent has always been there. You cannot say today people are more talented than in the past. What has become clear is that today's designers are better at multitasking… that's because they're used to being bombarded with information. (TR Hamzah and Yeang, partner)*

A staff member at Foster + Partners expressed a similar thought about multi-skilled designers:

> *Our architects are quite multi-skilled these days. They will build models. They will do analysis. They will do parametric design as architects, to some degree. Once it starts becoming a bit more specialist in terms of wanting some real high-end analysis, then we'll take it another step and farm it out or bring an*

expert in to that project team to work with them. Our engineers will build BIM models. They'll do the analysis. They're a different breed from how they were ten years ago. (Foster + Partners' Design System Manager)

From these two answers, we can deduce that architecture will be taught with a different emphasis that includes handling knowledge from different disciplines. The architect has a general knowledge about specific problems, which is a qualification for a leader to have in the decision making process:

Architecture is not a theoretical subject, not like science or mathematics. A lot of architects try to find the theory on which they can hang their architecture. They like to call it a theory, but it's not really a theory. It's just a set of principles, a set of axioms in a way… So it's a little bit suspect that we call it theory, but that's what architecture is. It's a series of ideas strung together as a whole. Colin Rowe does design architecture as a series of aphorisms. Aphorism is an idea strung together. As a whole, you must act as a whole. (TR Hamzah and Yeang, partner)

Regarding the question of how sustainable design will change in the future, the HKS-Dallas office responded that the incorporation of BES will be standard or mainstream:

I think that you will see more firms doing what we are doing now with this architecture energy modeling… We are trying to standardize that into our design process… We still have a long way to go, but it's been interesting to see *the response from the design studios, and more and more of them are seeking us out to help them in the design process. Right now it is somewhat voluntary, and we are building capacity and training others within other studios to do the same things that we are doing… I think the importance of architectural* energy *modeling is going to be something that you see and that will be common place in studios in the future. (HKS-Dallas' Sustainability Chief Officer)*

A similar thought is shared by Foster + Partners, where integrated design will become significantly more fluid and mainstream:

> *It will almost be mainstreamed in terms of considerations. Sustainability in terms of process, yes, will become a lot more fluid, a lot more dynamic, and hopefully a lot more integrated than it is currently. (Foster + Partners' Design System Manager)*

To summarize, according to some of the participants, the skills and experience of architects will be different in the near future and will emphasize the ability to multitask effectively and to absorb knowledge from different disciplines. The next section is a synthesis of the main findings that derived the conclusions of this study.

5.5 Synthesis of the Findings

This section summarizes the main findings helping the reader to understand the connections from the literature and the data gathered from the interviews.

The critical literature review documented that design methods for sustainable buildings are not well documented in such a way that helps others designers who wish to adopt them. Most of the literature shows that BIM, BES and IPD/IDP are tied together, or that they each can leverage value gained from the others. Researchers seem to agree that a holistic approach is necessary for sustainable design, and that it depends upon fostering a multidisciplinary effort and accepting a radical change in processes because of the adoption of information technology. Building energy performance assessment methods (BES and post-construction evaluations) are currently not fully adopted, although some versions of GBRS are requiring it. BIM's full potential is currently not achieved in most firms. BES is increasingly adopted in design process to predict and improve building performance. IPD and IDP are considered critical aspects of a contemporary design model for sustainability and seem to have a synergetic effect on BIM and BES. The literature does not provide a generalized and simple but comprehensive description of design methods for sustainable architectural design that truly represents the current practice of advanced firms.

The interviews revealed that although the participants acknowledge limitations and challenges in the use of BIM, they have a positive assessment. The participants considered BIM to be the essential "vehicle" to facilitate communication and coordination between stakeholders by including IDP and BES. Some participants believe that their achievements would not be possible without implementing BIM. The participants are also making a significant effort in continuous education, in the development of internal standards and creating resources to improve proficiency and increase adoption. One problem is that BIM implementation is not equal across different users. Some firms create their own versions of standards adapted from public standards. Interoperability remains a challenge when sharing data with design consultants, and it is usually greater when BES is used. Open formats such as IFC or gbXML are perceived as insufficient in overcoming interoperability issues. A tangential problem identified was that contract agreements rarely specify who delivers the BIM and the extent and detail levels of the model. Technological issues could be resolved with maturity of users (proficiency, coupled with a shift in culture) and better tools.

Regarding the use of BIM from the participants:

- Given six offices, five have adopted BIM and have a strong commitment to BIM;
- Participants appreciate BIM capabilities to expedite design production and coordination;
- The appreciation for BIM is increased when used in conjunction with consultants,
- Interoperability remains a challenge, but the participants have implemented different strategies to overcome those issues;
- BIM standards remain a challenge, but the participants have created internal variations from established standards to better fit their needs;
- BIM has supported the implementation of BES;

Regarding the use of BES from the participants:

- Given six offices, six adopted BES in their design methods;
- Four out of six are implementing in-house energy simulation for schematic design;
- Six offices outsource BES for advanced design stages;
- BES use varies depending on projects' complexity and/or fee structure;
- During advanced design stages, firms usually outsource simulation;
- The firms are using in-house BES for early design stages;
- The use of a particular BIM tool can affect the choice of the simulation engine;
- High-end simulation such as CFD is usually used for complex buildings with a high fee structure that makes it affordable.

Regarding the use of IPD from the participants:

- IPD was rarely adopted (one office only once);
- Participants overall perception of IPD is positive, but some were skeptical about its liability agreements;
- IPD is structured to benefit large scale projects and large firms with a recognizable experience in BIM and construction delivery;
- Some firms have adapted IPD agreements based on the AIA IPD;
- Most firms are using an IDP instead of IPD;
- Large firms have included in-house multidisciplinary design experts; while medium firms tend to rely on outsource consulting.

Regarding the use of GBRS, the participants found that the differences between U.S./LEED and U.K./BREEAM were insignificant in terms of building outcomes/results. Their effect on the design process was perceived to be an addition of rigor in documenting goal achievements, making stakeholders accountable for achieving clear levels of performance. Their effect in the AEC industry is perceived as positive for creating higher standards and benchmarks for building performance. Additionally, the use of GBRS as a checklist to guide the process is considered by some participants as the closest attempt to standardize their design methods.

Some firms have made attempts to standardize aspects or sub-processes of their designs methods for sustainability. The commonalities found in their design processes suggest that a generalization is possible. The literature suggests the use of roadmaps to guide sustainable design, in particular, the use of GBRS (Vallero & Brasier, 2008; Mendler, Odell & Lazarus, 2005). According to the participants, one of the challenges in developing a standard design method for sustainability was flexibility, where the method should enable a good fit to most design situations. The other challenge was related to the type of method. A performance-based method would encourage innovation and higher standards, while a prescriptive model would lead to mediocre results as best (Yeang, 2008). A combination of both would allow an easy to follow description of steps (descriptive), while some sub-processes in each step would impose performance-based objectives (combining BIM with BES in an IDP). In this case-scenario, BIM enables fast modeling through its parametric capabilities providing quantity takeoffs, building envelope exploration, energy modeling and coordination with a multidisciplinary team. BES incorporates the information from the BIM model to help the design decision process through analysis of performance. The IDP aggregates knowledge and criteria from the multidisciplinary team to select the best design alternative and discuss strategies, budget and opportunities for improvement.

The AIA IPD guidelines offer valuable information that describes an integrated design process for sustainable architectural design, which is somewhat representative of the reality observed. Exceptions are described in section 5.2.4. The AIA contractual agreements lack clear specification of delivery for BIM (IPD) and the AIA B101-2007 is not representative of the non-linear process of design for contemporary sustainable architectural design.

Personnel training is done using multiple channels, and usually simultaneously with design. Documentation policies can be a helpful resource for staff to get familiar with the design workflow. Some firms are trying to leverage resources by taking advantage of technology. By hosting webinars and teleconferences, specialists from one office can help designers in other offices. Proficiency in using BIM and BES is becoming paramount for sustainable design.

6. CONCLUSIONS

This section is organized in several parts. The first part is the disclosure of my contributions, each with a discussion of its originality, reliability and validity. Second, I present the significance of those contributions. Third, I discuss the generality and limitations; and fourth, I present the implications of this study. Finally, I present suggestions for future work.

6.1 Contributions

This research led to three contributions regarding BIM and BES adoption, and their inclusion in an integrated design environment.

6.1.1 Contribution 1: Generalization of a Sustainable Design Process is Possible when Combining Commonalities from the Sample of Participants.

Best practices for sustainable design have not been standardized, despite there being common themes described in literature (Krygiel & Nies, 2008; Yeang, 2008; AIA, 2008, Mendler, Odell & Lazarus, 2005). This research revealed that participant's techniques for sustainable design are documented internally (manuals or private networks) and include suggestions how and when each step is to be executed.

In the next paragraphs I am including quotes from the participants as evidence that supports the commonalities found in the design methods of the selected offices. First, I am selecting some quotes that strongly support the idea of a generalized or standardized design process. Please note that bold letters highlight the evidence:

> ***…we came up with our first shot at our roadmap** of a **project process.** We came up with this **sustainability toolkit** that has tools that you will use to think about **water**, **energy**, **materials**. At each **phase** we will say "look at the **protocol for sizing your overhangs**" for example. (Lake|Flato)*

> *We are trying to **standardize (energy modeling)** into our **standard design process.** (HKS-Dallas)*

Then, from looking at the following quotes, I concluded that the design process of other offices also presented commonalities in terms of the steps taken:

> *…we'll look at a **site** and do **analytics** on just the **massing form at very early stages** in the design… What we look at is **using different technology** to do early stage studies **to give us reasonable indicators**… **look at** this **type of technology** for heating the building or **where you are in the world** or this **type of building**. Have you looked at what **passive solutions**? Then you can **invest the higher-end CFD** analysis for **specific schemes** to come out of it. (Foster + Partners)*
>
> *We start by looking at the **site**. We look at the **climate**… **we try and see what climate responsive devices we could use**. **Passive mode design is the starting***

point *for our building form. Then we look at the* ***ecology.*** *Then we look at the* ***program****, to try reducing the enclosed area. (TR Hamzah and Yeang)*

From this evidence, I conclude that standardization or generalization of design methods for sustainability is not only a possibility, but that it is possible to compile design methods for sustainability into a model of best practices. After analyzing data from the interviews and the literature, I created a model that attempts to represent the overall design process for sustainable buildings according to the commonalities found in the participants' firms.

The DEPROSU model attempts to address the need for a sustainable design process that better accommodates BIM, BES and IDP. The standard design process is imperfect because it does not consider BIM, BES, and IDP properly as a synergistic and simultaneous process. The DEPROSU model includes ecological aspects of design decision making (Fisk, 2009). The DEPROSU model represents an adapted and revised design method that departs from traditional and linear processes expressed in standard legal contracts for design and established design methods theory, to better reflect the dynamics of contemporary design for sustainability. DEPROSU builds on published guidelines that address specific information and methods for sustainable design (Yeang, 2008; Mendler, Odell & Lazarus, 2005; Kow & Grondzik, 2008; Krygiel & Nies, 2008; Fisk, 2009). To this date, this method has not been tested in a real case-scenario, and further research could implement it as a case study.

6.1.2 Originality of Contribution 1

Several studies have been made about design methods, IDP, IPD, BIM and BES as identified in the critical literature review, but very few attempted to address those issues simultaneously and holistically from an architectural practice standpoint, with a special focus on sustainable design. Previous research studies have approached these concepts from either a theoretical perspective or exclusively focused on specific and technical aspects. Both Eastman (2008) and Smith & Tardif (2009) have argued from a theoretical viewpoint that BIM technologies will change the practice of architectural design and business practices. However, the current practice of sustainable architectural design were not shown in those scholar’s work combining all the topics treated in this study, capturing perceptions and attitudes from different professionals and backgrounds.

This research combines strong theoretical models adapted from the existent literature and provides a clear prescription for structuring an integrated design process. The DEPROSU model is an elaboration of existent models based on HOK’s Guidelines for Sustainable Design (Mendler, Odell & Lazarus, 2005), the Manual for Eco-Design (Yeang, 2008), the AIA IPD/IDP model (AIA, 2007), and ake|Flato’s sustainability toolkit. The claim of originality resides in a clearer description of a non-linear process, the insight of two sub-phases on each phase of the process and a more precise definition of common themes. The ultimate goal is an attempt to be a closer representation of the reality observed in the design processes of advanced sustainable architectural designers.

The combination of theory and benchmarks observed in practice substantiates the assertion of originality.

6.1.3 Reliability and Validity of Contribution 1

Implementation of multi-methods (qualitative and quantitative) could strengthen conclusions based on larger sample/data and statistical analysis to increase reliability. The presented research methodology with its detailed coding and thematic analysis disclosure could be replicated with other designers to overcome bias and to increase validity.

The collected data and findings cover a broad range of topics where most participants' responses were consistent. The strength of evidence includes suggestions, expert opinions and perceptions from different leaders in the industry and in-depth observations of the overall design processes. However, the DEPROSU model might work well for medium and large architectural firms that have a strong technological infrastructure and multi-skilled employees experienced in multidisciplinary design teams and integrated design.

6.1.4 Contribution 2: BIM, BES and IDP are perceived as Essential Drivers to Sustainable Design Process having a Synergistic Effect.

All firms with the exception of Hamzah and Yeang have adopted BIM. BES is becoming standard in most firms from this sample, but only for schematic design phases to perform "what-if" studies of design alternatives. This shift in the design process is represented by the introduction of a multidisciplinary team to design at the early stages, front-loading design decisions and incorporating technology to aid design in all stages. The use of explicit knowledge enables more information exchange in multidisciplinary design teams, facilitating full integration.

The firms in this study are using in-house simulation for early design stages. This change in design methods for sustainability reflects and depends upon a continuous and growing adoption of BIM and BES in an IDP/IPD process.

To support the aforementioned conclusions, I am including some quotes that reinforce the synergistic effect of BIM, BES and IDP/IPD. When asked directly the question *do you think there is a synergy between BIM, IDP/IPD and BES in sustainable design methods?*, two participants responded with a succinct but definitive "yes". After analyzing the design methods of all participants, more elaborated answers related to the synergistic effect of BIM, BES and IDP were found as implications from other questions. The quotes below were more elaborated responses from two participants:

> ***Absolutely*** *... Today it's difficult to have integrated design if you're not on BIM.* ***If IDP is the destination, then BIM is the vehicle****. Then you take the BIM model; begin to work with the engineers and* ***the energy simulation****. What you're left with is* ***IDP****.* ***BIM allows that process to happen more fluidly, more efficiently****. (HOK-Houston)*

Integrated design is the biggest impact. The analysis informs, ratify *and just* ***refine*** *that* ***design. BIM joins the two together as the process flow****... Some of the towers and complex geometry we've got,* ***you just couldn't do it without*** *doing complete* ***simulation…*** *it just wouldn't be practical not to be confident with the design. (Foster + Partners-London)*

6.1.5 Originality of Contribution 2

The literature suggests that the use of BIM and BES is recommended for both IDP and IPD processes, and that their simultaneous use generates a synergistic effect where all parties are benefited. Some studies have supported that statement by analyzing particular and specific projects (AIA, 2007; Krygiel & Nies, 2008; Kow & Grondzik, 2007; Mendler, Odell & Lazarus, 2005). However, few studies have supported or refuted that assertion from a general perspective analyzing the perceptions of the implementation of BIM, BES and IDP/IPD into the design methods of reputable sustainable designers. Here lies the originality of this contribution.

6.1.6 Reliability and Validity of Contribution 2

Similar to contribution 1, the implementation of multi-methods (qualitative and quantitative) could strongly support this conclusion based on hard-data to increase reliability. The small sample presented in this study as well as the subjective nature of this methodology presents a limitation on reliability. A survey method is an appropriate technique to increase the number of participants, and statistical analysis is helpful in getting objective analysis from the surveys. The presented research methodology is appropriate to reveal perceptions and attitudes towards BIM, BES and IDP/IPD, so the questions for survey methods in future research can be guided by the findings of this study. Regarding the validity of this contribution, the methodology implemented could be replicated with similar designers to overcome bias and to increase validity.

6.1.7 Contribution 3: Firms That Are Known for Sustainable Design Make Extensive Use of Training in Advanced BIM and BES.

The research revealed that the profile of a designer working in sustainable or high performance building has changed and evolved. Most firms from the sample realized that successful designers are multi-skilled. The new skill-set includes, among others, expertise and knowledge from environmental design, computer programming, energy simulation and basics of mechanical engineering and construction processes. Some firms start getting formal training from certified third parties. After the firm members gain confidence in using the tool, they create an internal resource and the training becomes in-house. The following quotes support the conclusion about the importance of training for the staff to be proficient in sustainable design methods and to be proactive in integrated design processes:

> *Our architects are quite* ***multi-skilled*** *these days. They will* ***build models****. They will* ***do analysis****. They will* ***do parametric design*** *as architects, to some degree.* ***Once it starts becoming a bit more specialist, then we'll bring an expert in to***

***that project team to work with them**. **They're a different breed from how they were ten years ago**. (Foster + Partners-London)*

*…We are **building capacity** and **training others within other studios to do the same things that we are doing**… I think the importance of **architectural energy modeling** is going to be something that you see and that **will be common place** in studios in the future. (HKS-Dallas)*

*I got a really neat **crash course in how to use and where sustainable design fits into a project**… **We had a four-day workshop** with Atelier 10 (design consultants) …. They basically hosted and led this workshop in which they taught the basics of several software, including Ecotect, Vasari, Daysim, Diva… (HOK-Houston)*

***We have a classroom** over here that is setup for **BIM training** that we use pretty regularly… **There is a lot of intensive training going on**… **We bring together** the **individuals that excel in some capacity** and they end up being a resource… We periodically have something called our "**Revit boot camp**", even if is not specifically Revit… (HKS-Dallas)*

*These guys kind of work as a **traveling road show**: they will go from office to office and give little **training seminars**. (HKS-London)*

*…[**BIM training**. **It] is a shift in process in culture**. It's something that **you can't just do in a classroom**. **You have to do it with a working project** and actually mentor them through a project… (Foster + Partners – London)*

6.1.8 Originality of Contribution 3

This unexpected contribution emerged from the analysis of the interviews. Few studies have presented a general analysis of how reputable sustainable design firms are implementing training for BIM, IDP and BES and how they manage training with advanced communication and information technologies. More specifically, few studies show how world renowned sustainable design firms like the ones included in this study have approached training procedures on BIM, IDP and BES.

By collecting experiences, perceptions and attitudes from the interviews of different acclaimed designers, I was able to present valuable insight about the challenges and successes in training strategies as declared by the participants, which supports the assertion for originality.

6.1.9 Reliability and Validity of Contribution 3

The small sample presented in this reduces the reliability and generality of the results. Other firms might have different training procedures that can add to the variety of strategies to be implemented. The subjective nature of qualitative methods and interviews also limits on reliability. In a similar fashion as the previous contributions, the implementation of multi-methods could strongly increase reliability to support this conclusion based on hard-data. A survey method could increase the number of participants while statistical analysis could produce more objective interpretations. The presented research is reveals perceptions and attitudes towards training on BIM, BES and IDP, and could guide the creation of questions for survey methods in future research. The methodology implemented in this study could be replicated with similar designers to overcome bias and to increase validity.

6.2 Significance of the Research

Findings from the interviews and the critical literature review provided strong evidence about the emerging challenges for sustainable design, the current design practice and training. Environmental concerns coupled with technology progress are guiding and transforming the AEC industry continuously, and designers need to prepare for those changes (EPA, 2010; Eastman, 2008). Future professionals will have to deal with technological innovation and severe environmental issues, where sustainability will become mandatory (Krygiel & Nies, 2008; Yeang, 2008). Design processes and methods are subject to radical changes that require a new class of accomplished multi-skilled professionals capable of comprehensive decision-making (Ozener, 2009).

The significance of this research is that it provides evidence of commonalities found in the design processes of advanced sustainable architectural designers. These commonalities represented in the DEPROSU model can potentially be validated as protocols or standards, providing architectural design practices with concrete patterns for improvement and or validation of their design methods. Moreover, other design firms could use this information as a guide to plan for future investments in technology, training, and research. Software developers might use this information to guide development and improvement of their products. This information could also guide revision and updates to contract agreements and best practices documentation. The findings from this study present a snapshot of the state of the art in sustainable design in 2012. As technology improves and design requirements changes, this snapshot will become obsolete in describing contemporary practice, but will nevertheless have historical significance and serve as a benchmark.

6.3 Generality and Limitations

The scope of this research was to focus on the implementation of BIM, BES and IPD/IDP in sustainable design methods. The conclusions are general and valid providing valuable insight about perceptions of BIM, BES and IDP/IPD at different hierarchical levels in a sample of firms that also differs in size and scale. The conclusions deal with the design process as a whole. Specific issues of sustainable architectural design related to the use of BIM, BES and IDP/IPD are topics for further research.

This study did not assess:

- The effectiveness of the methods for sustainable design used in the firms;

- The appropriateness of the organization of each firm;
- The effectiveness of use of digital tools;
- The assessment of participants' building designs.

The interviewees expressed their personal opinions, which could be biased based upon their professional responsibilities and might not represent the views held by others in their firms.

The data set has obvious limitations. The sample of firms is not representative of all large, medium and small firms, or all design firms, and the interviewees do not represent the employees of the firms. The connection between BIM, BES and IPD/IDP is discernible only through the comments from the participants, whose roles vary from principals/partners to functional managers and assistants. These limitations impose constraints on the interpretation of results.

6.4 Implications of the Research

The implications of this research can be seen on different levels due to the wide range of topics covered. One example is the impact of BIM in the integrated design process for sustainability, from pre-design to construction and FM. Another example is the impact BES are creating in the design process fostering evidence-based or performance-based designs. A third example is the presentation of how integrated design is implemented in advanced architectural offices, coupled with an introduction to the challenges provided by current legal agreements. The research also suggests that educational curricula need to address integrated design more strongly and that future professionals need to learn new skills.

6.5 Future work

In this final sub-section, I identify additional research topics that were not addressed in this study. I have grouped ideas for additional research into three categories: (a) future trends in design methods for sustainable architectural design; (b) impact of architectural design firm organization on innovation; and (c) procedures to assess sustainability of architectural design.

6.5.1 Future Trends in Design Methods for Sustainable Architectural Design

In this sub-section, I am clustering issues that should affect design methods for sustainable architectural design.

Research could explore the implementation of a generalized design process, such as the proposed DEPROSU model, in an experimental case study. The DEPROSU model could be implemented in both academic situations (architectural design studios) and in professional architectural practice through the whole process, including construction and operations. A study of this nature could confirm or refute the flexibility proposed, as well as validate the process in different contexts. The limitation resides in how to implement this method in small firms, where budget is often limited for an advanced implementation of design methods and technology.

Arguably as a consequence of both IDP/IPD and BIM capabilities, the front-loaded effort in an IDP/IPD creates a mismatch between the traditional and linear design method where the major efforts and consequent proportional fees are dedicated to the later stages. A specific study could quantify or analyze the impact of BIM and IDP/IPD into design methods for contemporary architectural design with a focus on sustainability.

Another topic relates to improvements to contractual forms. This research mentioned several issues that need revisions or updates, such as aforementioned contractual agreements where BIM processes and fee's administration through the new design method/process, among other issues are clearly spelled out. The description of best practices (AIA, 2007) would also be benefited from revisions. The AIA IPD description is a better fit in terms of goals definition and multidisciplinary design team formation, but there are many other issues not well defined, such as BIM delivery and flexibility of liability agreements. Additionally, software developers would have to address interoperability issues (BIM and BES) and uncover strengths and weaknesses of their products to better inform design decision making processes (Crawley et al., 2005).

Reliability of BES tools is a key component of future research. With an improved and more automated processes for BES (thermal models' geometry and the selection of proper assumptions), all architectural firms could become more involved in sustainability, including small and medium firms. Increasing adoption and discussion of sustainable design methods would facilitate improvements world-wide.

The design process for sustainability is a complex multidisciplinary effort (Yudelson, 2008). The variables to be included in the design process can be identified as: capabilities of the design team, building performance goals, technological resources and capabilities, realistic goals according to the budget (understanding of the limitations), GBRS's selection, among others. Less experienced designers should know in advance the priorities according to different situations. Budget, technical resources and design team formation (knowledge) have an impact on the realistic goals of building performance. The selection of aspects to be included in the design process can set the environment to encourage innovation and collaboration, or bring negative experiences if done incorrectly, despite the initial goal. A critical analysis based on real experiences has the potential of being a valuable resource to help spreading sustainable initiatives for architectural design.

Currently, the need for evidence to support design decisions is changing design methods and perhaps, the cognitive process of design. Understanding the extent for this radical change in the design process might have a profound impact in the practice and academic work. As stated before, sustainable design methods require a multidisciplinary design team that fosters collaboration and innovation (Yudelson, 2008; Kow & Grondzik, 2007), but contemporary designers are trying not to leave space for risky experimentations due to the possible negative consequences on the environment. For that reason, there is arguably a predominance of explicit knowledge over tacit knowledge for sustainable architectural design to provide more reliability over design decisions. Here lies the importance of an academic research to investigate this issue in a less risky environment. The results from this study might serve as a base for direction of academic curricula changes.

6.5.2 Organizational Impact on the Innovation and Efficacy of Sustainable Architectural Design

In this section I present issues related to organizational structure of design firms, and procedures for continuing education of professionals.

Research could explore the impact of organizational structures on innovation processes of architectural design firms. The current situation of global warming encourages innovation in architectural design to overcome environmental consequences that can be irreversible. The analysis of the overall impact a hierarchical structure organization can have on the design creativity of employees could help improve the quality of architectural design (Teece, 1996). A qualitative exploratory research of real case studies with different approaches could bring valuable information to improve the design atmosphere in architectural firms.

Research could establish criteria to define training procedures on BIM and BES for architectural design firms. An issue is to know when it is appropriate to bring a BIM expert or a BES expert to the team. The trend of adopting in-house expertise on BES in architectural firms would also benefit from a holistic understanding of the impact of training procedures. The selection of the right BES tools for specific purposes and the adequate training to perform simulation according to specific goals is critical for a successful implementation of BES (Levring & Nielsen, 2011). Understanding the limitations and impact of training procedures could help adoption of advanced design methods using BIM and BES. The discussion of a theoretical framework for implementing training in different situations would help architectural design firms to adopt new techniques and to decide future investments.

6.5.3 Future Trends for the Implementation of BES in the Design Methods for Sustainable Architectural Design.

In this sub-section, I discuss ideas for future research on the use of BES for architectural design.

Currently, simulation of building performance is not accurate when compared to its actual performance while in operation. Several studies have been done on uncertainty of BES results (de Wit & Augenbroe, 2002; Torcellini et al., 2006). A series of heuristic assumptions could be collected as best practices from lessons learned from real buildings. Specific design situations and automated processes could lead to an improvement in accuracy. Understanding the reasons for uncertainty and presenting a theoretical and practical framework to manage and reduce it could help designers to improve their design methods and avoid costly trial-and-error processes.

There are several ways to get similar results using different software (Levring & Nielsen, 2011; Crawley et al., 2005). Understanding the general strengths and weaknesses of the most popular BES tools for sustainable design could help architectural firms decide on software acquisition and training. A careful and detailed study comparing different BES results of an existent building design would clarify expectations in terms of accuracy when compared against calibrated instrumentation. A breakdown of the assumptions made and their algorithms for each BES tool as well as their representation of the building's geometry would help software developers and designers to increase confidence and reliability in their application of BES tools for sustainable design methods and processes. The research could conclude about digital workflow paths presenting alternatives of software usage to get equivalent results for designing high performance buildings.

By conducting a qualitative study consisting of interviews of practitioners in leading sustainable architectural design firms, this research has produced a portrait of contemporary architectural practice. The research has confirmed the interest among practitioners in the topics of BIM, BES, IPD and IDP and the broad understanding that they are interrelated and crucial to innovative practice. The results show that a generalization of sustainable design processes is possible. A design process for sustainability (DEPROSU) model was created by collecting best practices from data gathered from the interviews and the critical literature review. The DEPROSU model can be used simultaneously with other established approaches such as Eco-Balance found in Appendix 4 (Fisk, 2009) and the sustainability toolkit from Lake|Flato (Appendix 5). DEPROSU is a descriptive method that combines a performance-based approach for specific stages of design. The implementation of this method may vary depending on the conditions of the project and it is not a linear process, but an iterative design process whose order of steps can be exchanged. BIM and BES processes enable this method to be implemented with an integrated design team (IDP/IPD). Secondary contributions show that BIM, IDP/IPD and BES have a synergistic effect in sustainable design methods, and that the human resource profile from these firms has evolved towards multi-skilled professionals knowledgeable in BES, BIM, parametric design, sustainability and construction processes. The DEPROSU model can potentially be validated as a protocol or standard for sustainable design, providing architectural design practices with concrete patterns for improvement and or validation of their design methods.

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APPENDIX 1

Interviews

HKS – Dallas

Q: Before we get started, I would like to ask you first and just to be familiar to what you are familiar with: I am investigating the impact of BIM, simulation and IPD or some kind of a multidisciplinary work. Are you familiar or have you used any of these three instances?

(0:46)K: I am familiar with all of them in a general sense, and participate in a leadership level at how we will employ some of those strategies, but I couldn't tell you how we work a BIM model. My focus predominantly is sustainability, but I am familiar with BIM and IPD.

Q: OK, that's good… So, HKS is a big firm, so I would like to ask you how is the hierarchical structure of the firm? I mean: does it have a sustainability division department, commercial buildings, urban design or any kind of a mixed team that work depending on the… ?

(1:47)K: OK. There are approximately 70 share holders in the company that actually have ownership in the company, and that number I am not sure exactly if that's correct, but approximately. And we have 4 individuals that serve as our executive committee, and 3 executive vice-presidents and our president and CEO. They are predominantly responsible for the business side of the company. We also have a management council that is comprised of various individuals throughout the firm that serve as an advisory group to the executive committee. And that kind of takes care from a business organization. From a project, marketing and delivery standpoint we are broken up into multiple different market sectors, and then in some cases, in multiple studios within a market sector. For instance, we have I believe 3 healthcare studios here, and then we have healthcare studios within other offices across the globe. Our predominant markets are healthcare, commercial, hospitality, sports, education, commercial interiors and there are others as well, and government… there is another sector. There is predominantly the sector we are in.

(3:52)Q: OK. And how do they interact with each other? et's say, sometimes you need to work together with healthcare and at the same time, commercial, and it is possible that they are in different buildings, so how is the dynamic of work between all those different studios?

(4:13) K: We try to feed off of each other. For instance, one of the things that we try to focus on healthcare is that we try to put a hospitality spin to the healthcare environment to make it more inviting to the patients, so we try to learn… each studio tries to learn from each other. While they are not working together every day, there is a lot of dialog and opportunities for dialogs between studios, so we get that cross-pollination. Unfortunately, for me, I have a sustainability studio that supports all of the market sectors, so I get a lot of overlap with all of them.

Q: How do you work when you have some other people across different continents? Via Skype? Do you travel a lot?

K: With international offices?

Q: Yes,

(5:35) K: Yeah, we do a lot of webcam meetings, teleconferences, some Skype

Q: And does it work well so far?

(5:49) K: It does, I mean, still the percentage of our work that is international is growing, but yet my actual involvement with it has been much less… most of the design work is still done domestically.

Q: OK. I heard that you opened an office in Brazil, Sao Paulo…

(6:13) K: We do, we have an office in Brazil, Sao Paulo but it hasn't taken off yet though. Is not a man office, it's the only office that we have that doesn't have employees in that yet, so…

Q: (Laughs) I was interested to see if maybe there was something to do with the Olympics that will be there soon, so maybe you had some project involved.

(6:40) K: Yes, we did have a number of sports projects that we were pursuing there, and doing business in Brazil is pretty tough.

Q: Is different…

K: Yeah… We are having much more success in China, India, than what we have in Brazil.

Q: Another question: How would you summarize the overall design process in HKS: How does it start? Programming, a group meeting first, you have beforehand some requirements from the client… is there a general process or it changes depending on the type?

(7:44) K: It varies so much between different clients, different market sectors, it just varies tremendously. It is very hard to tell you in one particular way, because sports projects are so different from a resort hospitality project to a hospital project, but usually our principals and our marketing guys, those guys still design and they will sit down with the client at the very first opportunity and brainstorm ideas, big picture ideas, but you know, in a perfect world, what we try to promote is a very integrated design process where we bring all of our project stakeholders together at the start of the project, before any pre-conceived ideas are developed and to really approach from a very broad prospective, from a very high distance. But not all projects do that… some of them start with a developer and a principal and they just brainstorm ideas and then a projects comes out of it, so (laughs) you know, it can vary…

Q: What would you say about the worst and the best experience that you have had combining for instance, BIM and an integrated design approach?

K: Should I start with integrated design first?

Q: As you prefer…

(9:52) K: I guess I would say that before the terminology integrated design was established, we were doing that A OT with our clients anyways… Probably the best experience that I had was when we were doing the Sabre Corp Campus on Salt Lake. That was an instance where the client wanted to do an innovative project too, it was our first LEED certified project. And basically, the client knew he had selected a good team and he held some partnering sections with the general contractor and all the consultants, contractors, and basically… he softened the atmosphere and we basically all agreed that we will do our best in this job, to deliver the best project we could and basically agreed and sent the document saying that we will not sue each other. I think that really opened the door for more creative ideas and the owner was receptive to trying some things that we were not sure for certain that they will succeed, but we did our best diligence to evaluate the pros and cons in some of the ideas, and we had a reasonable assurance that we will not going to, you know, come back to us from a legal prospective if something failed. Now, if there was a gross negligence or something, I am sure that wouldn't be the case, but… (pause)

Q: What year was this project developed?

(11:59)K: We designed this in 1999. And it was completed in construction 2001.

Q: So that is interesting because we have now very different possibilities of defining liability issues under the AIA kind of standard and the ConsensusDocs300, so it is interesting to see that even before all that formal agreements…

K: Yeah… That was probably one of our BEST experiences, and the client still remains one of our best clients, so…

Q: And how was the timeline of the project? It was finished before expected, under the budget?

(12:54) K: Everything was finished within the budget and on schedule. It was a very carefully selected team, all capable; all the companies involved… it worked pretty well.

Q: Well, you said it was a really good experience, but according to the following experiences, how important is the impact of working with a multidisciplinary team, either under an IPD formal process or just receiving a lot of feedback between the different stakeholders?

(13:36) K: I am (think and look in a suspicious way) a little bit uncertain personally about the value of the IPD contract. I still think there is a value there in the architect being the one who is looking at after the owner's interest. It is not that I don't trust contractors, I just think that (pause to think) it is a better arrangement for the owner to have someone that is strictly looking after his interests. The IPD contracts… we've done a few projects, a very few that were actually under an IPD agreement. We have some that we called "soft IPD agreement" where there are some incentives similar to those you see in an IPD contract, but then the owners are always reluctant to enter into the IPD agreement, because they are equally responsible for the success of the project.

Q: So would you say it depends a lot on the client's inclination towards accepting the responsibilities and risks?

(15: 15) K: Yes, still there is a lot of hesitancy on the owner side. Like I said, we only had just a few and we are a large firm, but there have been relatively few IPD projects. We are not really certain, you know, we think that it is going to catch on, but the spirit of the IPD contract is something that we embrace, but the legal arrangements of it all is something that I kind of have doubts on the owner going to buy into it, on the broad scale, I think it will always be an option of project delivery, I just don't know if it's going to take over as THE method of project delivery.

Q: So finally, how is your perception of how the IPD is so far? So-so, good?

K: It's been good so far in the projects we have done it. I wish I could speak personally from, because I haven't personally managed to job under the IPD process, but I hear feedback from those who have been involved with it.

Q: And usually, when you are using- it could be either an IPD or an integrated design project – how often do you have group meetings? Weekly, once a month?

(16:49) K: It depends on the type of project; it's not uncommon to meet weekly… and at least every other week. A lot of our projects that are handle out of state will go and meet one week and stay several days with the client at their location, then come back and spend a week developing, producing, [not audible] the project and then go back and meet again. And then in some cases we meet every week. A few years ago I was involved in the G C ity Center project… I don't know if you are familiar with that or not… The big Aria city center development on the strip in as Vegas, anyway… I mention it only because we have met every week for 2 and a half or 3 years.

Q: Wow! That's a lot! (aughs)

K: (Laughs)

Q: How is the exchange of information? With such a long period of information exchange, is always using print-outs, digital format, and physical models? How do you present those ideas and share with the team?

(18:16) K: We do all of the above. A lot of digital, 2d products, we do a lot of foam board models that you saw in the lobby there, a lot of those top of models to show shape and form, and then sometimes we still do final finished models that replicates the project as realistic as possible. A lot of the computer animations… we have a product here that is basically founded on a gaming engine, with some of the gaming engine that have more ability to do animation in some of the software that is designed for architects.

Q: But that is something external from HKS or something that you have in the house?

(19:28) K: Is something… It's a group in the firm that has developed this engine and we use it to generate animations with it. You mentioned about my thoughts on BIM as well… we have been using BI t echnology the BI pl atform now for a number of years, probably 6 years ago or so we started to migrate into BIM but I would say for the past couple of years we have being almost solely using BIM. We use Revit. There are some exceptions to that… cause some of our overseas work where our overseas partners are not using BIM yet, they are still using AutoCAD, then we work with AutoCAD only because of the limitations that they put on us. That's happens a lot in China…

Q: Do you feel that is kind of a drawback, making the process of design less effective?

(21:03) K: Yeah, I think so, I think so… For most of the work that we do in China there is a local [last ants] entity that is going to do the construction documents. And so, if we hand them off a BIM model, they can easily convert that over to AutoCAD documents, which is how they do their documentation, so in some cases we may do those in AutoCAD or in some other documentation.

Q: So you have a strategy of just sending the BIM and having an external agency to convert them to 2d so the rest of the team in China can work with that?

K: Yeah…

Q: Sometimes the adoption of IPD can be driven by regulation requirements, or just to accelerate the delivery process… why HKS adopted an integrated design approach?

(22:27) K: Definitely, integrated design will give the client a better product, created a more sustainable project, one that has the input of more than one stakeholder into the design. That is very important for a project that is supposed to last 50 years or better. I know our healthcare department does a really good job at that, getting the input from not only the healthcare department managers, but the nursing staff, interviewing patients, we try to get a really good prospective on what makes a good design. That's what integrated design is all about…

Q: The involvement with the client is always expected to be beneficial, right, at least under this environment?

K: absolutely…

Q: Have you had some experience where it was not beneficial?

K: Having the input from the client?

Q: Yes…

(pause to think) (23:56) K: I can't really say that… sometimes we have some difficulties where we have no input from the client. It's not unusual sometimes to get a client who removes himself too much from the process, and then it really impacts negatively the quality of the final project and it slows down the process of delivering the project. They may learn 6 months too late that a decision was made up here that they don't really like and you get to go and re do it, so…

Q: Do you think that adopting green building rating systems (LEED, BREAM, Green Globes, etc.) will affect the design process? And if so, how?

(25:17) K: Yes, it has a big impact. You know, we are early adopters of LEED, the Sabre project that I mentioned to you earlier, we started using LEED when it was still in the pilot program, it wasn't even published yet… it wasn't published until 2001 I guess… but yeah, the spirit and intent of the EED rating system is to promote that integrated design, to promote the input of more and more stakeholders, and we are seeing that, but unfortunately, you can still do a LEED project and not being integrated. I mean, you can force the rating system on a project that is not truly integrated. The new version of LEED for healthcare that has just come out a few months ago requires as a pre-requisite that you implement an integrated design process, so that is unique to that rating system, and you actually have to document that you got the input from all the stakeholders early in the design process. One of the things, that… we're talking about different facets of the integrated design process, and we talked a lot about multiple [stake holder's] input, but one of the things that I promote really strongly around here is more dialog between our mechanical engineers and our architectural design studios. One of the things that we have adapted is the 2030 challenge… are you familiar with that?

Q: Yes…

(27:23) K: so, the 2030 challenge requires you to do really high performance energy efficient buildings, and in some cases you can have a design studio think "well, that is an engineer's job", and the reality of it is that the architect has a huge impact on the energy efficiency of the building. We have actually developed a game. It's a presentation that we've done in conferences but it's also a game… It's designed to teach you in a very fun way, just how important architectural decisions are to the energy efficiency of the building. The idea for this came from the fact that we [met with wing] in this room over here next door we had about 25 of our engineers consultants that we deal with and [trying them to deal with the] 2030 challenge wanted them involved, wanted their input and we wanted their participation and helping us to achieve these goals, and one of the guys said "you know, you guys have to do good architecture first", and that really inspired us to bring in the ability to do architectural energy modeling in the house. We have individuals here that are trained to help any of our designers in modeling their buildings in the very earlier stages of form and orientation, sun shading… it's really fun game because we taught our employees that you can reduce the energy consumption of a building by 20% without ever touching the mechanical system, so it always teased me that you haven't touched the mechanical system and you reduced your design energy consumption by 20%, but you did make it smaller, so…

Q: just by working with the envelope… And what software do you use for that?

(29:58) K: We use eQUEST, Ecotect, Vasari; we use a number of different software. Predominately, for the quick assessments we use eQUEST… wait… Harvard, there is a Harvard student in Green Build that saw our game and they e-mail 3 or 4 months ago and they sent me a whitepaper they did, and they basically took the same idea and developed a graduate course out of it. They took it a step further, you know… the game that we did has a menu of options that the contestants get to choose from, a different type of glass, changing insulation amounts, arranging sun-shading devices… so they assigned "graduate schools dollars" that's what they called it to the different options, so they factored in the cost component into that equation as well. It's a fun program… it just makes it fun because people are so used to just PowerPoint presentations, and this actually gets people involved… we usually pick two sides of the audience against each other, so there is kind of this competition, we usually model each team, we divide the audience into two and they get to each model separate decisions, so there is a competition to see who makes the best decisions… it makes it kind of fun…

Q: Well, according to what you are saying I guess I see what you are going to answer, but in general, do you think that sustainable design can be somehow standardized? I mean, a collection of best practices can be recommended for everyone to use?

(33:08) K: To a degree it can… but buildings are so unique, so there are no two building alike, I mean… it will be difficult to do that. The International Green Construction Code (IGCC) is trying to do that, but …

Q: But for example: in your experience, using this game, have you seen maybe some commonalities? et's say, working with the envelope first… I am just making something up… Do you think that maybe that could be standardized somehow? Where people will start from there and then keep developing it?

(34:04) K: I think you can integrate that into the process... I kind of took your question of "could some of these best practices be codified…" et's say for instance that the intent of the code is that you have good glass in your building… OK? et's say that you are required by code to put on your building in this particular climate zone a glass with the solar heat gain coefficient (SHGC) of 0.23… Well what if I as the designer didn't want to spend the money on that high performance coding on that glass, and I instead want to put some shading devices on it to achieve the same thing or better? I want to have that flexibility, you know what I mean? So I guess: if things get codified, they should be based on a performance base and not a descriptive base.

Q: That makes sense… In your opinion, how are design methods for sustainable architecture going to change in the future? And how do you think that your firm is going to face that challenge?

K: Design methods?

Q: or strategies…

(35:46) K: I think that (pause to think)… I think that you will see more firms doing what we are doing now with this architecture energy modeling. I feel that we are kind of in the front end of that, in the fore front of that… we are trying to standardize that into our standard design process… and we are making some pretty good [headway]. We still have a long way to go, but it's been interesting to see the response from the design studios, and more and more of them are seeking us out to help them in the design process. Right now is somewhat voluntary and we are building capacity and we are training others within other studios to do the same things that we are doing, so I think the importance of architectural energy modeling is gonna be something that you see and that will be common place studios in the future. The use of BIM in the design process is still in a formulation mode… this [place] of how we use it is still somewhat in transition. I don't know how we standardize or if we are going to standardize, but you know, we don't use one particular software in the earlier stages of design. A lot of guys still use SketchUp, they start with SketchUp and then transition to BI … som e will start in BI and stay in BI but not in Revit… a lot are using Rhino and Grasshopper, so there are quite different ways of designing… quite a different type of software. So I don't know… then it can all be exported into a BIM model, but the tools that we use in the earlier phases of design seem to vary a lot from individual to individual.

Q: Regarding to that, have you had difficulties in translating from one software to another? et's say, something that you start using Rhino, and then you move to a BI model… Have you face some problems in the transition?

(39:04) K: Yeah, I can't really… I can't really speak to that from a "hands on" perspective, but I ask that question a lot and yeah, there are some software's that transition in or transfer easier than others and vice versa. That concerns to me, because I felt that we lose efficiency, that we are losing a lot in that translation. Intuitively to me, we should start in Revit and end in Revit, but that is looking from an efficiency standpoint thinking that staying in one, you know…

Q: The staff here, do they have a formal training on BIM?

(40:01) K: Oh yeah, we have a formal training. We have a classroom over here that it's setup for BI t raining that we use pretty regularly.

Q: And how often do you have workshops or classes?

(40:17) K: they kind of come in spurts… they will give a class in there and I… I couldn't really tell you… there is a lot of intensive training going on though… And then we will have training for just like project managers, who are not necessarily been taught exactly "hands on details" or how to draw, but they understand the capabilities and the limitations so that they don't overpromise or under promise to a client...

i scommunicate the capabilities…

Q: And what about the energy simulation? What do you think are the limitations with the tools so far as they are? Do you think there some aspects that could be improved? Maybe the geometry translation could be easier to just have a better feedback with BIM?

(41:18) K: Well, I think that the key… the limitations sometimes are really just (pause to think) … we have to learn how to draw in BI i n order to be able to get good energy data back or energy evaluations back. For instance, if we do a BIM model and we don't put a ceiling in, the computer doesn't think it is conditioning more volume that it really is, then you get false readings back, so it's a… you have to know and understand the information that the simulations are based on and make sure that you are providing the information that it needs to print out useful data or reliable data. Not everybody is going to have the time to put the time or emphasis on doing that, and that's why sometimes is good to have a studio that is dedicated to that and then you can go in and clean up a model so they can get a good readout.

Q: I don't know if you have seen this or not, but in some cases you can see that because of all this interaction and feedback that you need form different software different specialists, you may have one person in the firm that knows more about the software, or about information technology, or mechanical system, so he/she is required more often compared to other employees to solve particular problems. Have you seen something similar here in HKS?

(45:09) K: Yeah, I think it happens a lot…

Q: Can you elaborate more on that issue?

(45:18) K: Well, I think we have… we always have certain individuals that will really excel in learning better, more efficient ways of doing things, and then they end up being a "go to" person for other people, you know? "Hey, I heard you know how to do this, and you can do it a lot faster than the way we typically do…" and then they end up being a resource and the way that we kind of address that is that we periodically have something called our "Revit boot camp", even if is not specifically Revit… it's just a …. we bring together the individuals that excel in some capacity, like one guy that is really good at Grasshopper, and he figured out this software that connects Grasshopper to Ecotect and he can dynamically get Ecotect feedback instead of exporting it out and then getting data, he is figured out a way to get dynamic feedback as he changes the form and the shape and he get lots of feedback, so people come up with these, or find these more efficient ways of doing things and then we try to get them all together periodically.

Q: Is there maybe one person who is looking forward to see where are those individuals, to spread the knowledge?

(47:18) K: Yeah, so we actually fly people in from different offices that have really excels in some aspects of the software, technology… we have a room over here, I will show you when we leave, but it's where we do a lot of our training and coordination, and they all come together and we get the big screen to make them kind of demonstrate how they do things and try to teach each other having good ideas, so…

Q: We talked a little about the translation of the geometry for simulation, which sometimes is considered as a critical and costly part of the process, but since you have in-house employees that can do it, have you compared having an external service for doing that?

K: To do translations?

Q: Yeah, let's say that you need to hire an external service to do the energy simulation from your BIM model. How costly it is compared to having in-house staff to do it?

(48:52) K: (pause to think) Well, what I can tell you is that we don't do in-house right now… we don't do full-blown energy modeling, we don't do the complete model that… we are focused really on those decisions that happens on the schematic design phase and a little bit on the development design phase. We typically outsource modeling that is more holistic that includes the mechanical systems and detailed analysis of systems and that kind of things… we have key individuals that we have identified in the industry that we think do a good job at those… that's what we usually go to… and I am not sure what the extent of the questions was, but we have an office in India too where our labor is less, so some of our more tedious translations of… let's say that we get somebody that's developed a really complicated model in SketchUp and it needs to be converted to Revit, we may have somebody in our India office, and we may decided that we need that tomorrow so we ship it to India, so not only we have the value of someone creating it at a lower cost for us, but also it's done overnight… we get it the next day, so… there is some value in that.

Q: Do you think there is a synergy between BIM, integrated design and simulation?

(50:56) K: Yeah… yeah… I think it is coming. We are starting to… if you want to go with the software we use, we still predominantly use eQUEST, we are using Vasari, that component in Revit [it is another software developed by Autodesk that uses a similar interface as Revit], and that is relatively new, so we are starting to look at that. I don't have a comfort level with it yet, but it produces some nice graphics and some very helpful things to sell an idea to a client, but I am not really convinced that is reliable data, so when we do it in Vasari, we usually check it in eQUEST or Ecotect as well [Vasari uses DOE-2.2 as their simulation engine, just like eQUEST, but Ecotect has different algorithms for their simulation].

Q: Thank you very much for your time and this very interesting insight of HKS!

Note: after the interview, Mr. Teske invited me to a tour inside HKS. He showed me the room where they coordinate with other specialists and contractors by using Navisworks, and the technology used for international meetings (screens and projectors). In addition, he explained that they start their design usually by using tacit knowledge (intuition), but then they figured out during the process that many times their intuition was wrong after tested with simulation. Also, they have had experiences with interns in their design studios that provided a better design scheme (performance wise) than schemes provided by more experienced designers after their performance's validation through simulation. As an example of integrated design experiences, he showed the "Vision" design competition in Dallas, where engineers enjoyed participating and having a "say" from the beginning of the process. The interaction and cooperation make the design process smooth and efficient according to this experience.

HKS-London

Q: How was the beginning of this office in U.K?

JW: There were a lot of folks here from Dallas originally, from the Dallas office. Primarily came over when it was starting because it started as a healthcare firm. It started doing healthcare projects initially. Most of the healthcare experience came out of HKS in the States. There used to be a lot more. Now I think there's just myself, Melissa—

U: Luis.

JW: uis is ex ican, but he came from the Dallas office. I think that's it now, isn't it? That's all.

U: Yeah.

Q: The primary focus here is on civil healthcare?

JW: No. We're kind of a microcosm of HKS, education, healthcare, sports, hospitality, commercial, commercial interiors, healthcare and interiors. Did I miss anything?

U: There's a lot of challenging projects that we were working on that have come to completion. We're sort of in the process of trying to win new work, sort of in the either sectors.

Q: Well, let's start with—if you can introduce yourself and what is your primary function here in the firm. Then I will start asking a few questions.

FG: I'm F.G. I'm part of the hospitality design team. We use Revit pretty much on a daily basis.

Q: And your background is architecture?

FG: Yes.

SG: I'm S. G. I'm a projects architect in the education department. I am working on Revit for a school project up in Holland.

JW: I'm sorry. S. is also our sustainability champion.

Q: You have also an environmental design kind of background?

SG: No, not anything further than training during the architecture course, but I sort of was volunteered to work as the sustainability champion in the offices as a part of the Design Green group that's up in Dallas. I sort of deal with the correspondence for that for the London office.

PS: I'm P.S. I'm a project architect. I previously worked in the healthcare sector up until five months ago. I just joined the education team to work on a project using Revit. I've only just started using it. I mainly work in sort of delivery side from stage, stage team, maybe planning then through to completion.

Q: Okay. I guess the hierarchical structure of the firm is similar to HKS in Dallas?

JW: Yeah. It's very much the same. Although we're based here in ondon, but the structure of the organization works the same as any other office. We've got the principals that are also identified as directors. It's more of a UK term, but essentially the hierarchy in the organization breaks down the same.

Q: Is it also divided into different studios?

JW: Yeah, across the sectors that I mentioned before.

Q: How would you summarize your overall sustainable design process here? There's a parallel to the way they do in the U.S? There are some differences? Can you tell me a little more about it?

JW: S: can you help with that?

SG: I think generally here it's a little less champion-driven. It's more down to the individual designers to be leading sustainable teachings in their product. That may be a fair comment to make. A lot of the projects we do here are public projects, so things like the healthcare or education projects have a requirement as part of their funding to take on the BREEAM consultation. It's a sustainability—

Q: Are you familiar with LEED?

SG: Yeah, I am EED credited, but I haven't implemented it, but it is very similar to BREEAM.

Q: Do you think there are some special things or issues there slightly different when you work for BREEAM and LEED?

SG: Yes. In the BREEA , i t's not the architects working. It's the approved professionals. Here, you usually have a party BREEAM consultant working for us to do BREEAM assessment and guide us on credits. We have a design stage checklist which we use similar to what I think maybe in the States with LEED. We have a similar thing here with BREEAM, credits we can achieve. That is the clearest difference between it being the architects in the States running LEED and the third party doing BREEAM here.

Q: What would you say about how much that affects the design process, compared to other kinds of projects?

SG: I'm not too sure because I haven't really been involved in the early design stage. I don't think—I wouldn't have thought that we set up the design projects at a concept stage here, that we do it as [tribute period beyond] by the BREEAM credits course.

JW: What we try to do on projects early on, in the early design phases, especially in feasibility and early concept design with the client, is we try to get them to identify, first of all, what their goal is from any sort of standard sustainability standard, whether it's BREEA or EED. Depending on what sector we're talking about, here in the office, it makes a difference. Education and healthcare primarily do work in the UK. That would be very BREEAM-driven. Hospitality, for instance, in sports, we do everything out of the UK. A lot of it is LEED. A lot of the more international clients and a lot of the operators we work with in hospitality projects are Western. So they're either out of U.S. or Canada or whatever. They're more familiar with EED. So that sets up where we try to go in the first place as far as identifying what they want to try to achieve. We typically will advise the investors at that point, early on, or the ownership or the development team or whoever, that we need to make that part of the design process early on and decide if it's important for them commercially or ethically or however you want to define it, if we chase the BREEAM or LEED or whatever certification, and if so, how we achieve that. At the same time, as a firm, professionally, it's part of our—Kirk may have talked to you about this a bit more, but it's part of our ethos and strategy to work that into the design regardless. SO maybe, for instance, we're working on a project in ont enegro now, and they identified at the outset they're not going to try to achieve any sort of official LEED certification, but they want us to design in a process that complies with it, to a certain level.

Q: So that's happening here in the UK as well?

JW: Yep. Well, it's happening for our projects—it's happening within our design efforts here in our office in London on projects outside.

Q: Oh, okay.

SG: That's sort of parallel in the work that my chapter is doing where some of the schools they are looking at for a group called Apollo [ph 7:59]. They've taken an approach where they're going to try to build it to sort of a passive house standard approach. I don't think going for the accreditation or raising it as passive house, but using that as the design philosophy as opposed to following BREEAM. So in a similar vein, it's the design pushing sustainable in all sort of projects.

Q: They use LEED as a kind of a guideline, but here you mix them with BREEAM and LEED?

JW: It depends on what the project is and where it is. I worked on healthcare projects here in the UK and EED wasn't an issue. No one really, I don't want to say they didn't care, but it was more everything was set up more to have to meet BREEAM standards and not EED standards. They're government jobs, so they have certain criteria they have to try to meet. In education, they'd be the same way.

SG: LEED is not very well known or thought in the UK outside of maybe hospitality firms or developers that deal with hospitality or development over in the states.

FG: With some local projects that we do internationally, they also have certain codes they would want us to follow that don't follow either category, but we'd have to follow them if the client wanted them. It's also dependent on site-specific location of the project.

Q: How do you think green building rating systems will be in the near future? We have a lot of what they call LEED shadowing, which they just try to comply with the requirements but they are not looking for a certification per se. I don't know how much of that is happening here and how much BREEAM is changing through the years. What is your vision about it?

PS: Personally, I think here it should become a statutory requirement for buildings, as part of building regulations. I think there were moves to do that with the revised Part L documents, to introduce BREEAM or some sort of energy rating into the firm and site analysis calculations they do now. I think that's the way it will move towards it being. Actually, there is a requirement for public projects to achieve certain BREEAM levels. I think we'll see that more in private projects.

JW: Yeah. I think in government-funded projects or referendum-funded projects, however you want to put it, I think they can impose BREEAM standards on those projects and then everyone just has to deal with them. It would be paid for by public offers. I think other work, commercial, speculative work, hospitality, hotels and office buildings and things like that, I think there needs to be—in order for it to become a more prevalent thing or something that is imposed upon the project, from a commercial standpoint, I would think there needs to be more incentives for the developers in order for them to want to be able to do it.

SG: It always depends on the client, whether they want to just do the minimum to get through the requirements or whether they want to use it as a way of giving more value to the project in terms of its commercial appeal. If you're against other bidders that might be a strong selling point. They'll be more inclined to use more sustainability sort of techniques to drive the design. A lot of developers and clients, they just want to do the bare minimum just as a take-off excess, rather than an actual sort of ethos.

JW: In the UK, I don't think it's any different from anywhere else in the world or experiences I've had in the U.S. From commercial-type projects, a lot of these speculative developers that are building a project, with the idea that it will go to turn around and sell it, so their investment early on- of course they want to keep that to an absolute minimum- now, what you just said is very important: whether you can turn incorporating some sort of LEED certification, some sort of LEED standard, sustainable standard, into the building, which then gives it more value for when it is sold, I think that's something that would REA   Y drive how willing developers are to put the time and money into sustainable issues up front. When we first started talking about sustainability five, six, seven years ago, where it really started to become part of the process, there was a lot more you had to do in the beginning: the materials were always more expensive, the processes were always more cumbersome… and it seems like a lot of that has been engineered out now. It's not much more to do to get yourself into a certified, rating sort of window.

Q: Would you say it's becoming mainstream somehow?

PS: It's becoming the norm.

FG: I think also it's sort of imposed more. It becomes statutory. I think, for example in the hospitality sector, it is most likely that hotel operators would use it to their advantage. You see a lot of hotels coming up now where they will emphasize the point that it's a green building. They would use that to sort of attract a different type of clientele—

JW: From a marketing standpoint.

FG: —from a marketing standpoint. If they're going to do it, they're going to find ways to their benefit. If there is another level of incentive, that would be one for them for sure.

JW: I think the same thing with commercial, non-government-funded projects. Like I said a minute ago, the developer is going to want to know how it increases the value of their investment. Is it going to be more valuable for me when I sell it? Is it going to cost any more to do this and I'm not going to get it back when I sell it in five years?

SG: A lot of the emphasis now seems to be put on energy efficiency savings as a way of selling it to developers. There's a slight issue in the UK, in the way a lot of projects are funded as D&B where you'll have the owner of the building isn't necessarily the person who is operating it and running it. There's not always an incentive on their part to make the most energy-efficient building that they can. That part is a problem. I think we have to [relate that to] a lot of projects that are procured.

Q: So they are looking more to the certifications from a marketing point of view rather than energy savings?

SG: I think it's starting to become more of an issue. The building is going to cost you less to run, so it's at that point more desirable.

Q: Also, in the U.S., we have what they call IPD, Integrated Project Delivery. I don't know if you're familiar with that?

JW: Yeah, I'm familiar with that.

Q: I don't know if here in the UK you have something similar where, by the contract agreement, they agree to share, for instance risks and benefits. It's a very strong level of engagement between the three parties, the contractor, designer and owner or client. Do you have something similar here in the UK?

JW: (pause to think) It's similar but it's not set up in the same way as IPD in the States. Contractually, the relationships are similar to that setup. For instance, government work, PFI's and BSF, which is publicly-funded hospital and school projects, it's set up in a pretty similar way. There is a risk sharing agreement between those parties. It moves the project forward the entire way. Usually, in that instance, it's a contractor-driven arrangement. It's not equally legal. That's contractually—it's the same way.

Q: So that is the closest they have here with the AIA? Have you had experience using that? What would you like to share about the best and worst experience working under that environment?

JW: I can think of more worst than best (laughs)...

Q: Go ahead.

JW: It doesn't parallel what you're familiar with as far as IPD. It's similar. It's probably closer or more akin to a design-build type delivery system than anything else. It's very contractor-driven. As you go through the delivery process, from a negative standpoint, it can be incredibly difficult as a designer to really maintain the standards and level of design, level of things you're trying to achieve throughout the entire thing. ike anything else, it's getting value engineered all the way along the process and every step of delivery, how you're going to revise the cost plan. How are we going to do that piece cheaper, that sort of thing. To me, and this isn't true across all contractors, but in my experience, the contractors who are driving the process, they hold a bit too much power within that relationship. It's not an equal-equal-equal thing. You end up compromising, in my opinion, certain things because the entity driving that process has a little bit more clout to be able to do that. I don't know if that really answers the question. As far it goes in a delivery system and the team kind of moving forward, everyone is sharing risk to an extent. Everyone is contractually bound together. It's clearly driven with a particular—

Q: Is it hard for a designer to change some of the specifications during the construction process?

JW: Yeah. That's one example for sure.

Q: How about the good experiences?

JW: I think it is good having the entire team together and around the table, everybody having the same interest and goal and shared outcome results. A lot of times in traditional project setup, it's very hierarchical. If you're the lighting designer down here trying to get something done, it's very difficult. If you're a lighting designer as part of that consultant team that's around the table every time in a more equal relationship, or a more tighter design team—the design team tends to be a bit tighter. You're more part of the process.

PS: a ybe that's the difference between just the way things are done in the States and the way things are done here. But from my experience on the majority of our projects, because it's [the ending European RFA, having that so [unintelligible 20:07] early consultations with all the design team.

SG: So you get involved with the specialist contractors earlier for the main sort of framework agreement. Before you produce all the information, you can test some ideas with the specialist contractor. There are some—

JW: That's a really good point, actually. That's a really important thing. In the States—when I first came here, it was a tough adjustment for me because everything here is so D&B-driven.

PS: There are very few big traditional [job search unintelligible 20:43].

Q: What was this?

JW: Design and build. In the States, more so lately, but not before. It was much more conventional contract with the typical project structure, team structure. You're right. That's a really good point, actually. You do tend to get the team around the table sooner.

Q: Usually, how often do you get those meetings for projects like healthcare, education?

PS: There are so many meetings, you wouldn't believe. In terms of a sort of design team meeting with architects and consultant, we have those every two weeks. [unintelligible 21:34] meetings with different parties.

JW: P. was working on one of the big PFI healthcare jobs we were doing. I think everybody worked on it. [talking over each other] You were in Salford endlessly. As far as big design team meetings on another one of the big PFIs I was involved with, we were doing it on a weekly basis. You have the design team, at some level, around the table.

Q: In those meetings, I guess you use information modeling to exchange information with the different parties. How does that work?

PS: That's the priciest work. That job was, that was before sort of BI and Re vit, but they all share the same principals in terms of getting the meetings discussed, problems. Then you go away, do some work and then you swap files. It's not all in 3D like Revit, etc., but it's a similar process in that you exchange information working towards the—

Q: But nowadays is all the staff working with Revit or a mix?

JW: We still have a mix because we have some legacy projects that are still on AutoCAD.

FG: Also because there are some consultants who are not in Revit.

JW: Fundamentally as a firm, we have made the decision that we're a Revit firm. All new projects that come through the door, since two years ago, start in Revit. When we first made that stance and pounded the table and said, "We're Revit," originally the intent was that we aligned ourselves with other consultant design team members that were also working Revit, and we would all share the model and it would be nice and easy. That's not the reality of how it's actually happening... A lot of other design consultants don't use Revit. So we've changed how we do things. We do everything in Revit. We endeavor to do everything in Revit. We may save things back as an AutoCAD drawing and send it off to the lighting designer who has no desire to work in Revit or may ever work in Revit. But as a tool, when it comes to those design team meetings and that whole process, we get to a point where, (you can talk about this more than me –talking to F.), but we get to the process where we get the model to a good level, and then we hand it off to the engineers and they use that model and do whatever they do, and that model becomes THE model. I don't know if Kirk touched on this or not, but there have been conversations and discussions about how to better centralize that model. That model sits somewhere and everyone—

PS: Puts their hand on it. I don't think the uptake for BI i s quite as advanced in the UK as it is in the States at the moment. There's a real lack of any guidance, like the AIA level of development documents here in the UK. I think probably quite a lot of Europe hasn't quite gotten to that point. Contractually, the way projects are run here hasn't caught up with the idea of BIM and sharing central modal files. They kind of keep talking about public projects in the UK and healthcare projects doing what they did in the States and using BI as a mandatory approach to it. It's still quite a new thing here, I think. Oddly enough, it seems to be the MEP designers who are the furthest behind in BIM, from sort of starting off. Once you develop this modeling in the first place, it's now quite difficult, I think, to get them to use our models in real-time and do the modeling in that. They seem to farm everything off to so many different consultants.

FG: The EP , you're saying?

PS: Yeah. They do work in their own analysis software that isn't tied fully into Revit or BIM.

SG: Especially with the contractual clients appointed consultants. There is not a lead designer. You can probably work with those that have Revit and it's easier to buy into that whole process, because the consultant's appointments are usually separated so it's difficult to—

PS: We did some presentation work to some big contractors at the beginning of this year and last year about them and what the benefits for them were. A lot of them were pretty curious about what they could get out of it. They just see it as a way to speed up production of information [unintelligible 26:16], not how it can be used for FM, and it should be brilliant for PFI projects or how they can use it to reduce RFIs.

Q: Usually, how much time do they waste trying to translate the BIM model somehow to their own environment?

PS: I think it's more a question of you don't get the benefits from it.

FG: Yeah. If we worked on a Revit model and let's say we have to pass on the information to interior designers who we have yet to work with any who use Revit. For us, it's pretty straightforward because we take the Revit model, export CAD and send it to them, but, if it was the other way around and they were actually using it, they would save themselves time. Really I don't think we necessarily lose time anymore. It's the ones that don't use it. For example, when structures use it, it works beautifully. Then they actually send us their Revit model and we put it into our model and you can see if there are any structural clashes.

PS: You get a higher level of coordination early on.

FG: Whereas previously, if you are working in CAD, you have to check every single drawing. You want the 3D aspect of it. It's what saves—

Q: And talking about coordination, at least in Dallas they are using Navisworks. I don't know if you are using Navisworks…

JW: We don't use Navisworks, but almost all the engineers we work with use Navisworks as their clash detection.

PS: Quite a lot of contractors do, as well, I think, and a few of them have asked us to give them the architectural Revit model [and then they will still keep developing their drawings unintelligible 27:54] about the drawings.

Q: So it is still in the process of your regular work environment…

JW: Yeah…

PS: On the school project we worked on, the structural engineers used Revit. That's worked quite well. They have unique consultants. We're sort of halfway between using it.

JW: We had this hospitality project in Montenegro where M&E and structures were using it.

FG: I'm not sure if &E were using it, but structures were definitely using it.

SG: & E at the moment tends to be not using it for the right things as well. They're using it primarily as a model duct [reduce]. I don't know of anyone who's used Revit on a project analysis of energy models or some of the stuff with daylighting. We play around with the IES plug-ins with Revit to see if we can do some of the solar studies from an architectural point of view. I haven't seen any engineer using that tool.

PS: There are some benefits for cost plans.

JW: What we've been striving for, and I actually met with a structural engineer here in London last week about this. When we write our proposals, we tell the client we work in Revit. That's how we do it. We just work in Revit. Everybody knows what that is now. They're familiar enough with it. We go a step further and we advise them that they should appoint other consultants that work in Revit as well, for the reasons we've all just been talking about. From a delivery standpoint—from a design standpoint, we don't really—if you can use Revit as a design tool, great... if you don't, great, whatever… When you start to get into pulling the project together and the delivery of it and coordination with other consultants is one thing, we just talked about that, but then when you get into cost plans, quantities, bills of whatever, then you can take that a step further. You can take that model and send it directly to a manufacturer. You can start to take it a step further. We're trying to advise the clients that you shouldn't just use Revit because clash detection is much better and it's easier for us to coordinate the model. Yeah, that's a benefit, but you should make it part of the project as a standard because of all these reasons. For us, we use it and that's what we do. We're going to continue to use it. Hopefully the rest of the design team will use it and it will become much more—we can start to use it for what it can be used for. It's like we use ten percent of our brains. We use ten percent of Revit, ten percent of AutoCAD. There's so much more you can do with it. We're trying to at least preach the gospel and hopefully more and more will start to come along.

Q: When you want to pursue that with your staff it requires a lot of training. Do you have regular training here? How does that work?

SG: We have had training courses coming into basic courses, which is quite good. One of the problems is that if you can't do something, you're expected to find out—

FG: If you don't get the training and start a project, it's like in one ear and out the other. I don't know what you guys think, but for me, as a program, it's not so much how you do things but how you organize things within what you're doing. A lot of it is half the time you're just organizing. AutoCAD is, you know how to draw a line and you draw. This is like layers and layers of information that you have to manage essentially. If you don't have the training and then get into a project, it's not just a matter of knowing what buttons to press, it's a different way of thinking about it.

PS: I think that's why there are not a lot of companies using it, especially smaller companies and mid-size in practice. The investment in staff retraining is quite substantial.

JW: I think everyone, for the most part, has had the basic Revit training here. I totally agree that you can't go sit—we tried not to put someone in Revit training that isn't going to be working on a Revit project. In the Revit training, if you don't use it, it's not an effective use of time. At the same time, as a business, we try to hold off on that training until we have a critical mass that can take advantage of the training. We don't want to have just one person sitting in training for three days. There is some frustration sometimes with people not feeling like they're getting the training that they should get.

That's the basic entry-level training. We have, on one occasion where we needed some sort of follow-up help, we had a guy come in and do some Revit training for some specific issues we were having. We've done that with the Australian group. I think maybe one or more other times.

Q: That guy came from—

FG: No. He was a Revit trainer.

JW: He was a Revit guy. We do have, within HKS, we do have a Revit group that we can call and ask questions. Sometimes they can help us. Sometimes they can't. It's hard when you're not sitting there.

FG: They're pretty good, though.

JW: We have a facility available to us to be able to find information. On our intranet site, there is a BIM area where you can ask questions and see the tip of the day, stuff like that. There are people we can call that are part of this core group who will help us with problems. These guys kind of work as a traveling road show: they will go from office to office and give little training seminars. We sometimes don't benefit from that because geographically we're farther away. The offices in the States tend to benefit from that more than we do. I know that's an issue that they understand at the corporate level.

Q: It seems to be the trend that all architectural firms, contractors, will all adopt BI i n the near future because they are understanding what it is? They're not really engaged, could be for reasons I can't explain, but do you feel that is the trend?

JW: I do.

FG: Yeah.

PS: There's an awareness among the contractors that it's something that can save them time and effort and money.

SG: I've seen a few adverts that are looking to attract people that can use Revit so they can get space with the design companies that are using it.

FG: I think in terms of the architectural team, beyond the concept phase, definitely. I think concept phase there's still a little bit of, "Is it too soon to use Revit?" I think beyond concept, yes, but to use Revit during concept sometimes can be a little bit, not limiting, but it kills out the looseness that you have with other software.

Q: You want something that's more intuitive and play more until you get something that you are confident with and then you go?

FG: Yep.

Q: What about simulations?

PS: I think some of the architectural practices are getting a little bit further ahead on this. We do, to a degree, in the States. They're seeing it as a way of getting us more expertise in energy modeling and understanding what we're doing to the building, how it affects solar gain and energy efficiency. There are a few plug-ins kicking around for Revit graphs or things like that so you can model these things in real-time. It just saves us having to do it with the MEP engineer.

Q: Have you used any simulation tools here for energy in earlier stages of design?

JW: Not in this office. I know Kirk Teske and his group are looking at ways, as a service that HKS provides, doing that. We haven't done it in this office.

Q: Is it sometimes required by the client?

JW: It will be required by the client from the design team. Usually that falls into MEP.

Q: Oh, they will take care of it.

JW: Yeah.

SG: What it does at the moment, I think there's probably limited feedback from the modeling that the engineers do. They offer it as a one-time service. They'll do the energy model and submit it as a document as part of the contract package.

Q: So you don't have that much iterations and feedback from them?

SG: ess than there should be. I think that's what the model plug-ins will give us the ability to do ourselves. We lack a basic level of this energy modeling. Maybe the early design stage is just to get clear of how the building sits on the site.

JW: From what I understand too, the software, the engineers use when they do energy modeling, maybe it's just them saying this because they want more fee, but it's hard to edit that information. Once you run an energy model, once you crank out the output from that and you get a report and you have the model and the graphics and everything that goes with it, you can't just go in and tweak a few things and get a whole new—you have to rebuild what you've done. It seems like it's not very flexible. That might not be the case. I've heard a couple of contractors complain about that.

SG: They do a thing here for energy modeling for part of the building regulations, which are SBEN calculations. I think you can now—I think there's a plug-in for Revit to do those energy models. The way it used to be done was that they'd rebuild it in this SBEN software. That was like volumetric modeling, so it was quite difficult.

JW: It was building the entire model.

Q: Now Autodesk has Vasari. I don't know if you are familiar with it. It pretty much is the same interface as Revit, seeing as you are a Revit user already.

PS: I know the guys in Dallas have been using it, J. That's the way it should be used. That's what we should be using it for, in our design stage.

Q: That's my final question. How do you think design methods for sustainable architecture are going to change in the near future with the use of technology and integrated design approach and the use of building information modeling and all of that? What are the challenges that you would face and how will HKS be prepared for it?

JW: That's a loaded question.

SG: I think the biggest challenge at the moment is an insurance one where there'll be reluctance in the UK to take up the same modeling and the design will suddenly become part of the architect's package. I don't know whether there's an acceptance that people to PI insurance will cover the use of things like Revit to do that modeling. We may do it, but we still may have to point it in the direction of the MEP engineer to take it and say it's correct. I think the way it should go is you could—D&B projects, I don't see why there's any reason the EP engineer has to be involved in the early design stage. I think if it was fast enough, we could do it all through the use of things like Revit. They could get as they are at the moment, the construction stages, with the delivery. They can just do that side of things.

JW: I wouldn't disagree with that. I think, as far as the design process goes, it will evolve as the software evolves and as people learn what they can do with it. From a modeling standpoint, I guess maybe I'm a bit old school. et's say we're in a competition right now for a high-rise building in Bulgaria. We should know, from an energy standpoint, what we're designing and how it's going to basically perform. We're not presenting something that is going to be a total bust. Now we've got to spend 50 percent on the budget on a triple-glazed system, whatever. To be able to run that sort of exercise early on and get some basic information cranked out of it, absolutely we should be doing that. Whether that is feeding directly into what the M&E engineers and designs is a whole different story. It's a whole different level of specialism related to engineering equipment and performance and specification and all that kind of stuff. As a design tool for us to do something that we have to rely on somebody else for now just to get the basic information, it's a tool that's already there. We should just be taking advantage of it. I think a lot of it is that. The tools are there. It's just what you're willing to incorporate into your process.

PS: It'll mean you'll get in the design process at an earlier stage, which means you can get back more into the cost plan at an earlier stage rather than getting to the point where we could have done that but it's too late. a ybe that's where it'll help as well.

FG: I think it also forces you to question the design from a very early stage instead of later in the game, like J. was saying. If you know the building is not performing as well as it could have, if you know that sooner, you rethink the way you're designing the whole project, the concept.

JW: I think as a firm, I've worked with other various architects as a consultant to them. HKS, in its history, has always been very, very strong in delivering. We've worked with a lot of big-name firms, very detailed work. A lot of them do that. They do those exercises early on. They do a much higher level of design in stage C&D than we typically do in our services. That's what I've found from personal experience. I know HKS as a company, and under Dan [unintelligible 44:23], who's our design director, he's really pushing that we're doing the things we should be doing in design, and using these tools that we have available to us. As a firm, I think there's more we'll be doing and more that we'll be incorporating as we develop the tools and the ability to use the tools that exist. As those tools develop, hopefully we're taking advantage of those developments as well. As far as the process goes, it's what you're willing to do. It's what you're willing to incorporate into the process.

PS: It will also mean that there will be less risk associated with certain decisions because you can test it earlier rather than being hesitant because you can't test it until someone else does an energy model.

FG: I think you also have to be quite careful that not all these tools suddenly run the project instead of you controlling. It's like having a toolkit but knowing when you want to use what. If you get sucked into running this and this and this, you're no longer in the driving seat. It's just because those tools are there that you're using them to prove a point when it's not necessary.

SG: This is where it should be adopted more as [rigorous work unintelligible 45:43]. The professional body here has been quite slow. Then they're really pushing architects using it in this analysis sort of way, which I think is a missed opportunity.

JW: We've had conversations within HKS about when you start using Revit in the process. Do you not use it at all in concept design? You don't want to start getting locked in.

FG: It could lock you in very quickly. If you're a daily Revit user and you're part of the team and you're constantly in Revit, you suddenly start to ask questions that are geared from the use of the program, the use of the software, and not necessarily what's driving the project. If you were in CAD, you wouldn't necessarily be asking questions because of a CAD technical problem or something. You just have to be very conscious about why you're modeling things in a certain way. Is it driven by the project or by limitations of the software?

PS: I think that's why Vasari is going to be quite useful for us. It's that quicker, easier, rougher modeling-type sketch-up. Then people are less concerned about going through the whole process of setting up their regular template and choosing what door panels they're going to load in. All they have to do is build some massing and you don't have to worry about that with Vasari.

Q: How many employees do you have here?

JW: In London?

Q: Yes.

JW: Around 60.

Q: And what percentage would you say they use BIM?

JW: Pretty high.

PS: They have [unintelligible 47:34]. We're bidding for another project while parallel with sketch schemes, etc. that they're developing in Revit with the structural engineers.

JW: I couldn't quote a percentage against it, but it's relatively high.

SG: Seventy?

JW: I was going to say 70ish, 75. The only thing we're doing not in BI i s these legacy projects that are in AutoCAD.

FG: Does interiors use Revit?

PS: Half and half… at the moment in the school projects.

JW: And for the PFI, it's in Revit, so we'll have to incorporate whatever we're doing.

PS: In terms of production information, it's all Revit.

JW: As a firm and as our design process is defined and kind of structured, I think it's really important to, if you have a tool that you can use, you should use it. It's not like you're saying fundamentally we're not even going to turn the computers on until we get through concept because we want to make sure we're staying loose and not forgetting. You have to understand how a building goes together. Fundamentally, you have to understand that.

SG: So you use Revit.

FG: You have to.

JW: To design something, you have to do that. Yes, you can come up with a big picture, a vision, an idea, but as soon as you start to put that together as something that is going to actually become a building, and that's early concept, you have to understand how it goes together. That's part of the process. If you can do something with that tool at that time, great. Use it. It doesn't mean you have to use it.

FG: I would say even if, for example, as a teaching tool. If you think of Ben, for example, he's on his year out and he's using Revit. He's immediately forced to think of how things will be put together in reality. If he was in CAD, it's just lines. It's not necessarily; he doesn't have to think of how things will be put together.

JW: I've always been, as you're coming out of school and coming up through your early years in the profession, you do some time in CA. You're out on site and you know how things actually get built and know what the process is. When you're back in the office and designing something and drawing something, you understand what trade is going to come in when and that whole process. It's tough sometimes. You can't always manage that. A lot of the things we do are front-end design things. You don't even get to see a project in construction. I just think, getting back to your original last question, it's all about how we manage the process. It's all about how, as a company, our culture and our process are defined. Everybody designs a little differently. Some people just like to scribble. Some people like to get very detailed. It's just how you're using those tools and how you're developing with the ability of the tools you have. uckily, we're with a firm that has become very design-driven and very design process-driven how we're doing certain things. A lot of people are talking about it now. Hopefully we'll develop and continue to develop.

[Tape off]

HOK-Houston

Q: I want to ask you about your background, where you graduated and how you guys got to work here.

DM: Sure. My background is pretty atypical, I think, from an architecture standpoint. I studied biology in undergrad and environmental science in undergrad. Then went up to Rice and studied environmental management. So I got a master in environmental management. I started with HOK right out of Rice. They were looking for someone to focus fulltime on environmental and didn't necessarily want them to be an architect, because sometimes there's a conflict: different architects kind of assume that role because they want to design; they want to do technical work, interiors. They kind of do the sustainability as a piece of it.

Q: So they can't be as objective?

DM: Exactly. You can be more objective but you don't have the same kind of baggage going through and going to architecture school and looking at things a certain way. I have a different background, a different perspective, which is nice when you're approaching a problem, to be able to bring that to the table.

Q: What year was that when you started here?

DM: 2007.

Q: Okay.

DM: This is my fifth year now. It's kind of neat to—I was able to kind of apply a lot of the things I had studied, but in a much different way. I had to get up to speed in a hurry about what the development process was like and what the design schedule was like and all these kinds of things that you learn in architecture school. I kind of had a crash course in that my first year. I work within our office to kind of spearhead the sustainability efforts for our projects. All of our projects have to meet certain energy analysis requirements. I'm working as one of the energy leaders to help push that process with the team. To be truthful, HOK says that all of our projects are sustainable to one degree or another. Whether a client wants EED or not, we're still going to design with sustainability in mind. That's true to a large extent, but to be honest, I get pulled into projects and work a lot more on projects that are going after LEED or where there's a client that demands sustainability, more so than I do on every project that comes across the plate. It's kind of neat that I work with interiors on build-out projects and CI work. I'll work with the designers on competitions and new construction. I'll work on existing buildings, working with the engineers, working with the facility managers. You're kind of seeing the full spectrum of the design, build, maintain and operate component, which is pretty neat, the whole life cycle. Then I'm part of a firm-wide group, much like KS is, with BI . Th ere's a firm-wide sustainable leadership group. Just about all our offices now—all our major offices have someone like me who is a fulltime sustainability leader driving the process. We have different backgrounds and different expertise, which is kind of neat. It's a group we can go after and consult on certain projects and bring together whoever we need from a talent perspective to fill the need for the project. I kind of wear that hat as well.

Q: I have one quick question. Since HOK is such a large firm, it happens, I'm asking, that maybe you have some consultants in other offices, let's say, a daylighting consultant? So you are working on a project where you are in need of that kind of expertise and you contact them and work from a distance and they can be some kind of an in-house consultant?

DM: Yeah. I would say the way it traditionally worked is there are a few of those kinds of experts scattered throughout the firm. There wasn't much of an organization to leverage them. A lot of offices would use consultants. They'd bring in a special consultant to work with Arup or work with one of the big firms or small kind of local environmental consulting firm that specializes in daylight analysis or modeling or whatever. Now the way it's moving is we're focusing on bringing all that talent and expertise in-house. AS will tell you about this when he introduces himself. He was at a firm-wide event last week or the week prior?

AS: Last week.

DM: Every office sent kind of a design analysis leader. We had a workshop to review the software, the application, the process for Ecotect, for Daysim, the different design analysis software pieces. The desire is to leverage that expertise we have with some individuals at different offices to generate those content experts in every office. That's kind of where it's moving.

KS: To your specific example, with daylighting, we do have a group in the St. Louis office. We have several projects active in this office right now who consulted with our St. Louis lighting group for our lighting analysis. One of the things that—the direction we're moving in is breaking down the technology barriers so that whether we're working with San Francisco or Tampa or the London office, the transition between sharing drawings and information is seamless. The infrastructure and the network that we've built up and the technology that allows us to share our BIM models and drawings or design intent is something more readily available to all of our staff.

DM: That's a good point. We didn't show you our advanced collaboration room. I don't know if you'll see that on your tour. Right next door, we have a—

Q: You have a room?

DM: It's called an ACR room. There's a Cisco TelePresence. There's a big screen. Then there's a thunder system where we can basically share drawings, take pictures of drawings live and do sketching.

Q: I saw that.

DM: It's pretty amazing. You can go on and access any of the other office's servers.

KS: All of the offices have a room that looks exactly the same. You feel like you're looking on the other side of a window.

DM: It's like we're having this conversation right now.

KS: You can make eye contact through the image. It's kind of a weird experience.

Q: Have you ever had any kind of lag or delay?

KS: Not even a little bit. When you start speaking to somebody looking at you, the orientation of the screen is that you're looking directly back at them. Not like a webcam where it always looks like you're looking up or down. It's not like that at all.

DM: It's just like we are right now, on the other side of the table with somebody.

KS: Then there’s a camera mounted to the ceiling so if we have drawings, we can zoom in and draw. We have a digital whiteboard that you can project an image on the wall and draw with your finger.

Q: Makes it a lot easier.

KS: We’re trying to cut down on expenses and flying that’s unnecessary, traveling. We’re able to organize a worldwide meeting in a few minutes.

DM: You can leverage those experts a lot better, too. You have a daylighting expert in D.C. You tap in on ACR and work on your projects and hope on your BIM model and do the analysis. It’s pretty nice. That’s the advantage of working for a big firm, being able to leverage resources. If you can’t do that, you kind of miss the whole advantage of being with a big firm. The technology component can, I think, make us work seamlessly. It’s really important.

KS: I’m KS. I’m the BI m anager here. The way I got into this field is a little unique as well. I don’t have a background in architecture. I was always planning on doing it but it just didn’t work out that way. I was in real estate at the time. By happenstance, I knew someone who was working here. They said, “We’re kind of busy. Why don’t you come on and help?” I didn’t really know anything about the technology at the time at all. I started at the very bottom as a technician. I was just working on one or two projects at a time. Just my competency and understanding of the software, it felt very natural to me. Over time, I started supporting other projects and providing guidance and best practices. Now pretty much all the projects that come through the office, I coordinate with the other offices or the clients or the consultants. So setting up the strategy for what technology applications we’re going to implement on the project, what the schedule and budget permit, what the staffing permits to try and accomplish what our goals are.

Q: But you also work as a consultant for the software that you use, let’s say Revit? Or is it more like the big picture of how to use the technology within the office?

KS: It’s really both. I would actually like to be more of a consultant. There’s certainly a lot of feedback that we have that, when it goes unanswered, provides frustration and reluctance to try to use new things because there's less confidence in the software. If we get bad readouts or we get inconsistent data, there's less ambition to push forward, so I'm trying to make contacts with the development team themselves to provide our feedback.

DH: We talked earlier. I'm DH. Regarding architecture, I did—my route was more traditional. Undergrad architecture and MArch at same school. Then after that, I headed to Chicago and worked for a bit. I ended up at HOK. I guess the one thing we talked about, regarding my last two years at the HOK Chicago office, I got a really neat crash course in sort of how to use, where sustainable design fits into a project. We had a client who, prior to any design work, we had three workshops regarding sustainable design. One of those workshops was sort of coordinated by HOK, which went really, really well. We talked about large-scale objective versus local objective, where we agreed with the university, our client, which we would work with them with the city to change certain code requirements to allow simple things like waterless urinals and so on and so forth. Just the tone the client set about what the goals were kind of set the tone for the project. That allowed us, through the early design phases, to go through a series of iterations. We had an in-house workshop. Then the client had RMI, Rocky Mountain Institute, do another workshop. We also consulted the White Group through the process. You had HOK, the big think tank RMI, and then you had the White Group, who were the guys who could really get in there and tell you what the numbers are. We were able to sort of work with these guys at different scales and understand where in the process we can engage our engineers, start to engage our consultants, like the White group. Really we started early on with the mechanical engineers. We started focusing on fan loads. It lets us get to it, the building type we're doing. That's their energy model. Before we even put building, starting things on massings, there was a strategy about how the systems, the attitude one should take towards what systems they're specifying for the building. That was pretty neat. Then we started working with iterations of concepts. We were able to take simple massing, the program and give that information to the White Group and start, early on in the process, to sort of compare different options. We had atriums north side, south side. We were looking at wind, wind entrainment, this whole spectrum. We were able to, at that early phase, sort of put all the schemes into the same playing field and determine, from a sustainable standpoint, what the metrics are.

Q: For the analysis of those ECMs, energy conservation measure, what software did you use, eQUEST?

DH: We were using the White Group. Of course, they have their own proprietary system that they say, this is what we do. We've had 25 million years of experience to help us develop this sophisticated Excel spreadsheet. It sort of tells you what the math is. Actually, over the last year and a half, just working with other sustainable leaders… out on the internet, there are lots of resources to get metrics really fast, depending on what you're looking for.

DM: A. could probably highlight some of the technology and software that we've finally arrived at. eQUEST is one of them, but there are a handful of others. It's tough because there are so many.

DH: I think the key is, if you are able to or in a place and surrounded by professionals where you know what the goals are, it's much easier to then figure out what technologies and when you should implement them to get information, to constantly fine-tune what the thesis is, what you're trying to achieve.

DM: I think there's recognition, too, on our end, that because there's so much software out there—anybody can go on Ecotect and input some climate variables and put in a little massing scheme and do a quick study. It's easy to draw the wrong conclusion sometimes form the software. We recognize that it's better to have an expert that we've dedicated resources to training, to know the ins and outs of the software, to know what the pitfalls of the software are so we're not drawing the wrong conclusions and going ahead and advocating a solution to our clients that is wrong because of our lack of understanding of the software.

DH: Before AS jumps in, I think too, in our profession, there's this sort of concept or idea of intuition based on experience. One can make a case to a client. I think what a lot of the software is doing is, intuition and experience is fine, but now clients, and even ourselves, we're looking for metrics. We're looking for the numbers, the data to support—

DM: Science-based.

DH: The science mind.

KS: Evidence-based design.

DM: That's a good point. It does kind of break down the barriers. It's like if you have some gray areas and this is what you've done in the past, it doesn't mean its right. Show me…

DH: A simple one is a website where I could tell you Houston is a coolness dominated climate versus Chicago. What does that mean? There's a site out there that will give you numbers that shows you what it means relative to different cities. You can make a decision about what the heating load is, figure out metrics about cost really quick. It takes an understanding place and throws metrics behind it.

Q: AS?

AS: I studied here at U of H. I got my bachelor's in architecture right after that and joined HOK. That was about four years ago. I've been here since then. e a nd DH were on the same design team. We work with everyone and DM. I work with him sometimes on getting LEED on several projects together, a couple points, a couple credits. Then working with the BIM manager on basically having our conceptual masses integrated with the final Revit outputs. Recently, there's this HOK recharged effort where we are mandating the energy analysis on every project. One person from each of the North America offices convened in New York. We had a four-day workshop with Atelier 10 who are consultants that the New York offices typically use. I don't know if Chicago uses them. They do heavy energy analysis on some of the projects that the New York office puts out. They basically hosted and led this workshop in which they taught the basics of several software, including the obvious one, Ecotect, then Vasari, which is an Autodesk software as well, soon to be integrated into Revit. There were a couple more where it was a climate-consultant software, which basically input the weather data. It spits out everything from diurnal swings, thermal comfort levels, psychometric charts and things like that. Some other tools like Daysim, Diva for Rhino. Diva and Daysim both are also integrated into Ecotect.

Q: What is Diva? What kind of analysis?

AS: Diva does daylight autonomy and daylight factor.

Q: So its equivalent to Daysim but it works with—

AS: It's equivalent, yeah. The thing is, there are several different software. ike DH was just saying, it's better to know your goal and pick your tool and then work backwards to achieve your results. Because there are so many daylight software, you kind of have to perceive what you want to achieve, then pick your tool and go with it. The idea there was, after we went through the basics of these software, was to pick one software and be really good with it so you can achieve the analysis. Different software, different interfaces, different results, so just going with one and achieving maximum proficiency with that software is something all of us, or at least myself, try to do. There are so many software. I can't spend my time learning every single one. Daysim and Diva are kind of like plug-ins to Ecotect or Vasari or something like that. Just knowing the basics of all of them definitely helps going forward. The entire idea is to basically use these tools to do analysis on every project so that our projects become more performance-driven designs. The second part is, once you simulate all these things—these tools, they can very fast put out all these colors and graphs and charts and things like that. The next part, like DM said, we have to interpret them. If we can interpret it right, this will really inform our design. If we interpret it wrong or we assume stuff, we might go into the wrong path.

DM: To follow up on that point, I think the desire from a firm-wide level is to help facilitate integration. Before, a lot of times you could bring a design up to a certain point. Then, like DH said, you engage the engineers. You can't reach aggressive performance targets or energy targets unless that's a goal up front and unless the designers that are doing the schemes, developing the concepts they're going to bring to the client themselves are using those tools as a basis to develop the design. The whole idea of design analysis piece is it forces you to get those goals out there up front. Then you actually use these tools to inform the design. It's not like you design a building and use the tools to analyze it. You're using the tools to help study options and inform the design. So you arrive with concepts that you go sell to a client that are based on science, on evidence, based on analytics. When we go engage the engineers in a conversation, we can have some type of a fluid conversation about the impact of the architecture and the massing and the window location and what that's going to do to the loads and the mechanical systems. It's a more integrated conversation versus us just handing it over to the engineers and saying, "Do an energy model. Put your systems in. ak e it energy efficient." That's kind of a neat way of—I think that's where the industry is evolving. It has to be that way. If you want to get to Net-zero, there's no way we get to Net-zero unless—that is the key driver of the design. Every design decision that happens has to support that rule of Net-zero or you're not going to get there. This is kind of one step in that direction.

Q: I have one question. Since there are so many software out there, who decides "we are sticking with this software or this one"? There is a management group that takes care of those decisions?

DH: I was just thinking about that while we were talking. Up front in the design process here, and it's different in every office, the software you're using to explore design varies. I could imagine if we were in an office that was intensive Revit from day one, naturally Vasari might be the route you want to use to explore energy. But we are in an environment where it's heavy Sketchup and Rhino in the past, so it may be the technologies that are plug-ins to the software. That naturally makes sense. I'm not going to do Vasari if I'm not doing Revit for ten months. I think then it's just kind of a function of whatever the tools are in your local environment.

AS: It's that and also what's faster, what software puts out simulation faster. y machine almost broke down when I did one simulation with Ecotect. Everybody was churning out simulations, and I was "come 'on!!" Ecotect was thinking and thinking and thinking. What it was doing was studying solar radiation on the core facades. It was just a box. It was taking forever. Vasari opened it, imported that model. Within a minute, that same simulation was outputted on Vasari, so it's also the time and the integration of different software as well. We made a basic chart. That chart basically says "OK, in pre-design, what do we achieve? What should be standard? In pre-design, we do this much. In concept design, we do this much, DD, and on and on." We just use different tools and different analyses. That chart basically lays it out. Obviously it's not mandatory. It's whatever we think is best.

Q: So you are starting to make this kind of a standard process for everybody?

AS: Yeah, to help with the confusion of what to do at what point and what software to use at what point.

DM: To your question earlier, it's more of a community-based decision making than a top down. Jerry Faber or Sean Quinn, they're not saying this, this and this. They're presenting the host of tools you guys are using and trying to figure out what's best for that particular application or your particular office's design process, like DH was alluding to.

KS: The summit that AS visited is the initial steps towards standardization. Right now, just like we specialize in different procedures, I think the software has specific applications that it is more optimized for, whether it be high-rise or laboratory or healthcare environment. I think right now we're trying to discover which technologies fit which application. It's on a per-project basis really. To some extent, the preference of the staff in the office is what software they've used preceding the analysis. I think when the technology matures to a certain level, we'll start to see one or two software pull away from the rest of them and that will become more of a corporate emphasis or mandate. Right now, I don't know if there's enough history of projects for us to be able to say for certain that this one or this one. Certainly a large part of it actually is—we were talking earlier, the feedback from the community is which developer will respond to the concerns of the users. Either essentially do we fix the problems we're seeing or do the problems continue to live on? The software may not be used as much anymore.

AS: Also, in the end, whatever the software outputs, graphs, charts, whatever, most of it is for internal use, to inform your design. The way we show it to the client, they may be so confused by looking at those graphs and charts, so it's presenting it in a certain way so that they can understand what this graph is saying or what this shadow chart is saying.

DM: Distill it down to the key outcomes. You might not even have to show the—

KS: I think if we looked a little bit more into the future, what we'll see is that we're moving away from software based and more towards the cloud computing. The industry will develop the standard format of data. You upload your model to a server on the internet and a whole host of software takes its chores out of it and reports back analysis data. It's not really one specific software. It's a bundle and it's an integrated process. Each one of these software may specialize in a certain aspect, but they're all taking a look at the same set of data.

Q: Regarding that point, what kind of problems have you faced regarding interoperability, something that's being problematic to the easy workflow of design? What kind of experience can you share about difficulties you have found?

KS: The same problem we've had in the past is that when you translate something, maybe word for word it's the same, but the interpretation of those words is different. The drawing is like a language, too. When you convert it or when you translate it, something is always lost. It's the layer or some property of it. What we're really waiting for is, and I don't think it's there yet, is one format that Rhino, and ax and Revit and Sketchup and Ecotect can all speak to. IFC format and the XPS format are attempts in that direction. In my experience—actually just before this meeting, we were trying to bring in a mechanical systems model into our Revit model. We just couldn't get it to work. It just doesn't speak the same language right now.

Q: How much time do you waste on that? At what point do you just give up and start over?

KS: It's a good question. It always depends on what the deadline is. If it's got to go out—we just got this information from the consultant and it's got to go out this afternoon, we're going to try for five minutes and then we'll try something else. I don't know. I guess it depends on the person, too.

Q: And maybe the complexity of the project?

KS: Certainly. Sometimes it's something you just know is not going to work and it's not even worth trying. Sometimes maybe we can split the files into two or maybe we can merge it or compact it or try to extract. A lot of the time, actually, we'll use a middleman. We'll convert it from this program to this program to this program. For instance, from Sketchup to CAD to Revit. There's always—it's interesting how each software has an input and output. Because it's developed by different people, you do the same input but get a different output. Sometimes you can find a way to snake through the software to get where you're going.

Q: With your experience so far, do you have an idea of what will most likely become the main software that people will use? In other words, are there a couple of software where you wish pretty much everybody knows how to use? et's take, for instance, Sketchup. Sketchup is very easy to work, to model… You can do some very quick presentations, especially for the beginning of the project, but it gets up to that… You can do so much more with it. If you start a project with Sketchup, maybe now you have to translate this to Revit or AutoCAD to keep working and you get lost sometimes.

KS: I may be a little biased, but I have to lean towards Revit. Ultimately, anything we design in Sketchup or Rhino will need to be redesigned in Revit towards our endgame. It's always the deliverable. Right now it's going to be the BI model rather than a Sketchup massing. If we would be able to incorporate the same design analysis techniques from a Revit massing as we could from a Sketchup massing—actually, the technology is there. It's a level of comfort and knowledge in the software, and expertise in the software, to be able to achieve the same results.

AS: I think it's getting there. Sketchup is used because it's simple, doesn't deal with details and numbers like you begin with Revit. The reason I'm saying it's getting there is because Autodesk has put out this Vasari software, which is stripped of all the details and numbers, like when you start with Revit. It's stripped out software where it's just a conceptual modeling tool. It's doing what Sketchup does. It's doing what Rhino and [unintelligible] does. I think once we can kind of explore that software and feel comfortable with that, we may start using that so that it's easier than Revit, because ultimately, as we [unintelligible 35:16], it's going to become one software.

DH: I think, too, like Ali just got it exactly right. It's about comfort level. At the same time, I know a lot of different offices, a lot of different consultants like Sketchup because it's free. It's easy to use. You download it and you start immediately. With Revit, one, it's not free, and two; it requires a human to open up Revit. For some folks, they would like some support nearby. I think we'll eventually get there.

Q: Have you had that kind of support here, let's say for the heavy-duty software like Revit? Do you have a formal training here? Or staff training? How often?

KS: Right now, I'm the support. The office is unsupported right now. When we first implemented Revit about six or seven years ago, and depending on the office, earlier or later, we had very formal training in a classroom environment. We had experts from a consulting firm sit in and give not only classroom presentations, but also live here in the office and worked on the projects with the project teams. The best case is [unintelligible 36:45], one of the largest projects this office has done. I think the trainers were here for about six months, not only training us, but also working on the project as well. To that extent, yes, it was very, very formal. Since then, the general knowledge of the HOK community has achieved a certain baseline. We pretty much all know Revit to some extent. Rather than having to outsource to an external trainer, we rely on an internal support network. We have email lists, support requests that anyone can send an email to the entire firm of the Revit experts to get feedback. We have an internal training website that provides videos and documentation and how-to, step-by-step processes.

Q: So it's like a library of tutorials?

KS: Absolutely… internally developed. We try to have lunch and learns and free things on what's new and the latest and how to use. Also, lessons learned. At first it was very formal. To a certain extent, that's helpful. Now I feel that the informality, the fluidity and the natural training is a little bit more comfortable.

Q: So it's been more comfortable now. The firm can solve their problems within their own resources?

KS: Absolutely.

Q: I have a question here. What's the hierarchical structure of the firm? It's just to get an idea of the dynamic of the design process. You have divisions that say HOK Sports, Healthcare—

DM: Actually, no. Sport spun off and they're Populous now. They're their own independent company now. They're not a part of HOK. I can give you a quick rundown on that from both an office perspective and a firm-wide perspective. Firm-wide, it's kind of a de-structured leadership. Our CEO and chairman sit in the San Francisco office. Our vice chairman is in the St. Louis office. Our president is in the Washington, D.C. office. That's strategic that they want those leadership positions spread around the firm so it's not in one concentrated location. Historically, HOK was founded in St. ouis. Our corporate office is in St. ouis. There's a corporate St. ouis and there's the St. Louis business unit, which is part of the north central region where D. is from. That's sort of a strategic alliance between St. ouis and the Chicago office. Texas is organized as a region. So Houston and Dallas is the Texas region. Leadership-wise, there's an executive committee. I think there are six or seven people on that. The ex com is kind of responsible for the overall direction of the firm and those key leadership decisions. They'll basically work with core boards. There's a board of directors. I want to say there are 20 or 25 members of that board, with people from all over the firm, all across the world. Then there are core boards. There's a marketing core board, a project delivery core board. There's a design board. I feel like I'm leaving one off. Those core boards will meet. They have their own agenda at their meetings. The ex com might give one of those boards a particular task look at or a particular challenge to look at. That's kind of the firm-wide organization. I think right now we have 23 or 26 offices around the world. The way the offices are worked, there's kind of a managing principle. It's kind of the PIC, principle in charge of that office. In our office, it's Jay Tatum. There's a director of operations who's kind of in charge of personnel and staffing and day-to-day functioning of a project. The way that we're organized—well, the way the firm is organized is there are different MBUs. There are market-based business units. It's around different broad areas. There's healthcare, aviation, transportation, science and technology—

KS: Interiors and architecture.

DH: Justice.

DM: Are we leaving any off?

KS: Planning.

DM: Planning and military. Those different business units—within each of those business units, there's kind of a leadership team. There are some knowledge experts that are firm-wide resources. If we're doing an S&T project, we might bring in one of the directors at S&T who's based out of our Atlanta office that might fly in to help put together our team, to interview, to provide expertise on clean room design, whatever it is. The way our office works—different offices have—not every office is really active in all of those different MBUs. Some are more active than others, depending on the market. For Houston, I'd say our big markets are corporate office, like corporate commercial, interiors, healthcare, science and technology, aviation. That's really it.

Q: So you have some specialties, team specialties distributed across the country. Sometimes when you are working on something that is very technical, very specific, you—

DM: Leverage those resources, yeah. They report to—I think they're funded out of the B U. The way it's funded is all of the different offices, there's a certain amount of overhead that will get incorporated or [unintelligible 43:11] MBU and they fund the salary, essentially. They're working—part of their time is specifically devoted to a firm-wide. They're helping to win work and helping to generate expertise within each of the offices, building that talent or practice area.

KS: I think on a day-to-day basis, those market business units have a much larger presence than the board meetings or the ex com do, or they're making the general decisions about the direction the company should head in. When it comes down to it, if we're approaching a marketing effort toward a science and technology project, then there's a very specific set of people in that group that we go to. Usually one office or another may focus more. We're very healthcare-oriented, I think. Atlanta would be more science and technology-oriented. Sometimes we'll exchange that leadership and that expertise on the basis of what type of project it is.

Q: You somehow help me to understand how is the overall design process in the firm, especially how to define the scope of performance levels, budget and to really define how the project will be. I don't know if there's something extra you'd like to add. I'm also familiar with the—

DM: The ten steps to integrated design?

Q: Yeah. These guidelines seem to be very inspired in the LEED credits, the way you define scope and the objective, how to define the steps and stages of design, the involvement of the owner or client…

DM: I would like D. to take a stab at it. He's in the design group. I can give you my perspective. Something we've developed is the ten key steps to integrated design. There are ten separate steps with different tasks within those steps. I guess it's important to talk about the different roles in an office. These guys are designers. They're on the design team. There are also the project architects, who are more of the technical architects. We do have that kind of separation between design and application. Then you have interiors folks who just work on interior design. Then you have project managers. The project managers, their whole job and function is to build the work plans, allocate the hours, manage the client relationship, make sure the team stays on track, meets their deadlines. They're purely management based. They're not really—most of them don't really get into the design or get into the weeds on the technical side, but some of them do.

DH: They're there to cut the design, cut the budget.

DM: Exactly. Then you have whoever the leadership level is. Pretty much their role or principle in charge is kind of to make sure the client is happy, their team is meeting their deadlines, but they're not really involved in the day-to-day project activities. I think within that context, you have to look at each of those people have different roles and different responsibilities within the design process. I think the ten key steps to integrated design is a pretty good summary of how it should work. That doesn't necessarily always work that way.

Q: That's one of the questions I have. For instance, when you say teambuilding, documents and specifications—what I'm trying to ask is, now we have this goal of integrated project delivery, which is a contractual agreement. You have to share risks and benefits and all of that. The AIA is trying to push that as a main model for project delivery. However, and similar to using the term that you have in the book, LEED shadowing, you use LEED as a guideline but you are not necessarily trying to have the plaque in your building. It also seems to happen that the IPD, especially when you have people that never worked or doesn't know the other really well—if you don't know the contractor and the owner, how confident would you feel or trust to get to that level of engagement? There are a lot of people out there that are not using IPD because of that. They are trying somehow to focus the same—

DM: I would think IPD would help facilitate the trust. If I'm not working with an owner or contractor or consultant that I know very well, in the IPD, at least you're contractually bound to hit certain milestones, so everyone is equally incentivized. For me, I would think there is less risk working with a contractor with an IPD process. You're contractually bound to collaborate, versus a normal process; the contractor could be whispering something in the other's ear. I don't have direct experience with an IPD project where we're contractually bound. I've heard several different case studies. Some of the contract language is kind of wild. I've seen where there are eight or nine different parties that are all contractually bound with the IPD. There are incentives to hit all these different milestones. It's definitely very interesting. I agree. I think it is kind of the future. The thing I thought was most powerful when I heard about it is that basically it puts all the cards on the table from the get-go. One of the biggest fears on any project is litigation. If the project doesn't go well, if there's any kind of an issue or delay, lawyers are going to call and you're going to have the threat of litigation. Rather than that threat being a black cloud and the risk of going to court and dealing with lawsuits for years, you're putting all your cards on the table. You're agreeing, "I'm not going to sue you. You're not going to sue me. I'm not going to sue him." We're locked in the disagreement. For me, I think that's kind of interesting. I bet the lawyers are a bit concerned. For me, it's kind of interesting. If you try to limit that liability, people are more up front, because everyone knows the budget… The contractor is not sitting there with the wallet looking at the budget and no one else on the team knows. Everyone knows the budget. Everyone knows what you're working towards, what you're incentivized to hit. For me, I think that level of transparency is powerful.

KS: I think that speaks to why it's been such a slow transition. The track record of the industry is finger pointing between the different parties, "Well, the architect didn't clearly note this, so we're going to charge a little extra. This is a change order" or "Well, that's not how we document it to be built." Then who's speaking to the client? Is it the contractor over the architect? There's this level of trust that is then not present for so long that it's going to take the next generation to slowly begin to build those bonds that have never really been there before.

Q: Have you had any experience with the IPD model?

DH: The short answer, no. It's been a big idea, big concept that I know our firm has been talking about and in some instances implemented. I think it's more about finding the right project, right client and right partners. I think scale has a whole lot to do with it, too. You try to get people involved as parties who you feel really comfortable about the quality you're able to get from the contractor, and he feels really comfortable about what he can do from the design standpoint, then having that client that embraces that. Again, now you're trying to get an agreement between multiple parties. I think those, at least at this stage, are few and far between. Go back to what you said. You've seen emails flying around with images of contractors on a boat and the name of the boat is Change Order or something like that. That is the perception in the industry. Then he has a little trailer boat that's called Addendum or something like that. It's part of the industry. We've done design build. We know design-bid-build. I think this new process is one that needs to be done just a little bit longer.

Q: I saw a webinar of HOK New York, and James Vandezande was a part of it. They were explaining their experience with IPD. According to the presentation, it was a great experience. That's the thing. We don't know how spread is this new environment being used. That's why I was going to ask you if you have had any kind of experience with this integrating model. What do you feel—do you think that it's kind of elite? You have to have the right designer, the right client, the right contractor.

DM: Do you think it's kind of what?

Q: Elite.

DM: Who's in the driver's seat is the owner. If the owner wants it, especially now, how competitive it is and the way the market is, I think the owners are going to drive this. If the owners demand it, contractors, consultants, everybody is going to get in line. What choice do they have? They want to get the jobs. They want to work for the owner. To me, I think the real shifts are going to happen when the owners start saying, "I want an IPD contract."

DH: The AIA, they're behind it. It makes a lot of sense. Just like the big sustainable push, owners start requiring certain standards for projects.

DM: You're exactly right.

DH: I think AIA can push sustainable design all day, but until the client—

DM: Until the client says we're building nothing but EED gold buildings, then all of a sudden everybody has to build LEED gold buildings.

DH: If you think about the construction industry, it's one of the industries that have changed the least over the last thousand years. If you look at the auto industry and where cars were and where they are, the standard is totally different. The construction industry, for a residential house, is still studs 16 or 24 inches on the center—

AS: Actually, the standard is maybe creeping down a little bit.

DH: Should we really still be building houses that are wood studs, 16 inches on the center, nail guns? It's the industry. It's a slow-moving creature.

Q: That's the other question. I don't know if you feel that IPD could be used mainly for larger projects or larger firms. Do you see, for instance, IPD being used in very small firms and residential for instance?

DH: I see the big benefit is that it can be used on large projects to minimize the exposure of the client, the architect and the contractor.

DM: And the incentives are going to be a lot bigger on the big project. If it's residential, is it really going to motivate the contractor to get an extra two percent of $50,000? If we're talking two percent of $50 million—so it's a matter of stakes, too, how much skin you have in the game.

KS: I think if IPD is the destination, then BI i s the vehicle. It's kind of forcing us to focus on the same playing field. Design build is probably our training wheels to become familiar with collaborating together at the beginning rather than handing off the project and wiping your hands clean of it. So just sharing the personal stake in design build where you're working on the budget and design. Then you take the BI m odel, so you begin to work with the engineers and the energy analysis and simulation while you're designing. What you're left with is IPD.

Q: Do you think there's a synergy between BI , IPD and simulation?

KS: Absolutely. I don't know that it can be done without it. It's the one form, the one platform that everyone can come to the table on and have their influence over the project.

Q: Do you have kind of a ranking of what instance has made the greatest impact in the design outcome, between BIM, integrated design and simulation? What do you think has been the most important to achieve the outcome?

DM: You said BIM and what are the other two?

Q: BIM, integrated design, like a multidisciplinary team, and simulation.

DM: I think K. is spot on. You talk about you have the destination and BIM is the vehicle to get there. I think that's a perfect description. I don't think you can really talk about any one of those elements without talking about the other. Today it's difficult to have integrated design if you're not on BI . How are you going to facilitate the sharing of the data, sharing of the model, the open access, that whole transparency? I don't think you can necessarily rank them. You just have to know that they are all very connected or interrelated. In order to have success from a sustainable perspective, you need all those things. I will say I think we started off with integrated design. Before Revit was out, before we made progress with BI , i ntegrated design was let's hold a charrette, put a bunch of stickies on the wall, write things down, get the engineers in the room, the owner in the room, the landscape architect in the room, the architect, designer, everyone in the same room. et's talk about the goals. All those things, I think that predated BIM. I think BIM allows that process to happen a lot more fluidly and a lot more efficiently.

KS: This is exactly what I was going to say. We began integrating design teams together. Whether or not there was a three-dimensional model on the computer, the conversation would be what are the impacts of design on the heating and cooling loads? What do the engineers take off of it? Everybody is really adding to the design rather than responding to it. Then BIM is the next technology in that line that facilitates the conversation. Then I think simulation hasn't had as large as an impact yet because it's not mature enough. Definitely that will be the third component when the technology and the teams and proficiency all meet will be at the simulation. I think it's an evolution. I don't think it's a ranking. I think it's a timeline.

Q: How do you think HOK and firms in general are prepared to face the challenge of how to design in the future, how the design process will change in the future, and how HOK is preparing for it?

KS: I think we touched on it without knowing. It actually is going to be setting up the infrastructure for those processes in the future. It's not the infrastructure that's necessarily the technology, but it's also the expertise. We need the correct training on how to use the software. To a certain extent, you always get some sort of output that's our responsibility to make sure the integrity of the data is there. We need the proficiency of the software. We need the technology that allows us to exchange data between offices and between experts.

DM: I think Ali touched on this, too. He was saying how fast you can get a particular answer in the software. I think the speed at which you're able to progress versus having to pull out a chart and sketch all the different sun positions. You can get that result instantaneously.

KS: The fact of the matter is that I think the knowledge or sustainability in the simulation has already been there. It has never been feasible to apply on a daily basis as a design check. When the software gets there and we can simulate and design at the same time, I think that'll be our goal, to have that set up. What that really requires is the technology infrastructure. I think that's where the larger firms like HOK have really stepped up, and we've invested in networking and computing power that's a little bit beyond our requirements right now, because we're looking forward to the future. The same with the cloud computing. I think these developers are investing in a future technology that may not be necessarily applicable in today's world, but it will be in the near future.

DM: What we were talking about earlier, about requiring design analysis on a project, I think a good way to answer that question is to look at what are the design challenges of the future? I think 2030 and Net-zero is one of the biggest design challenges. In order to do that, it's a different way of working. We're starting to organize around that. Just like K. said, it's having different experts around the table from a variety of backgrounds. It's being much more integrated and seamless in the workflow and work process. It's about sharing the data, sharing access.

KS: Actually, now is the time to build those relationships or those future projects. When we're all thrown together in IPD and we're all bound to the same contracts, those relationships will push us to success. That's all we'll trust.

Q: Well, I guess I have one more question. Sometimes you see that someone in the firm is required more often to solve some particular problems or issues. It starts to get like a new position in the firm. I don't know if you've had any—

DM: You're talking to two guys with new positions in the firm. When I got hired, I was sending my résumé around to consulting companies. When I came in, there wasn't a position open for what I do. They were like, "Yeah, we've been thinking about having someone to focus on environmental." y first day, I was like, "All right, what do I do?" They're like, "I don't know. What do you do?" There was no job description. There was no hierarchy of who I should report to.

KS: You're the director of your own—

DM: Exactly. They just throw you in there. That was five years ago. Flash forward now and every office has a fulltime, almost every office, has a fulltime sustainability leader. We have a pretty clear description, for offices that don't have one, about who that person should be and what kind of background they need, what kind of experience they need, what their roles and responsibilities are, what they need to do from an internal perspective to consult on projects. All of that process and that whole series of job functions have grown. I think BIM is the same way. The way we work together as a group, all of a sudden that's changed significantly. It's not like there's a design group with seven or eight other designers, like A. and D. have, to bounce questions off, to work with, and collaborate. When we have a question, there's no one next to us to answer it. We have to reach out to the firm-wide resources. We function as a firm-wide group much like a team, but we're all over the world. We have bi-weekly web x's. We have list servers that we can get a quick question out to everyone that has a certain expertise and get an answer. We have a monthly leadership meeting via the ACR rooms that all the offices have. We can function as a cohesive group even though we're all over the place.

KS: It's the same story line with BI . I've been here for five years as well. That was right around the time when everyone was like, "Well, we've heard of this BI t hing but we're not really sure how to transition to it. What does it mean? What can we gather from it? We don't have anybody who knows what it is or how to implement it." Literally just started working on projects with the project teams and developing from scratch the best practices and workflows and strategies and pitfalls and lessons learned, developing the entire system when there was no knowledge out there. You couldn't really Google the answer.

DM: It's kind of interesting. There are a lot of parallels that I didn't see before. I think one of the biggest challenges we both had, as you start growing the group and the network, you need to share information. How do you share the information? We went from listservs to a webpage to a wiki page to more interactive. We try to find a way that we can share. If I'm writing a proposal for a certain type of service that somebody else is going after that same service, they should be consistent. They shouldn't have to start from scratch. It's trying to figure out how you can start sharing these resources.

KS: The challenge of how to share our knowledge and our resources is paramount. It's because typically you reinvent the wheel so many times. We have a challenge and let's figure out how to fix it and solve it. Two weeks ago, that guy over there completely solved the exact problem we're facing here. If we don't know that he's solved the problem, we're going to go through the same exercise. The next day, one door down, the next person is going to go through the same exercise, the next office. Multiply that by hundreds and hundreds of people and hundreds and hundreds of projects and you come up with a very inefficient machine. When we send out information, you're trying to share this with people. If it doesn't connect with them, if they don't see the direct, immediate application—there's so much flying at us from day to day, you just have to get your mailbox clean. If they don't see the immediate need for that information, it's gone. You have to provide a constant forum where people can gather and share their ideas and experiences to really capitalize on our previous experience.

Q: That's very interesting. It's a big challenge, but also it's the beauty of having such a large firm. You can share.

DM: If we don't get it right, then the whole demand of having a large firm is flushed down the toilet.

KS: We become a big, black hole of resources.

Q: I guess I have two more questions. They are short questions. I don't know if you have used the tools that you have, BIM, simulation or other, in such a way that it was not intended for, however the output of using that way was truly beneficial.

DM: How about like class detection?

KS: I was reading this question the other day. It's a very difficult one to answer. I think one of the themes of this entire conversation has been its very goal-oriented. If you don't stay focused to what you're trying to accomplish, you're going to wander aimlessly. There have been several instances where we tried to use a tool just for the sake of using it. At the end of the day, what do we do with this? Nothing. We just throw it aside. It's very goal-oriented.

DM: Have there been some things with Revit, though, that you didn't necessarily expect at first but it makes it a lot easier? Maybe printing a certain set or doing some takeoffs?

KS: I guess the other end of it is that things that don't comply with that goal, they have to—there's always a reluctance to change our process and change the way we do things. If there's something that doesn't fit that goal, we have to find a way to merge. For example, just by the fact that we can model a building in 3D, we can instantly do takeoffs of materials and finishes and so forth.

DM: That's a good point. It helps with, for me, scratching the surface on EED documentation. You don't have to go through and pull all these different sheets. You can go in and quantify all those things via the Revit model.

KS: So we instantly quantify the design. I think that's one of the things we didn't really expect. At the same time, we're not using it, not leveraging it, because there's also very heavy liability issues associated with doing cost estimation or materials summary in lieu of the contractor. Until that IPD process, until we're on the same team, there really is a conflict of "those are his numbers and they don't match my numbers". There's going to be somebody to blame. I think that's for the preliminary stages. The technology is ready for it; I just don't think the industry is ready for it.

DM: What about defining the deliverable at the end of the day? When you hand over the BIM model to the client, what should that look like? Should that be consistent from project to project? What's the client going to do with it? I know one thing that the government is talking about now is they don't have the resources in-house now to be able to utilize that model, but they want the model. I think from a facility management perspective, there’s huge potential. You could go in there and know in five years, all the lighting is going to be out and I’m going to need to replace it.

KS: How many lights—

DM: How many light fixtures, yeah, and tracking all that so you’re not having to have a maintenance guy go around with a flashlight. I don’t think we’re anywhere near there yet.

KS: I think some of the clients are getting smart to that, but again, they’re at where we were five years ago: OK, we have a model of the building, but what can we do with it? We don’t really have anybody who knows how to use it. a ybe they can open the model and look at it, but they don’t know how to report that data back.

Q: a ybe it’s a matter of educating the client as well as—educating the client towards the sustainable goals. Now the client seems to be more educated in that regards, but not so much in terms of what they can do with the project or what architects are giving to the clients. The BIM model has a lot of potential to use. The designer can give it to the owner, but the owner doesn’t know what to do with it.

DM: There needs to be a handoff almost, like a transition where they educate the owner.

KS: It needs to find its way to the contract and the deliverable, because the model that is for the constructability of the building is not the same as the operations and maintenance model. There may be a different data set associated to that. As an architect, we’re not necessarily obligated to put in the information that the client would need to use in the future. The question is: do we put it in for them? Do the engineers put it in for them? Does the client get into the model during the design process and put that information in? Do we hand off the model and the client’s responsibility is to put in the information of the manufacturers and specifications of the materials that they’ve used, installation times and so forth. A lot of that can fall on the contractor because they’re the ones doing the installations. They can begin to put in the installed on, manufacturer, item number and spec and so forth. As they build the building, they rebuild the model in a similar fashion.

Q: Talking about how to build the model, do you follow some standards for BIM, like BIMS?

DM: Oh, yeah. This guy is all about BIM Standards.

KS: Yes, we do. The pitfall of BIM is that the database is very fragile, meaning that if it doesn't communicate with manufacturer content or our firm-wide standards, the data becomes almost useless. It really has its communication process where the element needs to speak to the other element or the schedule or the tags or takeoffs or materials. It's really like garbage in, garbage out. We really do have to adhere to certain standardization or the whole system falls apart. Actually, this is kind of an unforeseen downfall of BIM. Right now, there is no real industry standard as far as the content and the parameters that are provided by manufacturers. When we download content directly from a manufacturer resource, we aren't necessarily able to use it at all until we translate it or apply our HOK standards to it before we can adopt it into our model. It's English and Spanish. The parameters don't speak. They don't speak the same language. Even though we can put it in the model, it's just not speaking to us.

Q: When you talk about manufacturers, what kind of—

KS: Furniture, curtain wall, anything, any sort of manufacturer, light fixtures, equipment. It's very—it's because they—again, they're kind of at the starting point. We're just now seeing vendors providing all of this great content. On their side, it may work just fine because they're in their environment. Once we get it, it becomes incompatible again. I think that was kind of shortsighted on their part because they didn't really realize that—it's not their fault because, like I said, there is no standard. I don't think that there is a means to that until the AIA or Autodesk or somebody—there needs to be an oversight on the standardization. We're talking about the entire AEC industry. All aspects of it are providing content. There needs to be one [talking over each other] or it just simply won't communicate. You have the points where you hit the boundary and you need to translate it into what your firm uses.

Q: So it has a lot of potential but you're not getting there yet because of miscommunication.

DM: It's also an opportunity for somebody. It's almost like USGBC came around and took sustainability and defined it for what it meant.

KS: It's the exact same story.

DM: You need standardization for BIM that everybody can—

Q: What is your opinion about LEED—right now with all this LEED shadowing, at many firms now, they—are happy with having just one EED AP because that's the guy who is going to sign. In case they want to pursue for certification, but otherwise it's basically a guideline.

DM: I think the best analogy I've heard is EED shadowing is like auditing a class. You might go to class for the first week. You might read a couple of the readings, but you get busy with your other work. You're not earning a grade on that class. You're not turning anything in. You stop going to class as much, stop doing the reading. All of a sudden you're not there. I think that's pretty—I've been on a few projects where they initially said, "This needs to be EED certifiable." I said, "Well, certifiable? What does that mean?" "Well, we need to at least be capable of being certified?" I'm like, "Who's defining that?" The whole purpose of certification is that it's a third party defining that. The only thing certifiable about asking for certifiable is that you're certifiably nuts for that. That doesn't mean anything. I think they've gotten away from that. The government used to have that language, it has to be certifiable. They've stopped that because they recognize that it's just not really applicable. We have a requirement that all of our design professionals be LEED accredited, just because we want a base level of knowledge that everyone has so we can talk to each other.

Q: So that's kind of the quality control of the knowledge.

DM: Right. The process—I think whether or not a client wants to go after LEED, every client is going to be different. It might not be a priority for them. They might not want to pay anything for it. We can't get a project certified without the client saying they want certification and they'll sign off on it. There are things we're obligating the client towards. The new 2009 LEED, they have to report energy and water metrics for five years. We can't make that determination for the client. All we can do is advocate why they should do it and tell them, "This is part of our design process. We're going to do these things anyway. We think you should pay the premium to have us document it for the process." Ultimately, if they say no, it's their decision. I think EED is powerful. It's very misunderstood in the market still. I think the best way to look at it is all it is a series of best practices that have been collected and organized in an accessible format. It's not the be all, end all. There are plenty of other systems. It has its limitations. It's also been tremendously powerful in transforming the market. That's the whole point. The whole goal of LEED since its birth was market transformation. I don't think we'd be where we are with respect to sustainable design without EED. It gave developers and owners a way to distinguish themselves that they latched onto, and the industry responded. You're getting all these projects now that are being designed so they can meet EED requirements. That's had a great impact.

Q: Have you used any of the other green building rating systems?

DM: As a firm we have. I personally haven't. BREEA i s the only one we've used on a more regular basis. Even England, even UK right now, they're all doing a big push towards LEED. USGBC has grown LEED locally, which I think is a good thing. Companies with global portfolios are looking for global consistency. If LEED can bring that to them—

Q: Do you think there is a difference in approach of design?

DM: There should be. If we're doing our job with integrated design and BI and having the conversations, setting goals, doing our sustainability charrette, all LEED should be doing is—all we're doing is checking off the boxes—

KS: It's like a road map to show us we're in the right direction.

DM: Just checking it off, making sure we haven't missed anything. I don't think you design with a checklist. You design as you normally would with sustainability in mind and performance goals and all those other things. Then you use LEED to help inform that process.

KS: It would be interesting to see—we say LEED certified. It seems like today BIM and EED have been interchangeable. There's a new BI ce rtification that's in its infancy stages. It was developed by the Building Smart Alliance, which is one of the founding partners of BI . W hat we're saying is a BI certified project will meet the conceptual design simulation and design authoring and facilities management, all the way through to the owner. Actually, that handout that you have, I think, has those topics it briefly hits on.

Q: Also parametric design.

KS: Absolutely. Parametric design falls right into that. Parametric design is our ability to respond to the changes, whether they are from the designers, architect, owner or the simulation or energy analysis. How quickly and how readily can we respond to those changes?

Q: I have one question regarding that. Since parametric design requires a lot of effort trying to find out the exact formula, that it will work correctly. aybe you're using Revit API or something. It's kind of a steep learning curve. Do you feel comfortable at a point that you can do it easily?

KS: I think I do. My goal has been to become one of the experts in this direction. It is a very steep learning curve to get the maximum out of the process of BIM technology. You can certainly use it as a very elaborate drafting tool. You can put a lot into it and take nothing from it. It's our responsibility to push the limits, to understand what direction we have not taken and what opportunities lie out there for us to take. Sort of what my position has really fallen into is overseeing each of the projects, not really necessarily working on the projects. Giving them some preliminary guidance and oversight on are we on track to be able to—

Q: An opportunity maybe to try something.

KS: Yes. We always have—everyone is at a different competency level, comfort level in the software. Some people will do quite a bit of effort to put the intelligence into the model, and then someone, maybe their first day on the job; they cancel out and negate all of that information by corrupting the data. You have to always keep a tight watch on are all the modeling standards being enforced on a project. Garbage in; garbage out. If we spoil it, you have to go back and fix it or it really gains you nothing.

Q: I think this will be all. I really appreciate . . .

[Tape off]

Foster + Partners-London

Q: I see that you have been using Bentley products for a while…

SH: Yes, since the very beginning, up to now.

Q: More than Autodesk products?

SH: Oh, yeah. We use very few Autodesk products, for mainstream CAD design anyway.

Q: Oh, okay. I see.

SH: We do use them for visualization. We'll use some of them, obviously things like Ecotect, which obviously wasn't, when we bought, it wasn't Autodesk, but since then has become. We've used those sorts of things. We look at—we don't limit ourselves to Bentley software at all. We'll use whatever design application we require to do the job.

Q: How do you manage everyone to know how to use those different tools?

SH: We train internally. We have dedicated training rooms here. This office has 1,000 people in it.

Q: So you manage a schedule for them somehow for regular training?

SH: Yeah. Everybody gets regular scheduled 2D, basic, 3D modulation training for mainstream stuff. Then we can run specialist courses and specialist applications as required. It's the only way to continuously develop our project teams.

Q: I saw you also have a special group, I can't remember, something like SWG.

SH: Oh, SMG, the Specialist Modeling Group.

Q: Yes.

SH: Yeah. We actually have a number of specialist groups. In fact, most of this floor here is a lot—there are a number of our specialist groups here. The other office is kind of admin. The actual architects are in two other buildings at the other side and one of the buildings on this side.

Q: So those are the people in charge of parametric design?

SH: Yeah, we do parametric design, but that's mainstream. We have uses in every project, actually in the project teams, doing parametric design. We don't limit it just to a specialist group, though they tend to do the high-end work. They'll also help out on complex geometry problems, as well as complex analytical problems.

Q: Can you tell me a little bit about the overall hierarchical structure of the firm?

SH: Absolutely.

Q: ike group divisions, let's say healthcare . . .

SH: We don't limit ourselves like that. We are split into six design groups, which each one is almost a small architecture practice in its own right. Obviously we have the board on top of that, heads of the design groups. As well as those six design groups, we then have specialist support teams around high-end visualization, high-end graphics communication, high-end modeling and complex geometry modeling. We've got programmers and mathematicians as well as model makers. We have our own model shop. We've got 30 model makers in it, not just the one you see here. There's also another sketch model shop. As you walk down the road, you see the long building there. The entire ground floor is our sketch model shop. Then we have an industrial warehouse about half a mile away from here which is our main production model workshop. They do not just make these models. These are what we call sketch models. They'll build any model you need, £100,000 models. That's what they do day in and day out. They are skilled, professional model makers. We do that as a commercial business as well as internal. We have the full spectrum here. We have things like our own materials research library, which literally is a room full of materials. It's like books on shelves but different materials, as well as having a specialist team who researches materials and will look at all the new materials coming through.

Q: So you have patterns of your own materials that you create or a combination?

SH: We would work with manufacturers sometimes as well as just researching new materials, looking at how they can potentially be utilized in our designs and buildings.

Q: I know that you have a Chilean fellow here, Andres Harris [ph], that was hired just for the material that expands and contracts with the sun.

SH: Yes, absolutely. We will work at all ranges. We like to think we're at that scale of architecture practice, and now multidisciplinary engineering practice as well. We now have structural engineers, mechanical-electrical, environmental engineers.

Q: You have all of them here?

SH: Yeah, we have all of them.

Q: Oh, okay. That's one of the things I—

SH: We have an entire floor below us which is nothing but engineers.

Q: Oh, I see. But when, for instance, you hire people like Arup [ph]—

SH: It depends on the project, the client, the construction, the complexity of it, and the scale of it. We've only recently, probably only in the last year and a half, developed our engineering side of our business. That's a relatively new venture. We're now starting to do full multidisciplinary projects. We still work with—it depends on the contractor, the client. They may appoint a structural engineer, mechanical engineer, environmental engineer. Or we may directly offer it as a complete service solution to the client. It depends on the project.

Q: Okay. So you have mechanical engineers, structural engineers?

SH: Environmental engineers, public health. We have the complete suite. We're now fully multidisciplinary. So yes, we can build entire buildings now, as well as just design them from the architectural side. Obviously architecture is still the larger portion of our business.

Q: What about in-house simulation? You mentioned Ecotect.

SH: We use Ecotect, Fluent, Radiance, Building Designer, and TAS. We're looking at AECOsim building design simulator, energy simulator, at the moment, and a host of other smaller applications and more niche applications.

Q: Hevacomp?

SH: Yeah, we've used Hevacomp. ost of our environmental engineers have got a background in Hevacomp. Hevacomp is a little dated now. Bentley has obviously bought it out.

Q: Oh, really?

SH: Yeah, Bentley basically bought Hevacomp. They're now importing all the technology out of it into energy simulator.

Q: They hired Drew Crowley [ph] from EnergyPlus.

SH: Exactly. He's now heading up the energy simulator development. In fact I had a video conference with him this week. He took it all through with me about what its doing and how it's working. Yes, it's basically on the EnergyPlus engine. They're now plotting out EnergyPlus 7 as the next venue for it. It looks promising. EnergyPlus compared to what the new versions of TAS are doing—TAs is very fast by comparison. It's more extended range of suites, but they each have their niche use and application.

Q: So what's your background exactly?

SH: My background actually is consultant, seeing construction as CAD management and data management and project management. My team looks after all the design systems, and also looks at how they integrate together, and look at best workflow. We're also responsible for putting BI into t he practice and getting best workflows for our projects that are moving into a BIM process.

Q: What experience would you like to share about the good and bad things of using BIM and simulation and coordination with all other different disciplines? What interesting stories would you like to share?

SH: The hardest thing is actually the interoperability. If you take the Revit world, Revit only talks to Revit. Even the AutoCAD world, BIM world, all the BIM modeling patches really don't talk well to each other. That limits their functionality, which means we're then limited to export formats like Gb , IFC, all of which have limitations.

Q: How do you overcome those problems?

SH: It's always a challenge. It means, unfortunately, sometimes you have to rework your models in another package. That is not productive. That's a waste of time. It's my biggest criticism of the software industry generally, that each company is too insular. There's not that great input as move to actually get some sort of interoperability platform or neutral format. IFC started doing it, but unfortunately is a language that's been bastardized by every single software vendor to suit their own application. As a result, it then becomes less operable with the other applications around. Sharing of information, reuse of model data isn't always appropriate, and it becomes a lot harder to do.

Q: Because of that, how do you decide, for a particular project, what simulation tools, what BI t ools you're going to use. I guess you use i croStation?

SH: We use MicroStation Bentley Architecture as our kind of mainstream CAD design application, partly because we've been a icroStation house for a long time. It handles big buildings. More importantly, actually, even though it may not always be the best CAD tool for the job, it tends to be able to talk to a lot of other applications more easily than most. It's that interoperability that, because we work in 40 different countries at the moment around the globe, we can't always choose who we work with. We have to be flexible as a practice. We have to be adaptable. We have to be able to talk to other applications. As a result, it means sometimes we have to adapt ourselves to work with a particular client or particular contract in terms of standards process, what applications we use. ost of the time, though, you're paying us for our design, not for what piece of software we're using. et us use the software that we know we can design a good building with. Don't try to tie one hand behind our back and say, "You must use this piece of software." et us choose that. Just give us open formats that we can talk to each other with. That's the thing that is really hard for us as a practice around the globe, to be that flexible.

Q: How often do you have to remodel the building because you have problems with interoperability?

SH: The problem is, any BIM model is not always fit for purpose for a particular type of analysis. Almost every time, you have to at least repurpose a model into another sub-format. That may mean stripping some information out. It might mean adding some content to that model to make it fit for purpose. If I build a hugely complicated BIM model and I want to bring it into Ecotect, I'm going to have to strip half of that off just to get into internal surface and close it all off.

Q: And you use the level of details on the BIM standards?

SH: Yeah. We limit ourselves in terms of GA[ph] BIM models to appropriate levels of detail. We don't over-model our BIM models. We model them—a BIM model is not a perfect 1:1 model of your building. It never will be. The sheer volume of data, it just would not be practical to use. We model to generate the GA level drawings and then we do separate detail levels if we need to do detailed studies and detailed BI m odels. It's much more flexible then for us to navigate through. And it keeps our buildings light, which means we can then reuse them for analysis much more flexibly than them being overloaded with heavy detail that is actually unnecessary.

Q: How do you store data here? How do you exchange with all the people here and out of the country?

SH: We've got a complete server storage area network here with hundreds of terabytes of storage. Then we actually have effectively a private network through all our offices around the globe.

Q: And backups on other—

SH: Yeah, we have crunch remote versions of that data for projects as they're done locally so we can co-share. We've become, effectively, one virtual global office. In the long-term, we'll move—we've already started to move some of that into the cloud.

Q: That's interesting.

SH: It's important. We will move into the cloud. I suspect that's where the industry, actually I know that's where the industry is going. There are already, in the CAD world, cloud [unintelligible 12:46]. I suspect analytics will be the next big generation to move into the cloud. It makes sense to have that sort of computer intensive processing in a cloud. Then you can move it in. That's where we see it. We're not going to invest in massive cloud—we can do group computing here. We have 4,000 processors in this office. We can do group computing and things like this.

We've done some exercises where we've done that. We've got render farms and processing farms to do analytics. You need that sort of crunching or else—if you try to do it on an 8 core machine, you'd be there for a month with some of the analytics. So yes, we have high-end computing processing capabilities.

Q: You also mentioned about contract agreements. Since you work internationally, we have, at least in the States, the AIA IPD.

SH: Yes.

Q: Have you had experience with that format?

SH: Yeah, absolutely. We work in every country around the world practically. We've got projects on all five continents live at the moment.

Q: What do you think about the format?

SH: its fine. There are a lot of formats in terms of certification of buildings around the globe. Whether you're doing to ASHRAE standards, EED standards, Part standards in the UK, they all are starting to converge into similarities in terms of requirements. It's how you—it's all very well to say, "Yes, we can build buildings to meet the standards. No problem at all." We're very focused on lots of passive design work at the moment. We design out energy inefficiencies by the nature of the design. Masdar City is a good case example of that. The whole city has been designed—

Q: For being passive.

SH: —for being a passive design city, with narrow streets that, as a result, the ambient air temperature I think is about ten degrees cooler than the equivalent city around the world, just through passive design. That's where good architecture comes in.

Q: What about, for instance, when by contract agreement they have to—say the three parties, designer, contractor and owner— they are sharing risks and benefits of the liability issues. How do you feel when you are exposed to that situation?

SH: It's interesting. I think it's—now that the lawyers have got their heads around it to a degree, and there are still a lot that haven't around the world, a lot of contracts we have say, "You will deliver BI ." T hey don't actually specify what we're delivering or what that content should be, what that level of detail should be in the model, what should be in that model, what attributes are required in the model, what the purpose of that model is going to be. Is it going through to facility manage the building in its life cycle, to energy manage the building in the future through its operational life cycle? Are we just doing BIM for coordination, basic site? How far are we taking this model? How far do we have to invest in that design? Particularly if we're only engaged, for example to go up to detail design stage, and then we're handing over to a local architect or something like that, what's our incentive to put all that information, all those hooks in early on, into a BIM model, for them to be filled in later or reused? Do we leave it open and let them do that? That's very rarely specified in a contract in terms of, particularly if we're effectively engaged to design the concept of the building and not actually go through to construction. That depends on our level of agreement and level of service that we have as part of the contract with the client.

Q: Have you had buildings that they are actually using the BIM model for facility management and things like that?

SH: Yeah, but very, very few. That's quite rare.

Q: What's been the experience so far?

SH: So far it tends to be totally repurposed, the model. The contractor will get a hold of the model. They'll rebuild it almost for construction and fabrication, suitable to whichever fabricators they've appointed. We don't always have an influence in that. Where we have that influence, we can have a much greater say and actually deliver. We've done that for the last 15 years. If you go back, say where we built city hall 12 years ago now, we were sending the fabricator data to do every pane of glass, because every pane of glass of uniquely sized direct from the BI m odel. We've done that. That was before any of the BIM applications even existed.

Q: Was that TriForma?

SH: Yeah, TriForma in very early days. Even write out own custom applications to do it. BIM has always been a process for us, not a piece of software, fundamentally.

We do BIM to different degrees on almost every project in terms of using 3D to analyze the building and reuse it and do that co-sharing and coordination.

Q: I guess your answer would be yes, but do you have projects that you have done in the past that you think you would not be able to do without BIM or without simulation?

SH: Oh, yes. If you take some of the towers and complex geometry we've got here, you just couldn't do it without doing complete simulation on the building, on that level of analysis. It just wouldn't be practical to do, not to be confident with the design.

Q: For instance, the Gherkin, you had CFD simulation, but you also used wind tunnel. Is that correct?

SH: Yes. Oh, yeah, yeah, absolutely.

Q: Were they different?

SH: I don't know, actually. F. would be a lot more—he actually was very involved in the project. When he comes along, that's something you can ask him. That was slightly before my time of working with the practice. I'm sure there are always going to be levels of difference between those. It's interesting. One thing we do as a company, we post-analyze our buildings. We'll be on a thermal imaging team that will go and post-analyze our buildings, to look at the performance. We can learn from our own designs. That's the other thing that's important. Every building is different. Every building will have a different result. What we need to do is learn from those buildings, capture those results and understand them, so that we can then develop further with that process and refine it.

Q: Usually designers start with an intuition of how the building shape should be and all. Now it seems that we are moving towards a stage where we do not trust intuition anymore. We will simulate to be sure that—

SH: Yeah. Even in early stage massing of a building where we're doing skyscrapers in China, we'll look at a site and do analytics on just the massing form to make sure we're getting the optimal angle for the building on the site for the solar gain on it, at very early stages in the design. We need to be orientating the building this way. You might have a bit of Feng Shui that comes in as well, so they say, “Can we turn it that way?” Yes, we will, and there’s a little bit of an offset on optimum performance. Actually, for other reasons, that might be a slightly better way, or there might be an access issue or something like that on the site. There’s always factors that means if you did it on a perfect energy basis, you could say this is the optimum position for the building and shape of the building for this design, but there are so many other factors that influence the shape and size of that building in terms of site access, height restrictions, rights of lots with neighboring buildings. All those factors then devalue that performance for other reasons that you are forced to compromise on your energy performance. Then you have real practical issues like we’d like to use this sort of glass because this would be the optimum performance for the building. You can’t get it in that country because they can’t manufacture it or the cost of manufacturing and transporting it halfway around the world just doesn’t stack up financially. There are some real practical limitations sometimes to the optimization of design.

Q: What about the cost of simulation? an y people complain that it’s so costly they cannot do more than two iterations, because then the budget will just explode.

SH: We’re fortunate we can do a lot of it in-house. We don’t have to outsource that simulation, so the cost to us is far less. We’ve invested in that. Given the number of projects, the size of company we are, we have that commercial advantage to be able to offer that internal simulation. But yes, it still comes at a time cost. There is an internal resource cost for us. Occasionally we do outsource, depending on the type of analysis we’re doing. It’s important that, from that side, we’ve got to get the right building at the end of the day. If it means we have to pay for ten iterations to get the optimum building, and as a result it saves our client half a million pounds, it’s worth doing in terms of heating costs, lighting costs, etc.

Q: Yeah, the final outcome.

SH: Yeah, yeah, the final outcome. We can go down that route, say that we’ve looked at 100 options for the building and this is the best one study. That’s all about getting some early stage results and doing light [unintelligible 23:00] analysis to get early indicators, then refining before you start investing in full detail simulation. Doing almost a double stage because you don't want to be doing a full CFD analysis on a building that actually is likely to change its height 20 times before it gets finalized. What we look at is using different technology to do early stage studies to give us reasonable indicators, to give us an environmental steer to what we think will be the best performance. Having our environmental analysts and engineers in-house also means we can do early stage, you ought to look at this type of technology for heating the building or where you are in the world or this type of building. Have you looked at what passive solutions there are for the shape and form of the building that you're trying to develop? All that comes into it. Some of it is having the knowledge in-house. Some of it is using earlier stage analysis that is fast and rapid and low cost. Then you can invest the higher-end CFD analysis for specific schemes to come out of it. There's a good workflow there.

Q: What funny story would you like to share about that learning process where you design the building, keep testing it after it's built, and then find out this is what's wrong. Can you share something?

SH: There's always something that comes out that you don't quite expect. That's sometimes the fun bit of architecture. Something sometimes comes out that's surprising, that you didn't realize. There was that hidden factor that you hadn't realize was going to take part in it. Sometimes you get—it is that whole we haven't done a building because something unexpected happens on the site that hadn't been factored in. All of a sudden you've got to totally change the scheme as a result. Or you'll always get you will build the optimum building and it is designed to perfection, but the client just doesn't like it. They're like, "No, we wanted something with gold everywhere." Its like, "Okay, but if you paint it all gold, outside the building, it's going to heat up." Sometimes they're like, "We don't care. We just want it." You will have clients like that. Sometimes you have no choice. Sometimes, unfortunately, besides all our best intents as architects, the client sometimes is right. We have to accommodate a client's whim, which means we don't always have that luxury. They are, at the end of the day, paying for it. If they don't like our design, they're not going to pay for it.

Q: How is, in general, the involvement of the client into the design?

SH: It depends on the client. Some are incredibly involved. Some are—

Q: For better or for worse?

SH: Some for better; some for worse. It really depends on the client. We've got clients all around the world, every country, every scale of client from private residential to full master plans of cities, airports. We cover every industry almost. Our clients range from very colorful individuals to large corporate enterprises. They all have different approaches. The secret is learning how to steer them.

Q: Are you still designing very small projects, let's say residential?

SH: Yeah. That's a very small part of what we do as a company. Yes, we do private residential houses. We design boats. We design cars. We design—obviously we have industrial design areas where we're doing interiors, products design. We do from that small scale right up to the tallest buildings and biggest buildings in the world. We're doing several airports at the moment around the globe. Skyscrapers in Mumbai—just about every country we're doing something in. It does vary in scale. Our general approach and process is still relatively consistent, regardless of the scale. You are always looking at good performance, good sustainability, good environmental factors, looking at the energy consumption of the building. These are all important factors. Whether because of contractual requirements or meeting regulation, regulation is only just catching up with where we've been heading, in terms of good performance. Our newer buildings totally outperform any regulation standards out there.

Q: What do you think about these green building rating systems? I guess you have worked with many of them.

SH: We've worked with almost everyone around the globe.

Q: What difference do you find working with them, the final outcome? What is your experience with this?

SH: It's one of those things that—it's not difficult to meet them. Again, there is sometimes the commercial need of the building mean that you will never attain a gold standard for a building, as much as you would want to. The client says operationally the building needs to do this. If it needs to do that, then you've got compromise from day one by the very nature of the use of the building or purpose of the building. It is never going to attain that sort of standard. You have to be quite realistic in terms of that, but you should always be striving for a high level of energy performance on the building. That's critical.

Q: Many people think of those green building rating systems as a kind of recipe or guideline for sustainable design or high-performance buildings. Do you use them for that?

SH: No, not in terms of—we're always mindful of it, but not in terms of—there are some projects where there is a target to build a gold standard building. That is one of the contractual targets or it's one of our aspirations to make this a high-performance, energy-efficient building, whether it's a sdar City wanting it to be totally carbon-neutral, totally energy sufficient as a city, to be a perfect green city. That sort of thing is what we're attaining and deliberately set out specifically on some of those projects. Other projects, the first requirement is having a functional, fit-for-purpose building. Yes, we will then do as much as we can to achieve a good energy performance on the building as well. You will never have that perfect, "We need step, step, step to achieve..." that's difficult. Every building is different. On every building, we have to adapt accordingly.

Q: Do you think somehow that sustainable design can be standardized, like a collection of steps and processes that can be used worldwide?

SH: It depends on the type of architecture you're doing. If you're doing production stock housing, then yes, you could. The sheer nature of the types of buildings we use—some of the buildings, the type of materials we use and the type of building we're designing has never been designed before. There is no template. There is no blueprint for us to follow. We can obviously base it on research and good standards historically and look around at comparable buildings. A lot of the buildings we design, particularly given their large scales and very unique style of design, it's almost impossible to have a blueprint standard that you must follow. You almost write the blueprint for the building.

Q: From the beginning.

SH: From the beginning, yeah. We will always look at optimum performance analysis. Environmental considerations are always there from day one in terms of what style of building it's going to be, where it is in the world. We will always do weather and performance analysis and look at the localized impact before we do anything on a building. There's no point in building a building in 40 degree heat that's going to sit there and cook. You have to be very practical about it. We're not going to build a single glass in a building and that's going to turn into a giant super greenhouse. We have to be very practical about our base designs.

Q: I read that, well, he doesn't work here anymore, but Ken Shuttleworth (Ken the Pen),

SH: Oh, yes.

Q: I can't remember what article that was. I think it was in building.co about the U.K

SH: Oh, yes.

Q: He said he wouldn't like a fully glazed building because it's simply not energy efficient.

SH: I don't think that's necessarily a fair statement. With glass these days and what you can do with triple glazed units and high-performance glazing, it's more than possible to do a very high-performance building in glass. Should it be all glass? Not necessarily, but could you do it? Yes, of course you could. There's no reason why you couldn't. You can get triple glazed units of glass that perform better than a brick wall in terms of energy performance. It just depends. There are so many new materials coming out and evolving. Yes, you can—I wouldn't discount glass just for the sake of discounting glass just based on historical buildings, big greenhouses that do cook. If you go back 20 years, 30 years when environmental considerations weren't always the number one factor, there were big commercial banks that always wanted a big, shiny glass building. That's another factor. That's where the client sometimes really weighs in. We can't always deliver an optimum building because they're like, "No, we want something glossy and shiny and it's got to be there because we want it to be part of our corporate branding and corporate image." Sometimes we have to guide our clients, as a good architect, and steer them into a more considered decision at the end of the day. That's what we do as good architects.

Q: Since you are in the top level of complexity on design and sustainable design and the scale of the firm, how do you think that design methods for sustainable architecture are going to change in the future?

SH: I think there will be a lot more information available on performance of materials. I think the analysis will become very mainstream and a lot faster than it is now, a lot more fluid. That sort of informed decision can be a lot quicker, a lot more dynamic. It will become far more integrated into the process rather than being a parallel analysis process as it is now. It will almost be mainstreamed in, in terms of considerations. There will always be a human factor there. You're not going to get away from that easily in terms of whether that's us having good experience and judgment, or whether that's the client saying, "No, I want something shiny." We can't always have that and we will adapt accordingly. At the end of the day, we have to have a certain commercial realism to it as well. Sustainability in terms of process, yes, will become a lot more fluid, a lot more dynamic, and hopefully a lot more integrated than it is currently. We're always striving to do that. Having it integrated in our process makes it a lot easier for us to design out issues at a much earlier stage.

Q: How is the workflow between the discussions and the decision-making process? You have all this team for analysis, but then how do you come to a point where you decide this material, use this shape? How is the workflow of design from the beginning to the end of the project?

SH: It's a constant iteration and it's a constant discussion. We, typically on a project, will every fortnight review the design, review where we are, or review the options that have been developed in the last week.

Q: How often are those revisions? It depends on the project?

SH: That means getting the project team around the table, looking at all… It depends on the project. They could be daily. They could even be hourly, or they could be fortnightly or monthly. It depends on the scale, the size of the project as to how that works. It is a regular work review. The influences and factors in the building. Yes, if we're the lead architect on a project, we will steer that and drive it. That's what an architect does. We're typically the one that will start steering it and then, with the environmental engineers, BIM are the next influence on it. From our original conceptual design, they may suggest that perhaps we ought to use this passive system or that passive system in this building, which would be our recommendation. We then adapt the architectural design to accommodate that. It has to be a constant iterative process with good communication. And BIM helps us do that.

Q: How would you rate BIM, integrated design approach, multidisciplinary team simulation, into the result of the final outcome? What is more decisive or necessary? What has a greater impact, in your opinion?

SH: Probably the integrated design is the biggest impact. The environmental comes into that in terms of, not necessarily from the analysis, but from the integrated team itself. Particularly if it's an experienced team, the learning's they have can have a big steer before the analysis happens anyway. That's your primary influential part. The analysis will then ratify that. Sometimes it informs and steers the design, but most of the time we'll ratify and it will just refine that design. The BI j ust joins the two together as the process flow, to get the information flowing cleanly and sharing that model data and the intelligence information coming out of it.

Q: In some cases, one member or more members of the team, is required more often to solve some particular problems during the design. What kind of positions, if you will, or purpose that person fulfills, can you identify that fits with that particular situation?

SH: We're fortunate because we have our specialist support teams. We tap into those as needed on a project. We'll get to a point where we want to do some high-end analysis on a building in terms of environmental performance. We'll just book an assigned slot with the team and say, "Can you come and work with us on this project for a period?" Sometimes that might be right from inception. It depends on the project. Sometimes we might just book some time and then schedule to do some analysis on it once we've done the initial design. We're fortunate in terms of having that almost like internal service delivery system. We don't always have to pull this person and this person together and put them as a team. Sometimes we do. It depends on the project. We're big enough to be able to flex and have that option to say, "Oh, no. We're at this stage on a project. We really need to bring these people and these people in and get them all working on the project directly", or we might just say, "Can we just phone this to you to do an analysis and report back to us?" It really depends on how the project, the nature of the project, size and scale, type of project as to how appropriately we adapt our teams.

Q: For instance, let's say that—well; the traditional design process a long time ago was basically architects and drafters. Now we have people in charge of parametric design, people in charge of model making, simulation... What kinds of new positions have been created lately in this firm?

SH: We've gone away from the traditional architect and architectural technician. We don't have that role. Our architects are quite multi-skilled these days. They will build models. They will do analysis. They will do parametric design as architects, to some degree. Once it starts becoming a bit more specialist in terms of wanting some real high-end analysis, then we'll take it another step and farm it out or bring an expert in to that project team to work with them. Our architects are very multi-skilled these days, as are our engineers. Our engineers will build BI m odels. They'll do the analysis. They're a different breed from how they were ten years ago. If you took an engineer, you had analysts and drafters.

Q: Do people move from one section to the other section often?

SH: Yeah. We have to be very fluid in terms of—we will grow and shrink teams quite rapidly depending on development cycles, scale of projects. We have to be very flexible these days and very dynamic. Having tools that are very integrated helps us do that, having good workflows, having it well documented, and having well-trained teams so that they are proficient. Knowing when it's appropriate to hand over to a more specialist team or having the support network so they can hook into that special team and feed in. That's constantly evolving. The technology is adapting all the time.

Q: You mentioned documentation. How is the process of documentation here? What kind of steps? 3D models, physical models? Do you have a separation of kinds of documentation?

SH: No. Our whole design [unintelligible 43:20], we very often these days do geometry statements that describe technically how the building is put together and how the design process is, as well as having environmental feed into that, describing the environmental design process and analytical process as a workflow. Very often we'll have a project setup that will describe how the project process is evolved, as well as developing obviously all the documentation for the building itself. The two go hand in hand, which helps as well when a project suddenly expands and we need another 20 people on a project. Then we can say, "Read this lot." Then you'll learn how this project has been put together so far.

Q: So you have something like your own library for the staff to go back later and learn new things?

SH: Yeah. Most of that is online. We can search for good buildings that were done like this, or this type of architectural projects that used this material. We have that all available as an internal resource, all online.

Q: But it's like an internal server?

SH: Well, it's an internet, but it's internal. We have a good base library, as well as external hook resources as well to international documentation and information. That's obviously all available as well.

Q: And all the other firms, in New York, they work similarly?

SH: Yeah. They're all connected here.

Q: Okay.

SH: They all have access to all those resources.

Q: I think we are almost—I don't know how much time you have.

SH: I was expecting F. to—unfortunately he hasn't surfaced, which is a real shame.

Q: I don't want to take too much of your time.

SH: You're absolutely fine.

Q: Are you good for a couple more questions?

SH: Definitely.

Q: Envelope design, daylighting, mechanical systems, and renewable energy are some of the aspects of sustainable design that are usually taken into account…

SH: Yes.

Q: In your feeling, what of those aspects have affected most the final performance of the building? I know you mentioned that now you are trying to go more towards passive systems.

SH: Absolutely.

Q: So would you say envelope, daylighting?

SH: Absolutely, right down to the orientation of the building, in terms of its solar gain, optimizing the whole performance of the building, its complete shape and orientation and form, right at early stages. Those are all factored in into the designs.

Q: Since you measure the performance later, can you say, just approximately, how much energy have the designs saved just from the passive system compared to a traditional building?

SH: That I haven't got off the top of my head. I can give you some facts and figures of Masdar on that. That would be a good case example of where we really pushed the boundaries in terms of optimum passive design. They've done—I know our firm imaging teams went out and did thermal analysis on the entire site to really look, and it's been a monitored site as well, to look at the whole performance as well as energy consumption of the whole university there, for example.

Q: That would be fantastic. Usually mechanical engineers, they like to say the envelope will not be more than 20 percent of the energy savings. Then it's just mechanical systems.

SH: In terms of pure environmental design, given the heat performance, even externally in the buildings and the public walkway areas, just the heat differential between there and say Abu Dhabi down the road, in the same temperate climate, there's something like a ten degree temperature difference between the asphalt road streets in Abu Dhabi compared to the pedestrian street in a sdar. That's a phenomenal difference just by passive design, effectually creating passive wind tunnels.

Q: Wind tunnels?

SH: Effectually wind corridors through the city, knowing which way the wind typically blows through that region and knowing how it changes and design the streets in the correct orientation to optimize that to control the heat loss and heat gain on the city. It's that level of performance that gives you some massive gains to start with. Then you can look at optimizing your buildings in terms of materials used, design, air flow, chimney stack flows, and all that sort of passive design into a building.

Q: What would you consider as the most relevant aspect to be improved in order to facilitate the adoption of simulation into design? Because it's costly, and especially for smaller firms, they cannot afford it.

SH: Having it online would be the best availability. Then you can just pay for a service.

Q: Like Green Building Studio?

SH: Yeah. Having analysis online, having effectually number crunching processes online that you can then say, "Okay, I can pay for the cheap service. It's going to take a weekend to process or I can pay for the fast service and it only takes an hour to process but I've got a thousand cores (processors) doing it. That's kind of where it's going. I think that's going to be probably the most interesting use of it. For a small firm to invest in a whole processing grid farm to do analytics, that's just not going to do as a small firm. We have that luxury as a large-scale firm that we can actually invest in that. The amount of analysis we do, we can have them running constantly and justify that investment cost. Even then, we're still looking at potential outsourcing. We'll be very interested in that technology as it becomes more mainstream, as cloud computing and cloud processing becomes much more of a mainstream application use across all, whether it's design or analysis. It's where the industry is likely to head up over the next five years, well, hopefully. That means, in theory, we become more environmentally friendly because we don't have processes under everybody's desks and huge amounts of resources dotted around that don't get used all the time, in terms of just sheer processing cores that are sitting there churning out heat and not actually doing anything.

Q: In general, do you know, what aspects of training the staff here have been the most difficult to address? Is it BIM training, how to use the technology for sharing information across the board?

SH: Probably BIM training. It is a shift in process in culture. It's something that you can't do just in a classroom. You have to do it with a working project and actually mentor them through a project rather than—we're all under immense pressure to deliver projects to deadlines. So getting users out of their projects into classrooms is always a challenge. It's much easier to have bite-size training and doing it in small chunks of time and actually do it specific to that project and mentor them. That's something we're always evolving to try and do as well. There are times when we have to mainstream teach.

Q: Do you think that there's a generation gap where it becomes more difficult to train? Like younger generations, do you think that they get it faster?

SH: Not necessarily. It's quite interesting, particularly with large, complex applications, sometimes they're very good at what they do but they're very complex to use. We've grown up with an box generation. They expect you to just push, click and it happens. The reality is it's not always like that. There's this certain need for instant gratification on results. [unintelligible 51:53] analysis can take time sometimes. There's always an impatience for it. That's where it needs to evolve so we can have that instant result or instant steer on a building and not have to wait a weekend for it to come back and say, "No, actually, you need to move the building two degrees that way." I'd rather known that two days ago and then I wouldn't have had to waste my time.

Q: Did that happen before?

SH: There are times when we need to do that. There's F., actually.

Q: Hello, F. Very nice to meet you.

FA: Nice to meet you. Sorry I'm late. It's been a bit crazy. How are the questions going?

Q: We've been through a lot of questions already.

SH: You can answer the last question.

FA: [unintelligible 52:51].

Q: Actually, I think S. and I got pretty much to the last questions. I have a few more specific questions I can ask you, especially regarding to the Gherkin, some parametric design and stuff like that. It would be good to start introducing yourself. What's your background? What are your primary functions here in the firm?

FA: Sure. I run the applied research document team, which is sort of the in-house team that's going to keep the Foster's on the leading edge to a lot of new technologies and processes. Usually pro-green, working with all the [unintelligible 53:33] and working with all the project teams, very project-driven… y background is aerospace engineering. So I can run all the software and simulation and came here about 12 years ago.

Q: How difficult was your transition from aerospace to buildings?

FA: Really pretty similar. It's a different field, but all the problems are very similar. It's a different level of complexity. In aerospace, you haven't really the challenge of aesthetics. Planes tend to be very functional. You don't have to worry how they look. They happen to look beautiful but that's aerodynamics taking care of that, whereas here you can be more willful. Certainly we're trying to bring more analysis into the design process, which drives the form of the buildings.

Q: Since BIM started with airplanes, I guess you are pretty familiar with BIM since the very beginning.

FA: Yes. [unintelligible 54:39] CAD and the like. I think the term is—it's just a phrase. I think one shouldn't ever use it—integrated product design or integrated design would be the term I'd use, sort of 3D coordination rather than a buzzword.

Q: You are Robert Aish's son?

FA: I am indeed.

Q: Oh, so he moved from Bentley to Autodesk?

FA: He did, a couple years ago. It was two or three years ago now.

Q: Here in Europe?

FA: He's mainly based in the UK, yeah. He sort of goes—Autodesk is basically all over the place, so he travels a bit.

Q: Interesting.

FA: It's in the blood.

Q: One of the questions I have is basically about parametric design. Since the Gherkin it's been studied everywhere in all the possible ways you can design parametrically. Can you explain a little bit how you got to that, you as a firm, got to that final shape? What kind of parametric design, the evolution of the design basically?

FA: Sure. I think the design was one of the first new skyscraper in the city for a while, and as a result, it was a very complicated mission. The planners were not too keen to a new tower in the city. At the same time, we wanted to drive the building from aesthetics rather than [unintelligible 56:25]. The form had to be very recessive so it wouldn't take up too much view of the skyline. That's why it kind of curves in towards the base to create more public space. The form is very aerodynamic. With a lot of tall buildings, you get a lot of downdrafts.

Q: Yeah, negative pressure.

FA: By making it kind of a bullet shape, the flow, no matter what the wind direction, would be pretty smooth around it and you've got a lot less downdraft. You could also use that to naturally ventilate the building. You've got a pretty consistent pressure differential from the leading edge and the fronting edge of the building. So we could use that to naturally ventilate the building.

Q: And you have the spirals.

FA: The spiral started out as being sort of grooves cut out to increase the daylight on the floor plan. Actually using a physical model, people were playing with this thing. Then they said, "What happens if we twist it?" That led to this thing, which actually helps the ventilation strategy. That also led to the idea of a diagrid, which is very strong and light. It actually uses a lot less steel. Most of the load is carried on the skin of the building. The core is taking a lot less load. It's more efficient for material. My colleague, he wanted to build a parametric model or a sectional model to fine-tune the profile. That was sort of used a lot by the design team to double check. That was tied into parametric floor plan models, so we can measure the areas as well. Then we rationalized the geometry further and I did some models in actually Excel and Microstation that would generate all the structural points, to say how the points and panels detail, some of the louvers… It was very early days, but it allows us to generate the building, which was pretty hard to draw back then. It allows us to control the geometry. Also, by defining the whole building as a geometric recipe, it allowed us to exchange the design with our contractors and be sure that they could model the building easily following that recipe and allowed us to check the geometry between sort of their model and our model. At the time it was very bad, outdated interchange to change between Microstation and AutoCAD and the other simulation. So by taking a very simplified mathematical model of the building, we could compare our model with the contractor's model and see if there were any errors.

Q: How long did it take, approximately, since the very beginning of the project until the final shape and parametric design?

FA: It was a long process. I think, due to the planning constraints—I couldn't give you an exact.

Q: Approximately.

FA: A couple of years. I think once—things did accelerate once—there was a lot of fine-tuning. I think it's reflected in the final geometry.

Q: I also saw that you used CFD simulation and at the same time a physical model in the wind tunnel.

FA: Yes.

Q: How different were the output from them?

FA: At the time—CFD is a very good tool. At the time, people still had some concerns about the accuracy, so people would use CFD to get the design roughly right and they just validated it in the wind tunnel. Nowadays, people are a lot more confident in CFD. We still put some of our projects through wind tunnels, but I think only as a very final check. I think the internal flow was simulated using CFD. The external was wind tunnel.

Q: How many iterations have you had from the CFD to refine the final shape?

FA: There were a few iterations. I think nowadays we have the same capability and we would do more iterations.

Q: In-house?

FA: Yes. At the time, I was working with consulting engineers at Arup and BSP and [unintelligible 1:01:03].

Q: I also read that you are working on your Ph.D. as well?

FA: That's right, yes.

Q: You also work with research with other universities?

FA: Correct.

Q: How much does that affect the design process here? What kind of impact?

FA: I think usually our collaborations are for specific areas where we think there is some potential. We haven't got enough resources in-house to do all the research we'd like to do. We like to collaborate with different universities and organizations to push that forward. For example, we're doing research with oughborough University on 3d concrete printing.

Q: What university is that?

FA: Loughborough University on 3d concrete printing. So printing 1:1 scale in concrete, it's quite an interesting research area. We can see the potential. We can provide a lot of input into that, but we essentially are working with Loughborough because they have the labs and materials, knowledge and engineering knowledge to actually build the kit. It works pretty well. We can provide ideas and stimulus and evaluate.

Q: That can build up your materials library and possibilities for future projects.

FA: Exactly. We do a lot of research in house as well. We're a very small team, it's just five people. We are actually kind of isolated in what we do ourselves, but we can bring in [unintelligible 1:02:39].

Q: I read in one of your presentations a quotation. It said, "As defined by Foster and Partners, the use of new technology have helped to improve both the design process and its outcome. This, in use with traditional design processes, enabled their firm to offer better solutions to their clients." What do you mean exactly by "in use with traditional design process"?

FA: I think we are not eliminating the traditional process. If you look around, you'll see a lot of physical models. I think we are trying to extend the design process, trying to augment it, so to speak, allowing us to do things you can't do easily with physical models. It's an added process, not subtracted. I think it allows us to investigate options in more depth. It allows us to do more options, try out things which you couldn't do manually or with physical models or drawings.

Q: So you're saying basically it's a combination of the traditional design with all this aid from tools and models?

FA: We will use whatever media and tool gets the job done. Sometimes a paper sketch is a very efficient design tool. Sometimes a full-on 3D parametric model is a perfect tool. We are not prescriptive about it. We will use whatever we need to use to produce the effects.

SH: Whatever software we need, whatever tool we need, just to build a good building. It depends on the building.

FA: The ends justify the means, basically. It's about using good architecture. I think if you look at the work of Gaudi, for example. Gaudi used some pretty primitive tools available to him, but he used them very, very well.

Q: He was a master at geometry.

FA: He created some beautiful buildings. He didn't have a computer. He didn't have CNC milling machines. He used the technology very well. I think that would be my view. We will use the technology we can and maybe invent some new stuff, but it's about what you can produce with it. I'm fascinated by the technology, but I'm here to design good buildings, fundamentally.

Q: That's what the firm is about. How will you define a better solution for your clients?

FA: I think there are a number of parameters you can appreciate a good building. The hardest one is for the aesthetics. If the client likes it, I guess that's accepted.

SH: The client ultimately has an aesthetic influence.

FA: Yes. Can you deliver a building that is cheaper or built quicker or uses less energy but is functional? One example is the Commerzbank [ph] in Frankfurt, which had this kind of green atrium. I believe there were some productivity studies which showed people tend to work better in this building than a regular office building because it was a much nicer environment. That's a measurable benefit that's very important for the clients. If their employees can work ten percent better or be more productive, that very quickly pays for the cost of a building. Those are the sorts of things you can measure. Then there are the more subjective things. Does it enhance the building environment? Take the Guggenheim in Bilbao. The local government estimates that it brought in a lot of extra tourism. So the building costs, however much, will bring in billions of dollars. Maybe you can measure these things. Yes, we try and deliver the best buildings we can. That's our goal. There is a lot of different criteria you can measure that.

[Tape off]

TR Hamzah and Yeang

Q: First, are you familiar or have you used building information modeling, simulation and integrated project delivery or integrated design?

A: I've used some but not all. Building information modeling, yes, but we've never tried—we tried to do it on a project, but we didn't fully complete it.

Q: Okay. And that is building information modeling?

A: Yes.

Q: Just to understand the basic dynamics of design and how the firm works, can you explain a little bit about the hierarchical structure of the firm, if it has, for instance, divisions of healthcare, commercial buildings?

A: You mean the office?

Q: Yes.

A: Well, this is my secondary office. My main one is in Kuala Lumpur. Kuala Lumpur does master plan, architecture, interior, landscaping for any building type.

Q: How many people work both here and in Kuala Lumpur?

A: Just about 20 to 30.

Q: Okay.

A: And then Kuala Lumpur has 62.

Q: Okay. How would you summarize the overall sustainable design process in your firm? How does it start? How is the general workflow?

A: We start by looking at the site. A couple of factors: we look at the climate… So if it is a temperate zone, we try and see what climate responsive devices we could use. If it's a cold climate, that's different, so passive mode design is the starting point for our building form. Then we look at the ecology and find out the ecology of that location. More important, we look at the type of site. Is it an urban site, rural site? Existing ecology on that site determines how much information you need to collect as a basis for this design. Those are the starting points. Then from there we look at the built-up area on the design program. We will end up with how this could be addressed in a sustainable way. We look at the uses and try to find out whether we can create an internal life that's sustainable, reduce the covered area, reduce the enclosed area. Once we enclose the area, energy comes in, so we try to reduce the enclosed area. We see if we can create in-between areas, interstitial areas or transition areas where activities can take place without being in a full energy consumption mode.

Q: Okay.

A: Sometimes this may not be possible. Sometimes people don't want to have a lesser level of comfort. We're so used to consistent—

Q: Air-conditioning, yeah.

A: Then we look at shaping configuration within the site, how the factors influence building form. We look at what it says there. Then generally the usual things about good architecture, which is what is it that makes architecture, all the spaces, all the configuration pleasurable to people. Giving pleasure to people, I think, is the major effect on design. That's why we're architects, you know?

Q: That's the goal.

A: I talked to somebody the other day and she said architecture is about making dreams come true. People have dreams when they have an architect. We really have a vision of what we want. Making their dreams fulfilled is a good part of what we do as an architect. So that with form-making with the second streams, making things green with the client's budget, that's where the challenge of being an architect is. That's where the design is about, making everything fit with each other. I think the best word is fit. The better the architecture, the better the level of fit, fit for the site, fit with each other, fit with the climate of the place, the culture. That's the magic of architecture. That is the secret in architecture. That is what makes each architect different. Sometimes you get it straight away. Sometimes you don't get it. Sometimes it may take several flourishments, several reiterations before we can—

Q: When you don't get to that point of satisfaction, what is your experience? How will you balance? Is it more because of a client's attitude, a problem with the site and the climate? In your opinion, what has been—

A: Sometimes you're not happy with it. You're your own worst enemy. Of course, many times it is a client. Very often it's the budget. Sometimes we just don't get it. It may well be that we have some preconceptions somewhere. We just focus on the wrong priority. Some of us can be too arrogant about what we do. We just have to see this as a journey of discovery, I think. That's what makes architecture exciting. It also makes it difficult. You cannot predict how much time you spend on it. Of course, in our business, the faster you do it, the faster you get paid. It's always trying to find some sort of compromise between time and money and effort.

Q: What is your main critique to the way most designers are approaching sustainability today?

A: I'm not sure whether I can give a fair answer to that. These are some of the problems I encounter: first of all, most architects don't know enough. Secondly, some architects tend to be very accreditation-driven. They say, "I'm a EED professional." Some say, "We're good at living building challenge." Some architects just say, "I know everything about sustainable design." They do their own way. Some architects are very engineering-driven. They say, "I prefer photovoltaic, is just green design." I don't think a truly green building has been built yet. an y experiments, many different levels of advancements... I think we have to be a little bit open-minded and a little bit humbled by the whole thing, see the whole thing as so [validates??]. But I believe that a lot of problems are because most of the architects who practice today, of my age, my generation, were not brought up to be sustainable architects. They are quite in the last five, ten years. The next generation of architects will be trained. Once we train them, then sustainable design becomes automatic. It becomes second nature to them. They don't even have to think about it. They already do it. Then they can focus on architecture, the human side of it, the pleasure principle.

Q: That's a very interesting point. Architecture has managed so many variables. It will take forever for a really comprehensive architect to understand ecology, biology, construction and architecture as well.

A: Engineering as well.

Q: How do you think architecture teaching is going to change in the future?

A: I think it will change. For instance, when you learn materials at architecture school, what do they teach you? They teach you about weathering. They teach you how it is constructed. They teach you how to match one material to another material. They teach you about weight and things like that. The future teaching materials is how it's produced, what is the impact from taking the material from the ground. Do you destroy the ground? The process of making it, how much energy is used, what is the impact on the environment, the consequence of recycling it, how to use materials so that you can reuse it again. That is the future teaching of materials, not just about weathering.

Q: Also, do you think that the integration of multidisciplinary team will affect?

A: Yeah. I think the human mind is capable of handling it. If you go to the, let's say the top 20 schools of architecture in the world, they all have a different focus. One school will teach you about parametric design, like Columbia or other school where the emphasis is on [unintelligible 11:46]. These are sometimes distractions. Underlining these distractions—some of them could be good distractions. A distraction is not necessarily a derogatory term. Architecture is not a theoretical subject, not like science or mathematics. A lot of architects try to find the theory on which they can hang their architecture. They like to call it a theory, but it's not really a theory. It's just a set of principles, a set of axioms in a way. I guess a sense of stability, a sense of what you bring to the academic framework. It's not really theory. It is just a set of ideas. So it's a little bit suspect that we call it theory, but that's what architecture is. It's a series of ideas strung together as a whole. Colin Rowe [ph] does design architecture as a series of aphorisms. Aphorism is an idea strung together. As a whole, you must act as a whole. [cell phone vibrating] I think in the future, your generation and the next generation will do green design without even worrying about it, not in the way we worry about it now in my generation. You wouldn't know about it. They just know all the things. You will do it much better than we can. Then they can focus on the architecture, on the aesthetic and things like that, which today's generation is too distracted. Not distracted, but too preoccupied. We're getting the green things right. In the future, they will just do it. All the systems will be there.

Q: Also you mentioned about the green building rating systems. People are too constrained. Because they are following those guidelines, they think they are doing green design. Do you think that those green building rating systems will become obsolete?

A: No, they will get better. They will get better and more comprehensive. There are two ways of looking at this. One would be prescriptive. That means you have to design to a building must not consume more than 120 kilo hours per square meter or your environment will be maybe 23 degrees air change to air change. It is very prescriptive. The other process, the performance-based, says we're not going to tell you 250, just as much non-renewable energy as possible. Don't just say, "We should not use more than 500 kiloliters of water per person per day." They say, "The water cycle should be closed." It's a performance-based approach. Of course, performance-based is more difficult to achieve. It's like a principle. You can never achieve 100 percent. You can never close the water cycle because you lose a lot of water to evaporation and through inefficiencies. The idea is there. The principle is there. So you end up achieving as much as you can. I think we should not lose them. They provide a standardization of comparing types. For instance, I was talking to a physiopsychologist the other day. We were talking about intelligence. She was working on children, on school children. She said there is not just one method, but many methods for measuring intelligence. One is physical but there are many methods. There are different focuses and different outcomes. You can measure from the [unintelligible 16:10] ability, physical ability. The advantage of each one is that if you measure—let's say you want to develop 200 students, you can't use different methods. If you use one, then at least you can compare them. So you use, let's say LEED for the U.S. So it just becomes a standard we are measured by. Of course, these methods do not guarantee a good-looking building—

Q: Or a good performance.

A: —or good performance or even successful architecture. They're just like the criteria. That's the person has an IQ of 92 and another person has an IQ of 105. It doesn't mean the person with 105 is a nicer person than the one with 92. It is just a measurement. It's a qualitative—qualities of the human being. It doesn't come to the quantitative. y biggest problem is arrogance. Some people think, "I'm a EED AP and I do platinum buildings." I'm all about green design like everybody else. When you stop thinking, you start advancing.

Q: I have seen some of your projects and I know that you have used CFD simulation, for example.

A: CFD?

Q: Yeah, computational fluid dynamics. How did those simulations affect the general design process in terms of iterations, feedback?

A: My biggest problem is really time and cost. Getting somebody to do it is going to cost money. Due to the cost, maybe we do it once or twice. If we do it two, three times, several times, they charge a lot for it. We don't always have the time to do this, because once you do one, you can modify the design. But to modify design, to draw it up again, takes time. In practices, you don't have too much time. The most is maybe one, two iterations. Then we get a CAD view that this is what could work. Then we go and build it. For instance, one of our projects is the Ganendra[ph] Art House. Have you seen it? Check it out. There's a house that they use as an art gallery. It's called the Ganendra Art House.

Q: Okay.

A: It's in alaysia. With that project, when we designed it, we wanted to use a downdraft ventilation system. In Yemen, they have wind catchers to catch the wind and bring it down. Then they have a clay pot with water. The air comes down and the clay pot cools the air. That could work in certain locations. But we tried to use it in ala ysia. I said to the client, "Shall we try this out in the process?" Then I got somebody to simulate it. The simulator says, "It could just work. We're not sure." I guess Malaysia is very hot and humid. I said to the client, "Do you still want to do it?"

She says, go for it." We did it. The simulation proved it could work, not 100 percent, but it could work. After it was completed, they came back and did measurement to test whether it would work. Then they found that it could work, but you have to close all the other windows so that it could work. Otherwise you got feedback from the other windows. If you close all the windows to show it worked, the temperature goes up because you close all the windows. You cannot win everything. The client said it was an interesting experiment. Simulation showed it should work. Measurements showed it could work if we closed all the windows. If we were to use it in a normal circumstance where we leave all the windows open, the short circuiting of the wind flow was affected. Then we did another project where we wanted to do a plaza with retail below but no air conditioning. We did it in [unintelligible 21:20]. The projects were called The Plaza in Malaysia. She simulated it. What we had was—this is the ground level. We had six floor shops and then we had a canopy on top... but to create some [unintelligible… airflow?] here, I had three large wind turbines in here so that this whole thing is naturally ventilated. My professor friend at the university, her name is Dr. Shireen Kassim. I've been working with her since she was a graduate student. She is not talking to me at the moment because I haven't paid her some money for what she did. Some clients don't pay so I can't pay you. She simulated for me. The client wouldn't pay for simulation. That's the trouble. I have to pay for it. That's another problem, to persuade a developer client to pay for the simulation. So I said, "Shireen, can you just do"—I persuaded her to do it for me at minimal cost. She simulated the airflow. She simulated the daylight. She test simulated the sun shading as well.

Q: Do you remember what software she used for the lighting simulation?

A: You can write to her. Lucy will give you her email address and you can write to her. It was great. Then we told the client, " ook, can I invite Shireen here to present it to you?" so they found it very interesting. Then when they launched for sales, the people by the shops said "It going to be hot. That's no air-conditioning". Then the people who bought the apartment units said, "Why do you need the sun shading? Won't these apartments be hot because it faces west?" So my client comes back to me and says, "Can't you redistribute the figures and diagrams?" So I brought the figures and he showed to his marketing people to say "look at the simulation" to show it was cool. And with those apartments facing west, the sun shading prevented the sun heating up the space. So eventually they used our material for marketing purpose. They still wouldn't pay for it. If you want to know what software we use, contact Professor Shireen Kassim. She's a little girl, about this height. Her husband is a banker. I think he's Iranian. I'm not sure. She simulated maybe about four of my buildings. You can find out what software she used. She will tell you, yes, is this project successful or not successful? She knows all the success and failures of all my buildings, better than me. That's what we try to do. We cannot promise that everything is going to be successful. If you want everything to be successful, then you don't experiment. You just take the safe solution. You have to experiment a little to push the boundary a little bit.

Q: Have you had the opportunity to test your eco cells or the green ramps?

A: Look at the Solaris Building in Singapore.

Q: I have it here. I remember I've seen it.

A: It's been completed now. The eco cell is good. It collects not just—the Solaris stuff, they put a water tank underneath, so that it collects the [unintelligible 25:36] water. It also collects the condensation from air conditioning. Then the irrigation of the planting is not a trip system, but it is—I'm not sure what system it is. I think it's a sprinkler system, so you only use it when it gets too hot. Once it rains, the sensors switch it off because you don't need it. That's finished.

Q: Nice.

A: It's nice. We know, again, like an architect, if this doesn't work, it's no good. You always say we can do it again. You're never quite happy with the outcome.

Q: Trial and error.

A: Trial and error, yes.

Q: What aspects of simulation do you think is missing for a comprehensive analysis of a site ecological system? In other words, what is missing to truly simulate the carrying capacity of the site?

A: Carrying capacity is something else altogether. Carrying capacity, you have to use some sort of mapping technique. It's also data intensive. You have to map the vegetation, map the soils, map the drainage, groundwater, things like that.

Q: Do you think that a typical architect nowadays can do it by themselves?

A: No. A landscape architect would know how to do it.

Q: So you need a multidisciplinary team to do it.

A: Yeah.

Q: et's imagine a case scenario with the existence of reliable simulation tools. Do you think designers should use them?

A: Sure. It speeds things up and you get the results much faster than if you do it manually.

Q: Okay.

A: Actually, you can do a lot of things. When you do the master plan, you can simulate the wind flow through the system. You can simulate air pollution and things like that.

Q: Do you use any kind of simulation here in the office, in-house?

A: No. We get somebody else to do it.

Q: Okay. How do you combine intuition with analysis of performance?

A: That's a very difficult question. I was talking to an architect the other day. In the mid-'60s, there was a lot of interest in design methods. I read a book called Design Methods by Chris Jones. Chris Jones is one of the world's authorities on—I was reading about this the other night, Design Methods by Chris Jones. He has a book with maybe 100 design methods. They're very interesting. Some of them are actually methods for invention as well. He's a very smart man. What they conclude with design methods is the principle is you collect data before you start design. That's not in the data collection. What do you collect? There's so much stuff to collect. Where do you start? You can never collect enough data to do design. On top of that, just because you have good data collection doesn't guarantee good design. There's always whether you design plus collect data or collect data before design or somewhere in between. The conclusion is that there's so much data to be collected, you have to pick and choose. I said, "How do you know which one to choose from?" Then he said to me, "This is where intuition comes in. You use intuition to decide which are the most important data to collect. You have to develop a sense of intuition. The better your sense of intuition, the more accurate you are, the more appropriate the data collection will be, or more appropriate the effect is on architecture." That is why architecture is so much an art. We can't be 100 percent deterministic about what factors you want to take into consideration. The intuition of data is there. The intuition of space, form making of [unintelligible 30:51] and putting everything together, the intuition of the aesthetic, what you do… The best architects, I think, are the ones with the best sense of intuition.

Q: That's an interesting answer.

A: It's our life, too. Everything you do in life is—

Q: Make the right choices.

A: Yeah, make the right choices. Very often you make choices intuitively and you rationalize it afterwards. It's like go to a shop and you want to buy something. You generally head toward the ones that you like. I started reading a book about why the iPhone is so successful. First of all, it's beautiful.

Q: And intuitive to use.

A: Then it is also intuitive to use, good to use, easy to use, so these are the three criteria: First of all, it's good to look at. Second, it's easy to use and pleasurable to use. You get a lot of pleasure out of using an iPhone or iPad. This is what makes a successful product. It's very often—what I've found is that when I present projects with a client—when you present a project to a client, it's very different from when you present a project to your school. You present it to your school showing site analysis, the facts that affects your design, and this and this and that, and then how that leads to your design, and then your design! If you present that to a client, the client wouldn't go to sleep, you know? The client's decisions, I find—

Q: Are numbers-driven?

A: No. Emotion-driven. They say, "Do I like the look of the building?" If they like the look, very often that overcomes everything, supersedes everything. The emotional aspect of it is there. You'll discover it. I'm sure it's true. So now instead of showing the perspective at the end of the presentation, first I'll say, "Do you like the design?" Whatever rationality you have is not going to make them like it. The intuition and the emotion aspect of it are extremely powerful.

Q: That is very interesting. If you don't mind, let's go to some technical aspects of how the design workflow is here. Usually you have meetings with your clients and meetings with consultants and your design team. How often do you usually have these kinds of multidisciplinary meetings? It varies depending on the project or it's constant?

A: It varies on the project. It varies depending on the issues of the project. Sometimes the issue may be with the… it could be people driven, it could be with authorities, it could be with [unintelligible 34:14]. It could be with the site. It could be with the adjoining, whatever it is. Every project is not simple, because there is always some stuff and issues we have to address, and once you solve one you have to solve another, then you bring people together to solve it. You cannot generalize it. You just have to address the issues. What drive the project are the stages of work. The client has some priorities. The client's priorities are usually getting approval from the authorities, getting planning approval, building approval. Unless you get planning approval, you don't have a project. Nobody has a project. It can be a nice design but if you can't get planning approval, then, no point. That is what drives the project, the client's priorities. Sometimes the client's priorities are such that you could have regular meetings. Sometimes the client says you start off first then you and come back to me and tell me if it meets these criteria and then this, and sometimes the client is happy…

Q: Well, you work internationally. When you have international projects, how can you manage your schedule and work? You always travel or you try to use teleconferences and stuff to help you?

A: Sometimes.

Q: You also talked about green building rating systems as a way to standardize the performance of a building. Do you think there's a possible way to standardize the design process for sustainable design?

A: No. Right now today, there are too many ways to get to—I think there are many ways to skin a cat, many ways to get to the end result. It doesn't have to be one way; it can be many ways. Everybody has their own way. Some are faster than others. Some are more appropriate for some of the projects. I try not to be too deterministic about it. That's my view. Some people think there's only one way.

Q: There are some of these questions we have addressed already. How do you think your firm and firms in general could prepare to face the challenge of the future? How can you prepare for that?

A: I think innovation is the way. You have to constantly innovate.

Q: Your firm has been awarded recently with innovation. Do you think there's a recipe for innovation?

A: Recipe? (pause to think) I think techniques are encouraging innovation. Yes, I think there are techniques. Knowing when to—for instance, they say the human mind works in two ways. One is convergent and one is divergent. Convergent means you know more and more and more about something. This is what most scientists do. et's say I'm interested in black holes in the sky. I can study it and know more and more about it. Divergent is what artists do. Divergent will go and get ideas. The trouble with being an architect is you cannot be always divergent. You can be divergent in design stage, but at some point in time you're out of time. You have to bring everything together and converge them into a solution. Knowing when to diverge and converge is something. With innovation, there are many books written about it. Some, for instance, articles call for the bisociative approach. Bisociative says there’s no such thing as new ideas. All ideas are combination of old ideas. If you bring two ideas together and fuse it together, it becomes a new idea. It’s bisociative thinking. That is an astrophysicist called Fritz Zwicky. Have you heard of him?

Q:	No.

A:	He is an astrophysicist and has discovered stars other people haven’t discovered, new stars. He wrote this theory, this paper about Zwicky’s or phological Method for Discovery of Invention. I think he wrote it in the ‘40s. It’s an interesting method for innovation discovery. You must not mix discovery with innovation with invention. Innovation is an idea. It applies to process, it applies to systems, and it applies to objects. It eventually means you actually take it up and put it up and implemented it in the marketplace. That’s invention. I think that is—it’s not just objects. It applies to processes as well. It applies to concepts as well. It applies to concepts, premises, processes, objects, devices, so I think that is the way to—that is what makes a company competitive.

Q:	I guess I have two more questions. How do you think technology has affected the design process today?

A:	Technology changes the design processes. It upsets design processes. We must be aware of the latest technologies that we use. It has to be clean technologies. For me, it has to be clean tech. It has to be eco-engineering and eco-technology. Some technologies which are not eco, then we shouldn’t use it.

Q:	The impact has been for better, for worse, mixed?

A:	You can’t generalize. Some technologies have made human life—like the electric light bulb. If we wouldn’t have the light bulb, what would our evenings be? We can’t read. Everything would be dark. We’d be using candles or kerosene lamps. Now we can get—now this must be about 300 lux. Then the sanitation. If we didn’t have the toilet, the flushing toilet—it was invented because it prevents disease. It’s made life a lot healthier.

Q:	But the technology for design, you also think it’s been for better?

A:	Yeah, some are better. For instance, it's very difficult to say [unintelligible 42:30] of design. I started practice in '75, '76. At that time, we buy five drawing boards and a couple T-squares and that's it. Today, before you even start, you have to buy software. You buy computers. You have to buy a fax machine, internet. Before you even start, you already spend a few hundred thousand already even. In those days, for instance, '75, when I want to see a client, I have to travel out to see him, see him for half an hour and then take a flight back. y whole day is gone. Then by the '80s we had fax machine. Then [unintelligible 43:15] and I save my day. Now we can actually use internet. Technology has made design—it's radically changed the whole process of how architects work. We used to do drawings by hand but now AutoCAD. I used to employ somebody to do perspectives for me. Now we can, with Sketchup, we can actually quickly see through the 3D model and you can look at it from different directions. Technology has essentially enabled us to affect design in a much—actually, it has contributed to improving design. A lot of design that you see today, the shapes and forms that Frank Gehry does, you cannot do it in the traditional way. You can only do it with the machines that he uses. Technology has advanced a great deal.

Q:	Have you used, for instance, parametric design here in your firm?

A:	No. I am not a great believer in parametric design. Not because of anything that—you see, architecture has, for me, has the need to create a form of internal life which is pleasurable and unique. Of all the parametric designs I've seen, they're beautiful, they're clever, but internal life is nothing. The road test of architecture is the internal life.

Q:	Do you think the emotional part is missing there?

A:	No, the internal life, how people use spaces internally. There's a sweep floor, like an office floor, and then I said: this has aesthetics… it's your shape and then my shape. Does it go beyond the form making and question internal life, question the (pause to think) way people use these buildings?

Q:	Do you think that maybe that's a kind of fashion thing today? As soon as they get used to them, they will not approach the same way? They will use it just when it is necessary or then we'll have an intelligent use of parametric design later on, as soon as it's mature?

A: I think they have to take it to the next level. For instance, I saw a parametric design where the design is solar responsive. That means for different facades, it has variations. That's very clever. That's very complicated to do. That's the next level for parametric design, to make it much more environmentally responsive, to make it sustainable. To go beyond form making, you have to make it location responsive, climate responsive, energy responsive.

Q: How would you rate today the importance of the designer's talent, an interdisciplinary team work and the intelligent use of technology?

A: Talent has always been there. You cannot say today people are more talented than in the past. What has become clear is that today's designers are better at multitasking. They can do several tasks at the same time. Children today, they can do their homework, listen to the iPod and watch television at the same time. In my day, I couldn't—that's because they're used to being bombarded with information. They've been conditioned to that. Being able to multitask and multifunction is certainly [unintelligible 47:56]. Also today's people are much healthier. That means the ability to work for long hours, ability to live longer. Sometimes when you're healthier, you perform better. So talent has to do with increased quality of life, if you like, and also the condition that comes with modern lifestyles. Working as a team, I think technology has helped a great deal. As I said, with video conferencing, you can look 12,000 miles away. About 20 years ago, I was in offices in Taiwan. This man had a very large office. He employed about 300 to 400 people on several floors. He would have a video camera on every floor. I thought video camera was to look at the employees, but actually he installed them because he will go "can I see the project?", but who was there to draw it to him? And he points it to him (laughs), and he was at the 10th floor and he was talking to someone at the fourth floor… Rather than an employee going out and shows it to him... I thought that was really funny. With video conferencing, with the internet, with the iPod and iTablet, working by team has become much easier. Sharing information is much easier. [Just send software for a set of practice and then you close it and send it back to you]. That's teamwork.

Q: Do you think there's a synergy between; let's say simulation, building information modeling and integrated design?

A: Oh yeah.

Q: —or IPD? I don't know if I'm familiar with the IPD, the contract agreements…

A: [unintelligible 50:08]?

Q: It's a three-party agreement, the contractor, the architect and the client where they're sharing risks and benefits on the project and all of that. Have you had any experience with that kind of approach?

A: No. For that to work, you need a very sophisticated contractor, very sophisticated architect and very sophisticated client. That could work. A lot depends on the project. If a project is big, a reasonable timeframe, some of these could work. I was talking to—I had breakfast this morning with a developer. I do some development work myself. I was telling him [unintelligible 50:58], I've found that, if I'm working with a developer and the developer wants me to design a project not once but twice, even three times, I [unintelligible 51:12] this guy doesn't know what he's doing. I get pissed off and I send a huge bill. Pretty normal. When I started doing work for myself, I'm the developer and the architect. I found I had to design a project eight times. To get a project right, sometimes it's not because I don't like the shape, but I have to get the financial model right. I have to get the costs, the marketing features in, get the sales price right, getting authorities.

Q: The things that you are not familiar with.

A: No, no, because you are crafting a product that will sell. Just because you do one that you think will work, they may not sell. As a developer, you are creating a product you have to sell. You cannot sell it at low point, no matter how beautiful the project is. If you cannot sell it, it will never get built or it could be disastrous for somebody. Very often I realize that if you have to redesign it, you don't have to redesign the whole project. It's basically just shaping the spaces just to get the areas or to test the financial model. We don't understand it. If the client tells you to do something, the client is always not very good at communication. You think he wants me to redesign it. You go back and redesign and do a ton of perspectives. The client says, "Don't do perspectives. I don't need perspectives." You do it because you think you need to do it. Sometimes a lot has to do with human communication. That's how I see it.

[Tape off]

Lake|Flato

Q: I would like to ask you a couple of questions about how the firm creates the design, especially, sustainable design. How BIM, IPD or integrated/multidisciplinary team and simulation affects the design process. Is your firm familiar with these 3 instances?

H: Yes,

Q: What is the hierarchical structure of the firm?

(0:44) H: We have two principals: David Lake and Ted Flato. We have six partners that are involved with the firm almost since the inception of the firm… we got started in 1984, so they joined shortly after. We have four associates [better] bellow that and everyone have their name so far and composes the group, so they make decisions about how the firm operates and things of that nature. From there on down, we have project managers, which, you know, is a pretty easily recognizable job title, [what] their roles and responsibilities are, and then there is project captaincy, and there is technical, and I guess, if you want to go bellow that, we always have a group of ventures here as well.

Q: Ok. Do you have some special divisions or people that are more involved with, let's say, commercial buildings, sustainable design…?

(1:45) H: Yes, there are some. We are organized by studios in the office, so some of the studios, for example, the second floor is mostly residential work, and we do a lot of residential work, I would say about 40% of our projects are residential. And yes, people tend to stay with one particular building type, but if you like to participate in something different, I mean, the firm is really the [minable] to do that as well, if you want to get experience in different project types.

Q: And the interaction between them?

H: We are three story office…

Q: So if you have some questions, it's easy to just get feedback from others.

(2:24) H: Yes, we are an open office structure, so we encourage people to walk around and in talk to the neighbors about different ideas, you know, the staircase can sometimes be a little bit of a barrier between forces depending on the type of personality you are… and I hate to say that, but it is true… I mean, sometimes, just going up and down the stairs can be enough so someone will feel lazy and not want to do it, but for me, and I think for most people in this firm it's kind of energizing just to get up from your desk and walk around and find out what other folks are working on.

Q: How would you summarize the overall design process for sustainable or high performance buildings… how does it start, how is the workflow in ake Flato?

(3:11) H: Ah, yeah, that's a good question. We actually, starting from last year we came up with our first shot at our roadmap or a project process for project teams to use as a tool whenever they are working through design, so that's the first time we ever tried to have some kind of a checklist for folks in the office as far as you are going phase by phase, you know, "I got to the end of SD (schematic design), what should I have done to this point?" So it involves a lot of sustainable considerations but it is also a lot of other stuff as well… for each phase, there is usually some kind of a EED checking that needs to happen or… ahh, we came up with this sustainability toolkit that has tools that you will use to think about water, energy, materials, so at each phase we will kind of have a little note saying "go to the toolkit and look at the protocol we have written for sizing your overhangs" for example, so that's how we are trying to infuse sustainable, so it's kind of top-down instead of bottom-up, but I feel we are doing sustainable well for a number of years with the bottom-up approach, so we are trying to take now all that knowledge and process and come up with empirical, you know, data and evidence of what we have figured out over the years…

Q: That's very interesting! What about this sustainability toolkit? It's like a software or just some standards or steps that you need to go through?

(4:57) H: It's a little bit of both… I mean, software is an over statement, but we do have some spreadsheets and there you can enter stuff and that it will give you results, so it's not sophisticated enough to be called software, but it is really just an adobe file. So it is setup as InDesign and we have a few different categories, so it is like climate analysis, orientation, energy, water, renewable, materials, glazing, so it is kind of organized more or less into LEED categories with a few extra things, so you click on each one there is a page that kind of tells you everything you need to know about glazing. So if you are selecting a piece of glass for your building, here are all the things you need to take into consideration. So it covers everything from energy performance to daylighting.

Q: And you try to apply this toolkit for every design?

(5:51) H: Yes… yeah.

Q: OK… that's cool! What about a combination of multiple disciplines? How many different consultants you usually interact with, or if they are mostly in-house? How is that dynamic?

(6:10) H: We try to collaborate with consultants as often as we can. I mean, we don't think that we are experts in everything, especially when it comes to sustainability so we can bring in, you know, a solar consultant, a mechanical consultant… we love to rely on their expertise, so I think we are pretty collaborative. I mean, everybody in this office is… their education is architecture background, except for administrative staff and me… I am a mechanical engineer by background but I by no means try to do any MEP design or things like that. So we are definitely architects and designers and we don't try to be any other kind of consultants…

Q: Wear different hats…

H: No, no… we have to hire mechanical, structural; you name it, consultants to make the project a good one.

Q: Under that structure of design workflow, when we talk about integrated design, you can also find some very formal agreements like the Integrated Project Delivery from the AIA, or something that is not as rigid. So what kind of contractual agreement Lake|Flato is more familiar with?

(7:32) H: The more conventional contract agreements… we probably have done by definition, one actual IPD project so far (finally, we found out that the client decided not to do the project with the formal IPD-the client finally decided for a format that is close in spirit with the AIA IPD but without sharing benefits and risks), I believe we are moving closer and closer to that but we do still have conventional contracts and conventional fees structure for the most part.

Q: And how would you compare the differences between the formal IPD and the more conventional agreement?

(7:58) H: I think we had a really positive experience with IPD. I think a lot of it has to do with, I mean, we would love to do a lot more of it, but it is definitely a client perception that we need to work on it. I think the design community needs to work on that. I mean, being able to communicate the value because I do feel that, you know, the chart of the EC about the effort vs. cost and that nice curve where it comes down… we didn't see that on our projects, you know… to say that most firms so far have not seen that, it's more… that's a lot here and doesn't taper down to exactly the low level that everybody would like to think it does, so there are more hours [span] working on these projects at the moment while we are getting familiar with them… maybe they will get more efficient as we move through them, but I do think that it is also producing a much greater value, I think we are getting a much better project, so THAT's what we need to work on, it's not so much convincing the client "oh, it's gonna cost less" because at the moment, it doesn't seem to be the case, but they are getting a better project.

Q: But would you still agree that the major efforts are put into earlier stages of design?

(9:12) H: definitely, definitely… and it does [inaudible]. I just don't think that the argument about costing less in the long run… again, we don't have as much experience as some other firms do, we would love to do more of them, we just aren't getting much of a demand for it, but the one we did it, it didn't cost less at the end, it didn't cost A OT more, but it didn't cost less, but we do think we did a better project.

Q: Do you have some stories to share about really good or really bad experiences working with an IPD process or an interdisciplinary team?

(9:51) H: ---------

Q: and talking about coordination, how important is in your opinion the use of BIM in the coordination of different specialists?

(10:42) H: I think it is incredibly important, I mean, I think it is the reason that we and so many other architectural firms have adopted them with the assumption that, you know, we expect that other disciplines will join them because, I mean, for you to get the full value of all the extra effort that we are putting into a BIM model I think that everybody has to be creating their own, and having them to work together.

Q: Have you perceived that some stakeholders are not really into BIM?

(11:26) H: Definitely, definitely… I mean, even in that project in particular, there is a lot of experience when the project doesn't work well together the way we model… is it compatible? It just requires constant communication…

Q: Interoperability problems?

(11:43) H: Yeah, definitely, definitely, is that what you are asking?

Q: Yes, just to see how fluid is the workflow… what kind of problems you have faced?

(11:55) H: You have to communicate constantly for it to be able to work. I mean, I think a lot of the Revit tools are getting more sophisticated now, so maybe it will be easier as the software becomes more intelligent, but at the moment, it requires a lot of communication.

Q: So you use Revit?

(12:10) H: uhum ("yes" with her head)…

Q: Do you use Navisworks for clash detection?

(12:16) H: No, we don't use Navisworks… yeah; I think we have a seat on it, we've tried it for things but we are not using it day and day out on projects.

Q: Do you think that adopting a green building rating system (LEED, BREEAM, Green Globes) does affect the general process of design?

(12:34) H: Sure… I definitely think it does… I think that, you know, a lot of what you hear about green building rating systems is a lot of clients and project teams will ask for it to be LEED equivalent instead of actually going through the rigorous process of getting it to be LEED. In my experience without it (LEED) is being that people just… since they are not hold accountable they might not necessarily do everything that is expected from them, so whenever you have the rigorous third party certification system it really holds people's feet to the fire makes them do what they said they were going to do. I think it just adds an extra level of rigor to the process…

Q: So do you perceive it as a positive thing?

(13:16) H: I do, yeah, absolutely.

Q: In general, so you think that sustainable design can be standardized? I mean, should best practices of sustainable design being collected into a recommended workflow and steps, similar to what you are doing here, but do you think that it could be widespread?

(13:38) H: Ahhhh, it depends on how standardized it is, you know, because we all know that for something to be truly sustainable it does need to be climate responsive, so we know that something that works really well in Texas is not going to work well in California. Another is project type, you know, what might work for one particular project might not work for another, so that's why I think LEED has been so successful… because it is truly just a framework and it is not prescribing the exact strategy that you have to employ to meet the credit, it's just an intent. It's an intent that gives you different options on how you can achieve them, but really at the end of the day, if you accomplish the ends, it doesn't matter what the means are. So that will be my only worry on the standardizing process, on how specifics it can be… does it allow you the flexibility that you will need for various project types, client desires, climate, if all of that was taken into consideration that will be an impressive undertaking!! (laughs), but at the moment I think that a loosen framework like EED… ahhh, I don't really see a "need" to have anything that is more standardized than that.

Q: Do you see all these green building rating systems as some kind of a standard guideline for sustainable design?

(14:56) H: Yeap, sure!

Q: In your opinion, how are design methods for sustainable architecture going to change in the future?

(15:05)H: Ah, they are always changing (laughs)… I feel like we are revisiting what we are doing all the time… we find out that some of the strategies or the products that we are using weren't as sustainable as we thought they were, so I think it is constantly evolving! It's absolutely going to change, it's gonna keep changing and if it doesn't, that it is not truly sustainable… we have to revisit it to make sure that we are in the cutting edge of what's best for our environment.

Q: And how do you do that?

(15:34) H Ahhh, constant research (laughs)… It's hard to stay, I mean, it's a full time job literally; I am a proof of it… to stay on top of all the products that are out there, all the strategies that are out there… but we have a really impressive network of people working on this stuff, so…

Q: Well, this firm is widely recommended as one of the top sustainable designers, but at the same time it is a small firm, compared with other big firms, so do you have people for instance, that are in charge of taking a look at what is the state of the art in design, and try somehow to apply this knowledge here, or train people?

(16:17) H: Ahh, that's probably more my charge than anything else, we do have a group in the office, it's called… well, the structure I told you about earlier with the principals, partners and associates it's kind of a [side load]… it's very vertical, so we had a consultant coming a few years ago and talked to us about marketing and our structure here and everything, and one of the really useful things they gave us was that we needed some horizontal cross-cutting entrance groups, and they called "BI "… they probably were trying to be kind of cute about it, you know, construction terminology… I don't love the name BI but it stuck (laughs), so we have a Technology BIM that looks at computer issues, [inaudible] software and things like that… we have a Design BI t hat gets really into detailing and things like that and then Green BIM that does sustainability around the office and projects, etc., so there is more BI 's than just that, but that is just a few examples… but the Green BI , t hat group collaborate with me to make sure that all the ideas that we have in the office are going to be executed, so that way is not just me by myself but I have a little sub-committee that kind of help me with it. So that's our internal way to get things done, and externally, you know, being a member of the USGBC, AIA's committee on the environment, and I am also a part of the network of "Sustainable Design eaders" and it is this sustainability director or whatever your job title might be for each of 50 firms around the country. So I collaborate with that group, to kind of share what we are doing and what we are struggling with, so that is immensely helpful too. Finding out what other firms are doing and looking at is helpful too to make sure we are in the cutting-edge.

Q: OK… How would you say is the function and purpose of (1) BI , (2) integrated project design. How would you describe the function of those?

H: The firms in terms of… I am sorry; ask the question one more time?

Q: In other words, why Lake|Flato adopted BIM, and why Lake|Flato adopted integrated design?

(18:40) H: well, I will answer BIM first, because that one I feel like we have 100% made a firm commitment to… IPD I am not sure if we made the same commitment to that… But BI , t he reason we decided to, is we just believed that is where the market is going. We think that it is one of the greatest values to our clients and it is a greater value to us. It makes a lot more sense in the way we are modeling, but we believe that is the way the market is going, and if we were not going to adopt it we will just gonna be left behind, so we decided to stay on the cutting-edge and become one of the first, I mean, we were one of the smaller firms, but we were one of the first firms to adopt it firm wide and made a 100% commitment to it.

Q: And what would you say are the benefits of adopting BIM, compared to a standard CAD process?

(19:30) H: Ah, (pause to think) I think the 3D views are really beneficial for us, I think it allows us to communicate ideas to our clients more easily, and it allows us to put a lot more detail and information into our models which is a great value, especially if we are going back into looking at our projects, so maybe the project team, we may have members that left the firm, so it allows us to look at later. And I think, most importantly though is that provides more value to the client. I mean, the client now has a lot more information at their fingertips about the building, so I think that is the greatest value.

Q: And does the client have a copy of the model later as soon as the project is finished?

(20:19) H: That's our goal right now, at the moment we are probably not building enough into our BIM models for that to be the greatest value, but sure, I think that when we have University clients, they have a facilities group and they want to find out what model HVAC system they have and how to change a part in it…

Q: So they are requiring that now?

I: People are starting to ask for, yeah…

Q: That's interesting… Usually, when you have these integrated design meetings, how often do you get together? I guess it varies depending on the type of project…

(20:57) H: It does, it does… and again, we don't have, you know, a huge amount of experience with it, but the one that we did that was a true IPD project [again, finally it was not a truly IPD], we had teleconference weekly, and e-mails and other individual phone calls were constant, but we did have a formal sit down, we knew every Tuesday at 10am we had a conference call where we all get together.

Q: At distance, using Skype?

(21:22) H: Right, right… I think we got a system called dumdum actually, but we will project the Revit model on the screen and talk about it "OK, this is what we've done, and this is what you've done, and these are the issues that we are having… let's work through it for the next hour…"

Q: And it worked well?

(21:37) H: Yeah, and we had face to face meetings on a roughly monthly basis while things were going quickly. They were [last off] after a while, but we have other projects that maybe assumes some semblance of IPD but they weren't a formal IPD project, and those probably roughly falls into the same format that I just described.

Q: And when you have face to face meetings, the format for exchanging information, apart from the BIM model are printouts, physical models, or something else?

(22:10) H: Well, yeah, in the face to face meetings, sure, we will have all of those things and we are discussing a lot more with the BIM at those meetings.

Q: Would you say that the involvement of the client into the project is always beneficial?

(22:30) H: I think it is more beneficial than not. I think, I mean, there are of course plenty of experiences where depending on the client's background and preferences it could get in the way of maybe the best decision for the project, but I think it's great to have the client involved in sustainability decisions, design decisions, as long as we can still provide some level of expertise and do what we are hired to do. I think it's great to have the client involved!

Q: Can you tell me of some challenges that you have addressed under an integrated project design that you feel you could not be able to address without the feedback of all the different stakeholders?

(23:17) H: Sure! I think that the best decisions are always made in a collaborative environment.

Q: In some cases, one member or more members of the team are required more often to solve some problems, let's say, someone who is a champion on BI , or knows a lot about information technology, or sustainability issues… Do you have here in Lake|Flato one member that is required very often to solve different kind of problems?

(23:55) H: With BIM specifically?

Q: Or sustainable design?

(24:00) H: Yeah, I will be the one that does, I mean; I am the sustainability coordinator, so anything about sustainability will go through me and it might be somebody else that is actually doing their [inaudible] work on it, but I am kind of overseeing the management and all of that. We also have a digital… I can't remember his job title now, but it's like a digital coordinator or digital manager, but he basically is our BIM person, or any other technical program or software program, and he oversees all of that.

Q: And do you think that you both have been requested more and more every day (laughs)?

(24:31) H: Definitely, definitely, and we do have kind of like a… pretty conventionally, in terms of what he does on a day to day basis and we have an IT person as well, so but we all work together to solve problems…

Q: Do you use simulation? What kind of simulation? In what stages of design do you implement them?

(24:56) H: Sure, sure… we do energy modeling and energy simulation if that's what you are asking… We, unfortunately right now, I don't think that any of the Revit or Autodesk products export from Revit in an accurate fashion, say that you can export your model from Revit into a GBXml format, and you can import them into software packages like Ecotect and things like that… we found that that export/import process is not very good, you lose a lot of information that you build into your model, so you end up having to rebuild your model anyway, which is kind of frustrating, but I think that's something Autodesk is working on right now, which is great. SO at the moment, the software packages that we really enjoy using, I think Green Building Studio is pretty good, we really like that… it's good for comparisons, even when the model that you have imported might not be very accurate, maybe you don't trust the utility bill estimation (laughs), but what you can do is to send a building A and then you remove some glazing and send the building B and see what impact that makes… a percentage difference.

Q: To test the "what if"?

(26:12) H: I think it is pretty helpful for that… but otherwise we are using eQUEST for commercial buildings and multifamily, and then we are using REM rate (residential energy model rate), so that's the energy modeling program that EPA and Energy Star program uses, LEED for homes uses it. Before I started working here, I was a residential energy consultant [inaudible] so that's a software that I was trained on, so I still use that a lot too… so these three packages are mainly what we use here, and we are always looking for other things…

Q: But usually you implement those tools at early stages of design or also for final?

H: Yeah, as early as possible… both… but I think that earlier phase modeling has a much more of an impact then the later on down the road, but yeah, the idea is that before pens on that paper I have done some kind of a box modeling just to see roughly what mass and orientation makes the most sense for a giving climate and that given building type. And somewhere at a slighter later phase, I will start to do some [influence??] model, so we will look at different materials and see which envelope assembly makes the most sense, and then I will continue to refine it. So usually I am meeting with project teams on a monthly or bi-monthly basis to revisit the model and then make any updates they made to the design, so then they can understand what impact it's made.

Q: Have you seen that some of the projects that you have designed, the outcome finally was different than expected?

(28:10) H: Oh yeah, definitely… all of them (laughs)…

Q: For better or for worse?

(28:12) H: Both (laughs)… usually worse, unfortunately (laughs)

Q: laughs

(28:15) H: But yeah, it's never exactly as you modeled, but I have actually three projects that have performed a lot better than modeled, so that's great, but yeah, that's usually from a slightly to a lot worse, and that all has to do with how people move into the building. But it is really educational for me every time, because it teaches me something new about an assumption that I should have made in the model but I didn't, and it just makes me that much better on the next models.

Q: Usually, when you start a project, come people start with some an intuition on how the project will behave, and other people start right from the beginning testing different alternatives of design… How do you think this firm approaches design?

(29:13) H: It was intuitive since 1984 and it wasn't until I got here, that [we] have any kind of a trust worthy tool to test assumptions, so that's been a pretty radical change I think for most folks here in the way they design, I think there are even a few designers in here that were resistant to that… because their intuition and their educational background told them one thing and then… I mean, I figure out something new and surprising every time that I run a model…

Q: laughs…

(29:43) H: I found out that things that I assumed work, don't, so it's a learning experience every time. Buildings are really complex… So now we are trying to implement that change and trying to get people to work on a way that's more about testing iteratively different scenarios and what results it might get, so I wouldn't say that we have been totally successful in the three years that I have been here to have everyone thinking that way, but it is starting to [premiere]… I think people are becoming to be a lot more receptive to it and it is becoming a lot more natural for people to think that way! It's just really hard to change the way people are used to working.

Q: I think it is funny to see that people have to accept that their intuition was wrong!

(30:38) H: It's hard! (laughs)… It's hard for me too… I mean, I have people come to my desk and ask questions about, you know, "what do you think? should I do this, and this, and this…" and they want a quick answer, and I try not to make quick guesses like that, because I have been wrong on so many times, but in a situation where I do, I always make the quick answer and then I go back and test it, and I can't tell you how many times I had to come back to their desk and say "you know, what I just told you is inaccurate, and here is why" so it is really important to just keep testing what you think, because (1) while you model, the faster it becomes so it is not really this cumbersome process anymore, but (2) if you just keep designing like you always have, you are not pushing yourself.

Q: Thank you very much for your time!

Continuation of interview- Skype

Q: One of the reasons for adopting BIM was that it can bring a greater value to the client. How would you define that greater value?

H: Just our ability to deliver more information about the project in a really succinct way. I think that this is useful for building owners, operators and facilities to be able to have one central file where all the information is held, and it is a better repository for storing all the information rather than having a folder scatter to our servers, a consultant folder, you know, it's kind of having one central hub for everything so we know where to find the most accurate information.

Q: You told me that you have had one project under the formal IPD process, and that normally you have your own integrated project environment or conditions that work for most of your projects. Can you elaborate a little more on how exactly are those conditions?

H: Well, it doesn't follow the text definition of IPD but we do try to be more collaborative, more front loaded in the way that we think about our designs, I mean, one good example is what we have been doing with energy modeling and things like that… those kind of analysis earlier in the project rather than waiting until the end, but I would say that we strive for a process to more closely resemble the conventional definition of IPD… it's just different than what most clients and most project teams are used to work in like, so it's a work in progress.

Q: What would you say are the most complex aspects of the normal IPD to be adopted or incorporated widely?

H: I definitely think that is getting the client on board, and communicating the value to the client, so that is something that is demanded. I tell you at this point, it's kind of a [inaudible] battle trying to convince the client that this is a good idea for their projects.

Q: You also talked about a project that exceeded the initial expectations. Can you talk more about that particular project?

H: Well, I don't know exactly what project do you refer when we talked about, but that has happened a few times… It all has to do with how you are simulating the building… there are a lot of assumptions you made in terms of lighting and appliances, which tends to be the most variable, you know, if you don't know much about the client and their energy use habits, it's really hard to make an estimate about light and appliances, so typically that's the arena where we will find that we either overshot or undershot on energy estimates. And traditionally also, we found that the model underestimates photovoltaic production, so when we work with a project that has renewable energy installed, usually the PV performs a little bit better than we expected to.

Q: Well, probably because by the time the software was developed, the PV systems weren't as good as they are today.

H: Right, it does seem to be not consistent among energy modeling software that it never model quite as well as it actually performs.

Q: When you simulate PV panels, what software do you use for that?

H: Is the same ones that I mentioned when we met on Wednesday: REM, eQUEST… are you talking about actually sizing the PV system itself, or for modeling energy use?

Q: Yes (sizing)…

H: For sizing the PV system itself, we don't get too far into that, we prefer to use a solar consultant to help us with that process… pvwatts.org is a really simple calculator so we kind of use that to get a rough estimate, and we have been actually creating spreadsheets where we catalog all the different light appliances, I mean, every load in the house get our run watts estimate for that, and we submit all of that to the solar consultant and they interpret that.

Q: In the survey you mentioned that you have used BEES and Athena for CC/ CA…

H: We also use Baseline Green…

Q: What was the impact in the final design, if any, after using these tools?

H: Yeah, we definitely… when making a material selection we certainly look at operational energy use and weight that against life cycle assessment, how much energy does it take to produce it, so I think we weight all the impact of those things when we are making material selections.

Q: In the survey you also mentioned that not all of the project team members are using BIM yet. You also said that Lake|Flato has some BIM training protocols, so for the training protocols, you train one people at a time or is it like a group of people?

H: Every time we get a new employee we train them, so that can be one at a time. It does happen right now that we are hiring a group of three people at once so they will all be doing it together… I think that 99% of the firm is using BI at this point. The only people that aren't are… (laughs)… I don't know how to say this diplomatically… but it's kind of the older folks in the firm, partners, and some of them have them open to learning a new software but the rest of them, just kind of feel they hit a point in their career where they are not ready to ramp up and learn a new software (laughs) … but that being said, they are minable to using it, they are just not the ones that actually design it in Revit.

Q: In the survey you also mentioned that BIM Standards were used. Are you using all of them or some of them?

H: We developed our own similar to what I did with the sustainability toolkit. The office has its own BI st andards that we developed… I know that they used the existent BI st andards out there as a basis for that but I wouldn't be able to tell you specifically which ones.

Q: Should I ask Phillip Chan?

H: Yes, he is our digital coordinator and takes care of all that.

Interview with partner (e-mail)

Dear sir,

My name is Francisco Farías and I am a PhD candidate at Texas A&M University, and the title of my dissertation is "Strategies for sustainable design using Building Information Modeling (BIM, Integrated Project Delivery (IPD) and simulation".

Your sustainability coordinator suggested me to contact you to ask about some specific issues about Integrated Project Delivery (IPD) or integrated design, so I hope you don't mind helping me on this. The questions I have are:

_ Can you give an example of the common integrated design environment in Lake|Flato, regarding to legal agreements? In other words, what are the differences from a formal IPD process (shared risks/benefits, liability agreements, etc.)?

_ I have been told that Lake|Flato have used IPD before in one project. What contract agreements were used in that specific project?

_ What do you think about the engagement level of the design team and the owner in the process?

_ Is there any aspect that you think could be better planned or improved?

_ What would you say are the main reasons for not using a formal IPD agreement in most of the projects?

Please let me know if you have any questions, and I appreciate in advance your invaluable help.

Francisco,

Attached is signed form. I don't know if you and Heather discussed, but Lake|Flato has not done a project using IPD or BIM (we do most of our drawing in Revit, except for construction details (which are 2D because of the limitations of Revit) but hardly have "working" knowledge of the process from concept through construction.)

We've had a few clients bring a project, saying they wanted us to use IPD or BIM, but either the project did not move forward or the client changed their mind. I've reviewed AIA and Consensus Docs IPD agreements (and felt neither were very good, because they essentially relied on the Owner, Architect and Contractor 'trusting' each other (which sounds good, as long as no one goes to court.) Other than that opinion, I can't say I'm knowledgeable enough about them to give a very good interview.

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Reply
Francisco,

Thank you for contacting Lake|Flato and we'll try to help as much as we can, but have not done an IPD project as of yet (the project she referred to started out with the Owner wanting to do IPD, but decided against it (and we never fully understood why)). We've had another Owner propose using the IDP but the project was been put on hold pending funding - neither project got to the contract stage.

As for the contracts (which I handle within the office), I've reviewed the AIA and ConsensusDocs contracts (have not seen one from EJCDC and don't know that one exists, but expect it does.) In general (and in my opinion), the contracts need some work, as they seem short on reality as to the way the construction industry (as we've experienced it) really works. Logistically, sharing the model with the Contractor is not an issue, but the shared responsibility/liability between the three parties will have to be more clearly spelled out.

I've no doubt that we will do a IDP project in the future and imagine one the standard contracts will serve as a template for the agreement but also expect quite a bit of revised language. I do not anticipate a brand new agreement would be written from scratch, even though the lawyers would no doubt love doing so.

We probably are not providing you with all the information you had hoped for, but until we go through the complete process there is not much more we can provide.

Thank you for your inquiry. If you would like to discuss further we can certainly do so.

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Partner's phone interview

Q: I was reading your answers and I think it is quite interesting the fact that you have revised the AIA IPD and also ConsensusDocs documents and contracts, but they should pass some reality check…

K: Yes, I just don't think… well, we have a professional relationship with the member senior manager of the computer company that is all over the country, and he happen to be in town in a convention or something one day, and came in and gave several other presentations on… he built the building on each cost: west cost and east cost, using the IDP process. It apparently went well, he was just kind of telling his experiences and that kind of thing, and all along it looked good, it sounded good, we talked about this and that and at the very end of that we asked him "OK, what is [worth] to look at when you are using integrated process delivery?"and he said "you need to know the contractor really, really well, and you shouldn't work before with somebody you can't trust "… and I thought: OK… in the real world, we rarely work with the same contractor twice… it's very rare, so if this is an issue for the integrated project delivery working, that's problematic, because contractors aren't there every day, I mean, they have to go to projects and give bits… that didn't speak well of the process, so, that's what I mean. Essentially, you know, the three parties are signing on a bottom line that they actually trust and believe in each other. The way construction goes, yeah! You professionally trust somebody, but the profits which you are going to make in this building with the idiosyncrasies of another owner which you don't know, and the contractor that you probably don't know. And they don't know us! You know? (laughs), so it is a question… it's a real puzzle that we will have to work on… Basically, just setting up the drawings so the contractor can review and take off's and stuff is not a big deal, it's the wording of how those three parties will all work…

Q: So would you say that it's easier when the designer, the contractor and the owner know each other from previous experiences?

K: Well, it could be, but just in general construction, you know… out there, there are owners who have the contractor they work with all the time, they have a working relationship. And that leads to the application that: OK, if things aren't going well with the architect, the contractor just go over and tells the owner, this and that, and that… because I know each other… so that may not work as well, and I have seen that happen on projects. You know, the contractor goes around us and it is not supposed to talk with the owner directly as far as construction issues and they all do it, they go and talk with them. And it can lead to an enormous amount of problems. The real potential is that the contractor commits to the owner, we screwed up on something, it wasn't his fault, and the owner believes so. We had that happen. That's what I mean about the reality of the construction, that's the way real construction works… I am skeptical… not having done one, I am naturally skeptical about it, I mean, several years ago, I don't know if you are familiar with it, but this whole design-build thing, which still exists in the world, that the architect works as the designer and contractor. There were certain universities in Texas that committed to it… that was the only way they wanted to build their buildings. And they figured out that when the architect works as the contractor, the dollars define the architecture, and the contractor can deal with the architect whatever the building is going to cost, you know, as they are developing the drawings, the architect is completely under the thumb of the contractor as far as process is concern. And he can come in and say "well, you know, it turns out we can't do this copper siding… you will have to change all your drawings…" it shouldn't be a big deal but if that's not what he's been telling us for the past six months where we have been developing our drawings to get up to CD, that's a little hard to swallow… And some of these public universities found that, that they have been abandoned in the idea of design-build. You know, it is not too dissimilar that this situation, where the architect and the contractor is going to believe in one another to work very closely. In that situation, the bottom line is the dollars. I can tell you about a project we finished just recently where we had our contractor [all on all] was giving its pricing while we developed the drawings, and it turned out that when we finished the CD's he actually sent out for a pricing, he was just doing an in-house estimation and the project came to me in dollars high! And it was our fault to the owner's eyes, when the true was that the contractor hasn't being doing what it's supposed to do. So everybody was pissed off and nobody wanted to listen to one another. That kind of stuff happens, you know? It really is a big deal, and being a firm such as Lake|Flato, where the design is really a paramount thing to us, it doesn't mean we spend money [inaudible]… we really care about every aspect of the building, and if the contractor can't give us straight forward numbers, there is no word for us to go. That's an issue. That's the reason why I am so skeptical. I just don't know, and I haven't talked to anybody who's really gone through a complete IPD as the contract states the word is.

Q: But does Lake|Flato have one type of contract format that is used in most of the projects, or it varies a lot between one project and the other?

(6:53) K: Well, most of the contracts we see out there and they very rarely will see owner oriented contracts, owner originated contracts… actually we use AIA contracts. Most of them are built around AIA contracts, and we prefer them. There are fewer different owner contracts, and the thing I like about those is that those are all governed by another document: the AIA A201 General Conditions. It lays out the roles of the three parties and their responsibilities.

Q: What do you think about the engagement level of the design team and the owner in the process?

Is there any aspect that you think could be better planned or improved?

K: I think that if you have a fairly experienced and reasonable contractor and a fairly reasonable and experienced owner the process goes well using AIA contracts and traditional methods… You are working with people… Contracts may define the way the world exists but the world doesn't exist like that because you are dealing with personalities and attitudes. I mean, as far as I working with the owners we are very engaged with them, we have a lot of meetings with the owner. You know, we don't do malls, we have done some healthcare facilities but those are always in that capacity hooked up with a larger firm that will deal with the architectural record who knows all the infrastructure that is required for healthcare facilities and hospitals. That is very technical and we don't know and we can't afford or make any money on the project… we are not really interested… you know, typically, we will do like we are doing now, a research laboratory, and we will team up with a firm who knows all that kinds of thing intimately. We are involved in the design of the building, we generated the plans, we were dealing with the exterior of the building, we were dealing with the public spaces and that kind of stuff… they were dealing with all the infrastructure of the laboratory and how they work… because I know all that, and they just give all to us, you know? We kind of developed the plans, we give them the kind of the shell for the building, we think how the public spaces are going to be and they fill in all the interior spaces with all the very technical laboratory stuff. Those work real well… But there are certain kind of buildings we don't do because economically we can't afford to, and there are firm that can do it every day and can do a whole lot faster and better, and it is the kind of buildings we may not be interested in, so it is hard for us to justify why to spend that kind of time in it. And that's a big, kind of an old preaching thing while I am speaking because I am talking about some very specific building types that Lake|Flato finds we do well, you know, and we enjoy doing it.

Q: It's been interesting to know that ake|Flato has been involved with other designers working for those very complex building types and that it worked well… That talks very highly about the firm and the commitment not only to do sustainable design within the firm, but also outside of the firm.

(13:45) K: I mean, even five or six years ago, and definitely 10 years ago, I think we were the only people staying on the street corner preaching sustainability. A lot of the public and the owner did not understand it. There was a whole thing that comes down that still exists out there, you know: " EED buildings are more expensive" and we are finding that a lot of firms now don't buy it anymore, and it is making it a lot easier to work with people. And it is true for contractor and owners… so people are still getting educated about it, believe it or not. And that's another issue with the IPD projects, that we don't have, at least in San Antonio I don't know if we have any contractor who is even aware of it, or done it. A lot of them are aware of it but they have never done it, they are excited, they want to do that kind of thing. I think a lot of that is because of the region… particularly in the [spin] of the south, moves are a little slower and it takes a while for things to get down in this part of the country. You see it on the east and west coast, and a lot of that is true. I have never done it, but if you go back and track the amount of LEED buildings that we built, I guarantee that the south stands behind those who have been built on the coast, just because it took a little while for the knowledge to get down here. And that's one of the reasons we go to coasts: to work out of the state, out of the south! Because it is a learning process, you know? We are working on a project for the UTSA right now that requires complying with LEED because it is a state mandate, which I think it's wonderful! We celebrate it! EED is a problematic issue right now because of the silly paperwork that is involved to document it It's really not very user friendly, and you have to almost hire a special person just to do that. We have a sustainability coordinator in office, Heather Holdridge, who you spoke with, and Heather had done a mass ball of paperwork, it just takes too much time to track all that junk, so it is cheaper to hire somebody to do it than to pay you to do it.

Technical BIM Interview

Dear sir,

My name is Francisco Farías and I am a Ph.D. candidate at Texas A&M University, and the title of my dissertation is "Strategies for sustainable design using Building Information Modeling (BIM), Integrated Project Delivery (IPD) and simulation".

Your sustainability coordinator suggested me to contact you to ask about some specific issues about the use of BIM and software in Lake|Flato, so I hope you don't mind helping me on this. The six questions I have are:

1_ I heard that Lake|Flato have used BIM for code checking. How have you used BIM for building codes checking or compliance? Can you please elaborate on this?

I believe we have not used BIM for building code checking at this point since building official we are working with have not adopted the technology yet. I have read about some states are planning on adopting this as alternative for plan checking/building permit review process. But it seems like this is still an infancy stage at this point because of many liability issues.

2_ I would like to ask also how you have used BIM for construction coordination, quantification/estimation, procurement, and parametric modeling? Can you give me some examples of each, especially in parametric modeling?

There are more inquiries recently that the general contractor initiates the use of our model for certain aspects of construction coordination, sequence and cost estimate. There are a number of projects under design phase now that we will collaborate with GC for that scope of works. In terms of parametric modeling, I don't think we have used those with GC.

3_ What BIM standards or protocols are you using (NBIMS, LOD, IDM, etc.)?

One of the projects that we are working on with GSA will be governed by "GSA standard".

4_ How is the quality control on BIM monitored?

Can you clarify these questions?
The question "How is the quality control on BIM monitored?" refers to how the BIM model is controlled and overviewed. For instance, did someone have to look back at the BIM model to verify that the level of detail is appropriate before sending it to a GC or a MEP?

I personally have not done any quality control of the BIM model for this purpose, but I consider this is a collaborative process between two or more parties who are involved in this model. In other words, there should be someone from each party to be in charge of overseeing this process.

Also, there are some BIM standards developed by the National BIM Standard (www.wbdg.org/bim/nbims.php, www.buildingsmartalliance.org/index.php/nbims) which deals with some specifications on how to model for a particular purpose. Do you use some of these to approach modeling in BIM at Lake|Flato, besides the GSA Standard?

To further answer this question, we have in the process of re-ramping some of the standard within Lake|Flato that are similar to many other Arch firms as well as NBIM standard. It really comes down to the project type of our building. The big picture is to have a similar standard that is close to what everyone is familiar with.

5_ Is there any training protocol?

Training now is through in-house. Depending on the type of project one is working on, special training will be needed for those who work on a more specific project (for example on a GSA project). Since our project types are quite diversified, each user is equipped with different skill-set to work on those projects.

6_ What would you say are the most problematic issues for the transfer/workflow from a BIM environment to an energy simulation environment? Can you please elaborate on this issue?

Although there are many software in the market now that can claim to do any energy simulation, they are either too difficult to use (which require one to have a deep understanding on the program) or the one that are more user friendly (which lacks the accuracy). Autodesk has invested a lot of time on making this work, but I think there are still a lot of rooms for improvement in the future.

APPENDIX 2

IRB Documents

Consent Form:

Strategies for Sustainable Design using Building Information Modeling, Simulation and Integrated Project Delivery

Introduction

The purpose of this form is to provide you with information that may affect your decision as to whether or not to participate in this study. If you decide to participate in this study, this form will also be used to record your consent.

You have been asked to participate in a research project studying the influence and impact of three instances in sustainable/high performance building design practices. The three instances are identified as Integrated Project Delivery (IPD) (or integrated design process), Building Information Model (BIM) and simulation (testing of design alternatives). The purpose of this study is to examine the design workflow used in design firms that have different conditions and budgets. You were selected to be a possible participant because of your commitment to sustainable design, and because your firm has been identified in the press as one of the most significant in the field of sustainable design.

What will I be asked to do?

If you agree to participate in this study, you will be asked to describe in an interview your experiences and perceptions about the process of design using the three identified instances (if applicable). The questions are related to the general process of sustainable design. The interview has an expected duration of 30 minutes to one hour. Your participation will be audio recorded, and if you agree, video recorded as well.

This study may lead to a follow-up interview that can be done via Skype or e-mail, and you may be asked to refer other employees of your firm to fill out a brief questionnaire about specific and technical aspects of design.

What are the risks involved in this study?

The risks associated in this study are minimal, and are not greater than risks ordinarily encountered in daily life.

What are the possible benefits of this study?

You will receive no direct benefit from participating in this study, other than contributing to research in sustainable design.

Do I have to participate?

No. Your participation is voluntary. You may decide not to participate or to withdraw at any time without your current or future relations with Texas A&M University being affected.

Who will know about my participation in this research study?

The records of this study will be kept private. No identifiers linking you to this study will be included in any sort of report that might be published. Research records will be stored securely and only the researcher will have access to the records.

If you choose to participate in this study, you will be audio recorded, and if you agree, video recorded as well. Any audio/video recordings will be stored securely and only the researcher will have access to the recordings. Any recordings will be kept for 12 months and then erased.

Whom do I contact with questions about the research?

If you have questions regarding this study, you may contact Francisco Farías, +1(979) 422-6986, email es-1251957@neo.tamu.edu.

Whom do I contact about my rights as a research participant?

This research study has been reviewed by the Human Subjects' Protection Program and/or the Institutional Review Board at Texas A&M University. For research-related problems or questions regarding your rights as a research participant, you can contact these offices at (979) 458-4067 or irb@tamu.edu.

Signature

Please be sure you have read the above information, asked any questions you may have and received answers to your satisfaction. You will be given a copy of the consent form for your records. By signing this document, you consent to participate in this study.

______ I agree to be audio recorded.

______ I agree to be video recorded.

______ I do not want to be audio or video recorded.

Signature of Participant: ___________________________________

Date: ______________

Printed Name:

____

Signature of Person Obtaining Consent:___________________________

Date: ______________

Printed Name: Francisco Farías____

Attachment to Expedited Review Application

Interview Schedule

Firm Organization

1. What is the hierarchical structure of your firm (divisions, departments, etc)?
2. How do they interact with each other?

Process

3. How would you summarize the overall sustainable design process in your firm?
4. What combination of design techniques or approaches has helped your design team in sustainable projects? You can think about multidisciplinary work, use of technology, etc?

Note: in case the interviewee do not include BIM, IPD or simulation in his/her answer, use as a probe "some firms rely more on technology to help them in design - BIM/IPD/simulation, while others firms rely more on their past experiences, or cultural issues, budget issues, etc… does your firm fit in any of these categories?"
If **YES** for combining techniques, go from 5 to16. If **NO** combination is used, go from 17 to 20.

---

5. What would you say about the **best** experiences you have had by combining BIM, IPD and/or simulation (pick the instances according to the answers)?
6. What would you say about the **worst** experiences you have had by combining BIM, IPD and/or simulation (pick the instances according to the answers)?
7. In your experience, how important is IPD (or integrated design, if applicable) in a sustainable design process?
8. Do you have some examples?
9. In your experience, how important is BIM (if applicable) in a sustainable design process?
10. Do you have some examples?

11. In your experience, how important is simulation (if applicable) in a sustainable design process?

12. Do you have some examples?

13. Does adopting any particular green building rating system (LEED, Green Globes, etc) affect the general design decision process, or affect the definition of high performance building goals?

14. In general, should best practices of sustainable design be collected into a recommended process and workflow? In other words, do you think this process can be standardized?

15. In your opinion, how are design methods for sustainable architecture going to change in the future (or other disciplines)?

16. And how do you think your firms and firms in general could prepare to face this challenge?

---

17. Does adopting any particular green building rating system (LEED, Green Globes, etc) affect the general design decision process, or affect the definition of high performance building goals?

18. In your opinion, in general, should best practices of sustainable design be collected into a recommended process and workflow? In other words, do you think this process can be standardized?

19. In your opinion, how are design methods for sustainable architecture going to change in the future (or other disciplines)?

20. And how do you think your firms and firms in general could prepare to face this challenge?

IPD (use "integrated design approach" as an alternative when not using IPD)

1. Is your firm currently using IPD or an integrated design approach?

If **YES** for IPD, go from 2 to 11. If **NO** IPD is used, go from 12 to 19.

---

2. What is the purpose and function of IPD (or integrated design) in your design workflow?
3. How is the workflow between the discussions and the decision making process?
4. In average, how often you have group meetings (weekly, monthly)?
5. (ONLY IF IPD): In your opinion, while defining the IPD team responsibilities (liability and shared benefits/ risks), what have been the most difficult legal issues to deal with?
6. During the meetings, stakeholders can exchange 3D geometry, cost estimation, schedules, etc. In your experience, what kind of information was exchanged or shared, and how?
7. The adoption of IPD (or integrated design) can be driven by regulation requirements, intention of being up to date, accelerate delivery processes or for better coordination of construction documentation, etc. What has been your personal experience?
8. How would you describe the involvement of the owner into the design process? Was it beneficial or not?
9. Can you share some stories about how IPD (or integrated design) outcomes were different than expected?
10. Is there any new adventure/challenge addressed under an IPD (or integrated design) process that you could not do in your regular design environment?
11. In some cases, one (or more) member(s) of the team can be requested more frequently to solve particular problems during the design process. It can be related to technical aspects of the building design, or even to Information Technology (IT) issues. Have you experienced a similar case?

If **YES**, please elaborate… how often does this happen? If **NO**: Stop.

12. How is the workflow between the discussions and the decision making process?
13. In average, how often you have group meetings (weekly, monthly)?
14. During design meetings with other specialists, designers exchange 3D geometry, cost estimation, schedules, etc. According to your experience, what kind of relevant information was exchanged or shared, and how (digital file, what files/formats, printouts)?
15. How would you describe the involvement of the owner into the design process? Was it beneficial or not?
16. Can you share some stories about how design outcomes were different than expected?
17. Is there any new adventure/challenge addressed in your design process that you could not do in your regular design environment?
18. In some cases, one (or more) member(s) of the team can be requested more frequently to solve particular problems during the design process. It can be related to technical aspects of the building design, or even to Information Technology (IT) issues. Have you experienced a similar case?
19. If **YES**, please elaborate… how often does this happen? If **NO**: Stop.

BIM

1. Does anyone in your firm use or have used Building Information Modeling (BIM)?

If **YES**, keep going. If **NO**, go from 27 to 34.

---

2. What is the purpose and function of BIM in your firm?
3. Some firms use BIM for programming analysis, for initial cost estimation, for earlier simulation and testing of design alternatives' performance, building code

checker, down to construction management and facility management. How would you describe your firm's involvement with BIM?

4. Those BIM tools can be implemented in different design stages, so in what design phase have you implemented BIM? (give example of different stage implementations

5. Do you have a formal BIM manager or even someone that is informally in charge of the overall BIM process in your firm?

If **YES**, keep going. If **NO**, go from 16 to 26.

---

6. Do you know what functions associated with BIM that person fulfills?

7. Does your staff receive formal training on using BIM tools?

If **YES**, go keep going. If **NO**, go from 14 to 15.

---

8. How?

9. What experiences can you share about the benefits/costs of using BIM?

10. Is there any way you use BIM that was not originally expected?

11. Can you point out a problem in BIM that appears frequently in your design workflow?

IF **YES**, go from 12 to 13. If **NO**, stop.

---

12. How did you overcome those problems?

13. How does your firm store and exchange data (external server, internal server and hard drive)?

14. Do you plan on implementing formal training to improve your staff's knowledge and skills?

15. How does your firm store and exchange data (external server, internal server and hard drive)?

---

16. Does your staff receive formal training on using CAD tools?

IF **YES**, go from 17 to 19. If **NO**, go from 22 to 26.

---

17. How?

18. Is there any way you use CAD that was not originally expected?

19. Can you point out a problem in CAD that appears frequently in your design workflow?

IF **YES**, go to 20. If **NO**, go to 21.

---

20. How did you overcome those problems?

21. How does your firm store and exchange data (external server, internal server and hard drive)?

---

22. Do you plan to implement training sessions to update/improve the current staff's knowledge?

23. Is there any way you use CAD that was not originally expected?

24. Can you point out a problem in CAD that appears frequently in your design workflow?

IF **YES**, go to 25. If **NO**, go to 26.

---

25. How did you overcome those problems?

26. How does your firm store and exchange data (external server, internal server and hard drive)?

---

27. Have anyone in your firm or outside consultants, such as external architects or engineers, used BIM for some of the projects in your firm?

IF **YES**, go from 28 to 33. If **NO**, go to 34.

---

28. What was the purpose and function of BIM for your own design process in that (those) projects?

29. Some firms use BIM for programming analysis, for initial cost estimation, for earlier simulation and testing of design alternatives' performance, building code checker, down to construction management and facility management. How would you describe your firm's involvement with BIM?

30. Those BIM tools can be implemented in different design stages, so in what design phase have you implemented BIM? (give example of different stage implementations)

31. What experiences can you share about the benefits/costs of using BIM?

32. Do you have or plan to implement training sessions to update/improve the current staff's knowledge?

33. How does your firm store and exchange data (external server, internal server and hard drive)?

---

34. Do you have plans to implement BIM in the future?

Simulation

1. Envelope design, daylighting, mechanical systems and renewable energy are some of the aspects of sustainable design that are usually taken into account. In your experience, what aspects of design had affected the most in the final performance of the building?

2. Do you have some examples?

3. Did your design as constructed perform differently than predicted?

4. Does your firm use simulation?

IF **YES**, go from 5 to 8. If **NO**, go to 9.

---

5. The translation of geometry from a BIM model (or CAD) to any simulation model is often considered as a critical and costly part of the process. How is the procedure in your case?

6. How do you overcome the difficulties of getting data from BIM (or CAD) to simulation models?

7. Can you elaborate more about it?

8. What would you consider as the most relevant aspects to be improved in order to facilitate the adoption of simulation into best practices of sustainable design?

9. Do you plan to use it in the near future?

To finish the interview

10. Do you think there is a synergy between IPD (or whatever modality implemented), BIM and simulation?

How are you going to prepare your firm for the future challenges?

Copy of the e-mail to invite participants

To whom it may concern,
My name is Francisco Farías, and I am a PhD candidate at Texas A&M University.
I would like to ask you (or someone in your firm) to participate in my research. The title of my dissertation is *Strategies for Sustainable Design using Building Information Modeling, Simulation and Integrated Project Deliver,* and the idea is to examine the role of the instances of Building Information Modeling, simulation and Integrated Project Delivery (or integrated design/multidisciplinary design) in the methods and strategies for designing high performance buildings.
Attached you will find a copy of the consent form that provides specific information about your role as a participant and how the research will be conducted. If you have any questions, please don't hesitate to ask. My contact information is written in the consent form.

Sincerely,

Francisco Farías,
PhD candidate, Texas A&M University
College of Architecture.

IRB Approval Letter

TEXAS A&M UNIVERSITY

DIVISION OF RESEARCH AND GRADUATE STUDIES - OFFICE OF RESEARCH COMPLIANCE

1186 TAMU, General Services Complex	979.458.1467
College Station, TX 77843-1186	FAX 979.862.3176
750 Agronomy Road, #3500	http://researchcompliance.tamu.edu

Human Subjects Protection Program | Institutional Review Board

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APPROVAL DATE: 09-Aug-2011

MEMORANDUM

TO:	FARIAS, FRANCISCO
	77843-3137
FROM:	Office of Research Compliance
	Institutional Review Board
SUBJECT:	Initial Review

Protocol Number:	2011-0503
Title:	Strategies for Sustainable Design Using Building

	Information Modeling, Simulation and Integrated Project Delivery
Review Category:	Expedited
Approval Period:	09-Aug-2011 **To** 08-Aug-2012

Approval determination was based on the following Code of Federal Regulations:

45 CFR 46.110(b)(1) - Some or all of the research appearing on the list and found by the reviewer(s) to involve no more than minimal risk.

Criteria for Approval has been met (45 CFR 46.111) - The criteria for approval listed in 45 CFR 46.111 have been met (or if previously met, have not changed).

----

(5) Research involving materials (data, documents, records, or specimens) that have been collected or will be collected solely for nonresearch purposes (such as medical treatment or diagnosis).

(Note: Some research in this category may be exempt from the HHS regulations for the protection of human subjects. 45 CFR 46.101(b)(4). This listing refers only to research that is not exempt.)

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(6) Collection of data from voice, video, digital, or image recordings made for research purposes.

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(7) Research on individual or group characteristics or behavior (including, but not limited to, research on perception, cognition, motivation, identity, language, communication, cultural beliefs or practices, and social behavior) or research employing survey, interview, oral history, focus group, program evaluation, human factors evaluation or quality assurance methodologies.

(Note: Some research in this category may be exempt from the HHS regulations for the protection of human subjects. 45 CFR 46.101(b)(2) and (b) (3). This listing refers only to research that is not exempt.)

Provisions:

Comments:

This research project has been approved. As principal investigator, you assume the following responsibilities

1. **Continuing Review:** The protocol must be renewed each year in order to continue with the research project. A Continuing Review along with required documents must be submitted 30 days before the end of the approval period. Failure to do so may result in processing delays and/or non-renewal.
2. **Completion Report:** Upon completion of the research project (including data analysis and final written papers), a Completion Report must be submitted to the IRB Office.
3. **Adverse Events:** Adverse events must be reported to the IRB Office immediately.
4. **Amendments:** Changes to the protocol must be requested by submitting an Amendment to the IRB Office for review. The Amendment must be approved by the IRB before being implemented.
5. **Informed Consent:** Information must be presented to enable persons to voluntarily decide whether or not to participate in the research project.

This electronic document provides notification of the review results by the Institutional Review Board.

APPENDIX 3

Awards, Achievements and Publications from the participants

This section showcases some of the most important awards received by each firm. The number and type of awards varies according to the firm's scale in size and projects developed. A fair comparison should take this into account, as seen in the tables comparing size and amount of certified projects.

Awards

The following is a list of numerous awards HOK received for their design in the last few years, regarding their energy savings performance, use of BIM, LEED certifications and others (www.hok.com):

- *Honorable mention in the 2009 AIA Technology in the Architectural Practice (TAP) Building Information Modeling Award Design/Delivery Process Innovation Using BIM*, Autodesk One Market Street Gallery and Offices in San Francisco, California;
- *#1 Architectural/Engineering Firm, Engineering News-Record, April 2011.* This ranking related to revenues obtained in that particular year (http://enr.construction.com/toplists/);
- *One of the top five Green Design Firms, Engineering News-Record, June 2010.* This ranking related to revenues obtained in that particular year (http://enr.construction.com/toplists/);

- *2007 AIA Technology in the Architectural Practice (TAP) Building Information Modeling Award: Support for Human Use and Innovative Program Requirements Using BIM,* the Royal London Hospital in London, UK;
- 7 AIA Committee on the Environment Top Ten Green Projects;
- *"Most Influential Green Design Firm",* #1 ranking, by "Design Intelligence";
- "Organizational Excellence Award", by the USGBC;
- *"Sustainable Design Leadership Award",* AIA COTE, CoreNet Global and IIDA;
- *"Designing a Sustainable and Secure World Award"*, Global Green USA;
- *"Best Sustainable Practice Award"*, Sustainable Buildings Industry Council;
- *AIA Presidential Citation* for Sustainable Design;
- *Designed 1st LEED certified airport terminal (Terminal A at Boston Logan International Airport);*
- *Six consecutive years of recognition on the AIA's "Top 10 Green Projects List."*

The following is a list of the most important awards received by Lake|Flato:

- 2011 *AIA Committee on the Environment*, *Top Ten Green Project*, LIVESTRONG Foundation - Austin, TX;
- 2009 *McGraw-Hill Construction's Best of the Best: Green Building,* ASU Polytechnic Academic Buildings - Arizona State University, Mesa, AZ;

- 2009 *AIA Committee on the Environment, Top Ten Green Project,* Shangri La Botanical Gardens & Nature Center - Orange, TX;
- 2008 *AIA San Diego Committee of the Environment Award,* Francis Parker School - San Diego, CA.

The following is a list of awards on design and achievements from HKS' sustainable design work up to date:

- 75 million square feet of LEED certified and LEED registered projects, with an investment of $18.2 billion dollars;
- Ranked 6th in ENR top 100 Green Firms;
- 2010 Green Good Design, American Architecture Awards;
- Designers of the largest LEED project in the world;
- Ranked by *BD World Architecture* as the world's 16th largest architectural firm;
- Ranked by *Building Design+Construction* as the nation's fifth largest architectural firm (revenues);
- Ranked by *Modern Healthcare* as number one, in terms of volume of healthcare architecture, for 15 consecutive years;
- Named the Texas Society of Architects' (TSA) architecture "Firm of the Year" (2002);

- Selected "One of the Top 25 Medium Companies to Work for in America," according to the Great Place to Work Institute - producers of Fortune's "100 Best Companies to Work For;"
- Received the American Subcontractors Association's "Outstanding Architect Award" for the last 10 years and 15 times since its inception;
- Received 390 awards for projects including 21 Modern Healthcare awards, a first in the industry, and five ASHE/VISTA healthcare awards, which is another industry first.

The following is a list of awards and achievements from TR Hamzah and Yeang:

- 2002 Excellence Industry Award for Export Services [Malaysia External Trade Development Corporation (MATRADE)];
- 2001 Tokyo Fashion Association International Award (Work on the design of natural ventilation in skyscrapers); •
- 2000 Enterprise 50 Award (Government of Malaysia SMIDEC [Small and Medium Size Industries Development Corporation] with Andersen Consulting) [ala ysia]; •
- 2000 Academician of the International Academy of Architecture (Sophia, Bulgaria);
- 2000 Sir Robert Mathew Award, Commonwealth Association of Architects (CAA) (ondon, UK); •

- 1999 Prinz Claus Fonds Award (Prince Claus Fund for Culture and Development, HRH Prince Claus of the Netherlands. [Netherlands]; •
- 1999 Enterprise 50 Award (Government of Malaysia SMIDEC [Small and Medium Size Industries Development Corporation] with Andersen Consulting) [Malaysia];
- 1999 UIA Auguste Perret Prize for Applied Technology in Architecture (International Union of Architects) (Paris, France);•
- 1999 Honorary Fellow AIA (American Institute of Architects) [Washington, USA]. •
- 1998 Fellow SIA (Singapore Institute of Architects) (Singapore); •
- 1998 URA (Urban Redevelopment Authority) Ecological Design in the Tropics Design Award for EDITT Tower, Singapore (2nd Prize) in association with Swan & a claren Architects (Singapore); •
- 1998 RAIA (Royal Australian Institute of Architects) International Award for the e nara U N O; •
- 1998 Asian Innovation Awards (Bronze), Far Eastern Economic Review; •
- 1998 SIA (Singapore Institute of Architects) Award, Honorable Mention for ena ra U N O, Penang (overseas category);•
- 1998 Far Eastern Economic Review Innovation Award (Bronze), Far Eastern Economic Review journal [Hong Kong];•
- 1992 The Norway Award for outstanding contribution to quality in the field of architecture [Jotun Paints, Norway];

- 1997 IPDM (Malaysian Institute of Interior Designers) Award for design excellence (in the Corporate Category) for Conoco Asia Pacific td., Interior; •
- 1997 PAM Architectural Awards for the Central Plaza for excellence in design and building [ala ysia]; •
- 1996 RAIA (Royal Australian Institute of Architects) International Architecture Award (for the e nara esinia ga) [Australia]; •
- 1996 Aga Khan Award for Architecture (for the Menara Mesiniaga) [Geneva, Switzerland];•
- 1995 IAKS (International Association for Sports and Leisure Facilities) Award (for the Selangor Turf Club Grandstand) [Germany];
- 1995 SIA (Singapore Institute of Architects) Design Award (Overseas Category), Honorary Mention (for the Selangor Turf Club Grandstand) [Singapore]; •
- 1995 Merit Award, Kenneth F. Brown Asia Pacific Culture and Architecture Design Award (for the Roof-Roof House) (Hawaii, USA]; •
- 1993 PAM Architecture Award for the Menara Mesiniaga for excellence in design for commercial buildings [ala ysia]; •
- 1993 PAM Architecture Award (Honorary Mention) for Conservation (for the Standard Chartered Bank, Penang) [ala ysia];•
- 1993 IATA (International Award for Innovative Technology in Architecture), Top 20 Finalist, Quaternario [Italy]. •

The following is a list of awards and achievements obtained from Foster + Partners:

- DIFFA (Design Industries Foundation Fighting AIDS) Excellence in Design Award (Norman Foster);
- London Planning Awards, Best Built Project - 5 Years On (Swiss Re HQ, 30 St Mary Axe);
- Developers & Builders Alliance Community Advancement Awards: Outstanding Sustainable Project (The Harmon Hotel, Spa & Residences);
- Best Sustainable Development, Cityscape Abu Dhabi (Masdar Development);
- Condé Nast Traveler Innovation & Design Award – Sustainability (Masdar Development);
- AJ100 Sustainability Initiative of the Year (Masdar Development);
- Cityscape Real Estate Awards - Best Environmental Real Estate Project (Masdar Development);
- Global Green USA Green Building Design Award (Hearst Tower);
- Middle East Architect Awards, Architecture Practice of the Year (Foster + Partners);
- Gulf States Building Awards - Architect of the Year (Foster + Partners);
- AJ100 Most Admired Living Architect (Norman Foster);
- Wallpaper Design Awards – Winner Best Building Sites (Hearst Tower);
- D&AD Silver Award for Environmental Design & Architecture (Great Glass House);

- H & V News Awards – Environmental Initiative of the Year (Great Glass House);
- RICS (Royal Institute of Chartered Surveyors) Building Efficiency Award (Great Glass House);
- International Lighting Design Award of Excellence (Chek Lap Kok Airport, Hong Kong).

Green Building Rating Systems Certifications

In this section I am presenting a series of tables summarizing the certified projects from the sample as of 2012. Some projects are still being pre-assessed but they are aiming to get the specified certification. Also, the reader should keep in mind that the number of projects certified is considering the firm as a whole, not only the interviewed office, and some firms have multiple offices distributed worldwide. Moreover, the size of each firm makes a difference in the number of certifications, since one single office with less than 100 employees cannot compete with a whole multinational firm with more than 1000 employees. However, the following tables will give the reader a concrete idea about the commitment to sustainable design from the sample.

Table A1: Firm size comparison.

FIRMS	More than 1000 employees	Between 1000-500 employees	Less than 500 employees	Less than 100 employees
HOK	✓			
Lake|Flato				✓
HKS	✓			
TR Hamzah & Yeang				✓
Foster + Partners	✓			

Table A2: LEED certifications

	LEED				
FIRMS	Platinum	Gold	Silver	Certified	Total
HOK	10	58	32	17	117
Lake|Flato	3	7	1		11
HKS	2(2**)	27(12**)	10(30**)	10(16**)	49
TR Hamzah & Yeang	0	0	0	0	0
Foster + Partners	2*	3**	1*	0	0

*Pre-assessment.

** Aiming for certification.

Table A3: BREEAM certifications.

	BREEAM					
FIRMS	Outstanding	Excellent	Very Good	Good	Pass	Total
HOK	0	6	4	0	10	20
Lake|Flato	0	0	0	0	0	0
HKS	0	3*	11(4*)	0	0	14
TR Hamzah & Yeang	0	1	0	0	0	1
Foster + Partners	1	10*	5	0	2	7

*Project under pre-assessment or seeking for certification.

Publications

The following is a list of HOK's publications on sustainable design; where some are available for free download at www.hok.com:

- *Voluntary simplicity: Making smaller better.* (Valentine, B. 2005);
- *U.S. courthouse: A model for sustainability.* (GSA. 2005);
- *Sustainable design in Asia.* (Townsend, S. 2007);
- *Easing into green.* (Lazarus, M.A. 2007);
- *Many ways for facilities to go green.* (Lazarus, M.A. 2007);
- *Can labs go green? (*Grant, B. 2007);
- *The HOK guidebook to sustainable design* (2nd Edition). (Mendler, S. F., Odell, W., & Lazarus, M. A. 2005); and

- *The green workplace.* (Stringer, L. 2009).

The following is a list of HOK's publications on BI , i ncluding specialized books on how to implement and adopt BIM; and also case studies with detailed explanation of their implementation, failures and success (www.hok.com):

- *Mastering Revit Architecture 2011.* (Vandezande, J., Krygiel, E., & Read, P. 2010);
- *Using Building Information Modeling to expedite development: Emory's new PAIS building demonstrates benefits of collaboration tools.* (Allen, J. 2010);
- *From Mylar to digital models.* (Halamka, T. 2010);
- *KAUST: A case study in integrated delivery and BIM.* (Halamka, T. 2010); and
- *Technology adoption and implementation at HOK.* (Khemlani, L. 2008);

The following list shows some online publication about ake|Flato's sustainable designs:

- Lake|Flato Architects (Capps, K. 2011);
- ivestrong Foundation (" ivestrong Foundation," 2011);
- i ller Porch Ranch House (" i ller Porch House," 2012);
- ASU Polytechnic Academic Complex (Blair, S. 2008); and
- Shangri La Botanic Gardens (Bierig, 2008).

The following is a list of HKS' published work:

- *HKS Architecture*. (HKS 2010);
- *HKS: Selected and current works.* (HKS 2006).

The following is a list of published work related to K. Yeang's and his firm's sustainable designs:

- *Hamzah & Yeang, groundscrapers and subscrapers.* (Richards, I. 2001);•
- *Hamzah & Yeang*: *The ecology of the sky.* (Richards, I. 2001);
- *Guthrie Pavilion in Selangor.* (Van Schaik, L. 2001);
- *Rethinking the skyscraper: The complete architecture of Ken Yeang.* (Powell, R. 1999);
- *T. R. Hamzah & Yeang (Master Architect Series).* (Van Schaik, L. 1999);
- *Ken Yeang: Bioclimatic skyscrapers.* (Balfour, A. 1994);
- *Ken Yeang: Rethinking the environmental filter.* (Powell, R. 1989);
- *Designing for survival: Ecological design.* (Yeang, K. 2004). [in preparation]; •
- *A vertical theory of urban design* (Yeang, K. 2002). [in preparation];•
- *The green skyscraper: The basis for designing sustainable intensive buildings.* (Yeang, K. 2000);•
- *The skyscraper bioclimatically considered: A design primer.* (Yeang, K. 1997);
- *Designing with nature.* (Yeang, K. 1995); •
- *Tropical urban regionalism.* (Yeang, K. 1987); •
- *Tropical verandah city.* (Yeang, K. 1986); and
- *A theoretical framework for the incorporation of ecological considerations in the design and planning of the built environment*. (Yeang, K. 1981).

The following is a list of some published work showcasing sustainable designs from Foster + Partners:

- *The Reichstag.* (Foster, N., Abel, C. 2012);
- *Hearst Tower: Foster + Partners*. (Foster, N., Giovannini, J. 2011);
- *Free university of Berlin: The philological library*. (Foster, N., Jenkins, D., Kiem, K. 2011);
- *Foster + Partners: Catalogue.* (Foster, N. 2008).
- *Commerzbank Frankfurt: Prototype for an Ecological High-Rise* (Lambot, I. 1997). ISBN: 3764357401;
- *30 St Mary Axe: A Tower for London* (Powell, K. 2006). ISBN: 1858943221;
- *Rebuilding the Reichstag* (Foster, N. 2000). ISBN: 0879517158; and
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APPENDIX 4

(Courtesy of Pliny Fisk)

AIR DATA SHEET

PER CAPITA PHYSIOLOGICAL ECOLOGICAL FOOTPRINT

Ecological Footprint Required for Oxygen Production

According to NASA, the average daily adult human intake of O_2 is 830-850 grams or 1.83-1.85 pounds allowing for a period of moderate exercise. Averaging yields an annual per capita O_2 requirement of approximately 306,600 grams or 676 lbs.

Oxygen is released to the atmosphere by vegetation during the process of photosynthesis. The amount of oxygen released for a given amount of biomass (by weight, volume, or surface area) ranges from 13 to 136 lbs. per tree per year. Using the highest value yields the minimum footprint - 5 mature trees for oxygen production per person. Assuming an average size of a mature tree to be about 35 ft. in diameter - approximately 1,000 sq. ft. in area - results in a per capita ecological footprint for oxygen production of roughly 5,000 sq. ft. or 0.11 acre.

Ecological Footprint Required for Carbon Dioxide Fixation

Depending on the source, the average daily human output of CO_2 is estimated to be between 1,000-1,450 grams or 2.20-3.20 pounds. Using the lowest value yields the minimum footprint and results in an annual per capita CO_2 output of approximately 365,000 grams or 805 pounds.

In moderately bright light, net CO_2 fixation by plants with normal ambient CO_2 concentrations is 24-25 grams per square meter or about 0.05 (1/20) pounds. This means that 1,000/25 = 40 square meters or 430 square feet of active leaf surface is required to act as a CO_2 sink for one human.

On average, live trees in the U.S. are accumulating carbon at a rate of 1,250 pounds (0.625 tons) per acre per year. Converting this figure to carbon dioxide extracted from the atmosphere (3.66 lbs. of CO_2 are sequestered for every pound of carbon converted and stored in tree biomass) yields a value of 4,580 pounds (2.3 tons) per acre per year. Using these figures yields a per capita ecological footprint for carbon dioxide fixation of about 0.18 acres or almost 7,660 sq. ft.

Per capita co2 emissions ecological footprint

Trees also sequester carbon dioxide emitted from fossil fuel combustion and deforestation (burning of biomass containing carbon). Tree planting and the maintenance of forests and woodlands may be the most effective means of assimilating excess atmospheric carbon dioxide.

The average North American emission rate is 20-22 tons of carbon dioxide per person annually. To extract this amount of carbon dioxide from the atmosphere and to convert and store it as carbon in biomass requires large areas of tropical and temperate forests or woodlands. Forest ecosystems are capable of storing large quantities of carbon in solid wood and other organic matter. Major forestry management opportunities to sequester and store carbon include:

• Increasing forest and woodland area;
• Increasing the productivity of existing forests and woodlands;
• Reducing forest and woodland burning and deforestation;
• Increasing biomass production and utilization;
• Planting trees in built and agricultural environments; and
• Increasing the use of wood in long-life durable products.

[Adapted from Birdsey 1992, 1]

The average forest in the U.S. contains 158,000 pounds (79 tons) per acre of organic carbon. Trees, including roots, account for 31%of all forest ecosystem carbon averaging 49,000 pounds (24.5 tons) per acre. The forest understory, floor, and soil account for the other 69% of carbon storage.

Depending upon species, size, age, latitude, climate, and management practices, each tree sequesters anywhere from 26 to 666 lbs. of carbon per year. On average, live trees in the U.S. are accumulating carbon at a rate of 1,250 pounds (0.625 tons) per acre per year. Converting this figure to carbon dioxide extracted from the atmosphere (3.66 lbs. of CO_2 are sequestered for every pound of carbon converted and stored in tree biomass) yields a value of 4,575 pounds (2.3 tons) per acre per year. Using average figures yields a per capita ecological footprint for carbon dioxide sink of more than 9 acres.

At present, the global supply is less than 2 acres per person of productive forest and woodland. Every year, 20-30 million acres of the world's forests and woodlands are destroyed or converted to other uses. In the U.S., all forest land totals about 731,400,000 acres which is less than 3 acres per person.

Lifestyle assumptions

The U.S. annual energy consumption per capita and per unit of GDP is about double that of many European countries with comparable standards of living (such as Denmark, Germany, and Sweden). It was therefore assumed that the average American figure could be reduced by 50% without any major changes in lifestyle. The conservation lifestyle footprint icon is therefore about 4.5 acres.

The sustainable lifestyle figure reflects the potential of domestic fossil fuel energy consumption and resulting carbon emissions to be reduced by 75-80% to 20-25% of current levels. (See for example, Rocky Mountain Institute figures for advanced efficiency "megawatt" homes.) The footprint icon is therefore 2.25 acres.

Integration potential

The oxygen production footprint icon can be entirely nested within the following footprint icon(s):

- Trees required for carbon dioxide fixation.

The carbon dioxide sink footprint icon can overlap the following footprint icon(s):

- Trees required for oxygen production.

Weights and measures

Major volumetric components of dry air at sea level:

Nitrogen	N_2	78%
Oxygen	O_2	21%
Argon	Ar	< 1%
Carbon dioxide	CO_2	< 1%
Others		<0.002%

Weight of dry air at standard temperature and pressure:
1.293 kg./cu.m. = 0.0807 lbs./cu.ft.

Weight of oxygen at standard temperature and pressure:
1.429 kg/cu.m. = 0.0892 lbs./cu.ft.

Weight of carbon dioxide at standard temperature and pressure:
1.977 kg/cu.m. =.0.1234 lbs./cu.ft.

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BIOMASS ENERGY DATA SHEET

Biomass for ethanol fuel

In 1991, the U. S. average vehicle miles travelled (VMT) was 10,000-12,000 miles per year (about 30 miles per day) and the average vehicle fuel consumption was about 560 gallons of gasoline per year. The energy content of gasoline is 32.5 MJ per liter.

An average figure for ethanol production from feedstock (e.g., corn) is about 2,300 liters per hectare or 240 gallons per acre. The energy content of ethanol fuel is about 21MJ per liter, roughly 65% of the energy content of gasoline. The equivalent energy content of 560 gallons of gasoline is therefore about 870 gallons of ethanol fuel. To produce 870 gallons per year of ethanol from feedstock requires roughly 3.6 acres, assuming one crop of feedstock per year.

Ethanol production varies greatly with the type of feedstock used. For example, sorghum yields about 820 liters per hectare, wheat about 920, and 3,000 is the figure for sweet potatoes. To account for the differences in energy output of various feedstocks, the figure of 3.6 acres was rounded up to 4 acres. This is the proposed footprint icon for the average American ethanol fuel consumption for a passenger vehicle.

Biomass for wood heating

One cord is 4'x4'x8' which is 128 cu. ft. of wood and air and about 70-80 cu. ft. of solid wood. Sustainable harvest management practices yield about 35 cu.ft. of wood per acre per year of useable wood (lumber and/or fuel). Therefore, a sustainable yield of one cord of wood per year requires about 2 acres of woodland.

The heating value of wood differs with species, the hardwoods being denser and producing more heat than the softwoods. About 20 million Btus is the average fuel value of one cord of wood at 20% moisture content. At an average wood burning efficiency of 50%, one cord of wood produces 10 million Btus of space heating. Converting to land area, 2 acres of woodland produce 10 million Btus of space heating, or about 5,000,000 Btus per acre. (At 43,560 sq. ft. per acre, the figure is equivalent to about 115 Btus per sq. ft.)

The heating load of a residence obviously varies with climate, the physical condition of the building, the thermal properties of the building materials used, outdoor wind speed, and the indoor temperature. For the sake of discussion, let us assume a climate with about 4,000 annual heating degree days (Washington, D.C. and environs) and an indoor temperature of 68-72 degrees F with average winter wind speed. A well-insulated home with a significant passive solar heating fraction (60-80%) will require for space heating about 5 Btus per sq.ft. per degree day, a well-insulated home without passive solar heating about 20 Btus per sq.ft. per day, and a conventional home about 40 Btus per sq. ft. per day. In a climate with 4,000 heating degree days, the corresponding heating loads are:

- 20,000 Btus per sq. ft at 5 Btus per sq. ft. per degree day.
- 80,000 " " at 20 " " " " .
- 160,000 " " at 40 " " " " .

Since the 1950s, the average American house size has increased and the average number of people living in each house has decreased. The result is that today, the average American house is about 600-750 sq.ft. per person. At 750 sq.ft. per person, the annual heating loads and corresponding woodland per person footprints for each of the three heating loads are listed below.

- 20,000 Btus/sf x 750 sf = 15,000,000 Btus/year
  @ 5,000,000 Btus/acre = 3 acres at one harvest per year.

- 80,000 Btus/sf x750 sf = 60,000,000 Btus /year
  @ 5,000,000 Btus /acre = 12 acres at oneharvest per year.

- 160,000 Btus/sf x 750 sf = 120,000,000 Btus/year
  @ 5,000,000 Btus/acre = 24 acres at one harvest per year.

Lifestyle assumptions

For ethanol fuel, the conservation lifestyle footprint icon assumes the use of a fuel-efficient or hybrid vehicle that doubles the vehicle's fuel performance (e.g., 30-40 mpg compared to 15-20 mpg). Therefore, the fuel consumption and subsequent ethanol fuel footprint is reduced by half compared to the average American footprint.

The ethanol fuel sustainable lifestyle footprint assumes both a fuel-efficient vehicle and a 50% reduction in VMT (assuming that walking, cycling, car-pooling, and transit use have replaced vehicle travel). The resulting footprint is therefore one quarter that of the average American footprint.

For the biomass wood heating footprint, the conservation lifestyle assumes a well insulated house and a 50% reduction in heating loads compared with the conventional house. Thus, the footprint is 12 acres of biomass production.

For the sustainable lifestyle, the 3 acre footprint was used. This assumes a well-insulated house combined with a maximum passive solar heating fraction.

A reduction in the average house size per person would lower these figures. For example, at 500 sq.ft. per person, each of the footprints could be reduced by 33%. The conservation lifestyle footprint would thus be 8 acres and the sustainable lifestyle footprint about 2 acres. We made the assumption that a person practicing either a conservation or sustainable lifestyle might make a conscious decision to reduce their living space and, accordingly, have proposed these last two figures for the respective lifestyle footprints.

Integration potential

Assuming that corn or grain is grown, the ethanol fuel footprint icon can be nested within or overlap the following footprint icon(s):

- Food production water harvesting (site runoff).
- Straw building materials.

The biomass space heating footprint icon can be nested in or overlap the following footprint icon(s):

- Trees required for oxygen production.
- Trees requitred for carbon sinks forestrs and woodlands.
- Food production water harvesting (site runoff).

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FOOD DATA SHEET

PER CAPITA FOOD PRODUCTION ECOLOGICAL FOOTPRINT

Background

In addition to documenting the location of prime agricultural land in settlements and settlement regions, another question to consider is: How much land should be cultivated, or at least reserved for future agricultural use, in a sustainable settlement? This question does not necessarily imply that a sustainable settlement must always be entirely self-sufficient in food supplies, nor that it must refrain from importing and exporting food products. There is a difference between self-reliance and self-sufficiency. Self-reliance implies having characteristics of personal responsibility, self- control, and "trust in one's abilities" [Webster's], whereas self-sufficiency implies being completely self-contained or separated and having "undue confidence in one's own abilities" [Webster's, emphasis added].

> Food self-reliance does not necessarily mean producing everything the nation eats but producing enough of its basic foods to be independent of outside forces. Food self-reliance calls for the maximum utilization of local resources - physical and human - before seeking out foreign resources. While food self-reliance is not necessarily food self-sufficiency, it does imply the ability to become, in short order, self-sufficient enough to survive a sudden cut-off of imports. No people should allow themselves to be vulnerable to the disruption of their food supply due to natural disasters or wars elsewhere, or to the political manipulation of food exports by foreign governments. .... Food self-reliance is the foundation of genuine food security for all.
>
> [Lappe and Collins 1977, 457]

Problems of vulnerability and security can arise when a settlement or regional population continually depends on distant sources for all, or a vast majority of, its food without regard to local and regional food resource supplies and food production options. Evaluating the potential of local and regional food production requires both an estimate of the quantity of available arable land in the locality and region and an assessment, on a per unit of land area basis, of its food-producing capacity. By also knowing the average food requirements of a single person, the minimum land area that contains the potential capacity to adequately feed the present - and future - settlement population can be determined. This can be expressed in terms of a food supply and demand balance in the following equation where P equals the settlement population:

$$\text{food production area} \times \text{food production per unit of area} = P \times \text{average food requirements of one person}$$

Dividing both sides of the equation by food production per unit of area gives the following equation for defining food production area:

$$\text{food production area} = \frac{P \times \text{average food requirements of one person}}{\text{food production per unit of area}}$$

The question can be phrased in two ways: How many people can be adequately fed by food produced on a unit of land area - say, an acre (persons per acre); or inversely, what quantity of land is required to produce enough food to meet the sustenance needs of one person (acres per person, i.e., a per capita ecological footprint)? Both questions are different versions of the same idea - the per capita carrying capacity concept, or the minimum area into which the resources to support one person can be concentrated. The intent of reviewing studies of the carrying capacity concept as it applies to food production for human sustenance is to establish a minimum land area per capita benchmark for food production. This benchmark can be utilized for establishing the quantity of arable land that should be put in reserve for agricultural uses in a sustainable settlement region depending on the present and projected settlement population.

Three different approaches have been taken in studying the subject. The first approach documents the actual input and output of non-industrialized, labor-intensive agricultural methods practiced in many countries and cultures of the past and present. This approach typically attempts to arrive at an "acres per person" figure. It will be labeled the “case study” approach. The second approach arrives at an estimate of human carrying capacity based on calculations of the limits of biological productivity - the availability of solar radiation and the conversion efficiencies of photosynthesis - and the amount of land available in the world for food production. This approach typically starts at the global scale, estimating the world's maximum possible human population based on the limiting factors of biological productivity and usable arable land. It will be called the “theoretical” approach. Estimates made by the third approach are based on the results of recent scientific experiments. It will be labeled the “experimental” approach.

Each of the studies cited in this overview makes the same important assumption, namely, that energy subsidies to agriculture from fossil fuel sources will be drastically reduced or eliminated in the future. If human settlements are to become sustainable, they must reduce their dependence on fossil fuel subsidies to food production and shift their focus to agricultural practices based on the utilization of renewable sources of energy, specifically solar energy. All three approaches assume that the primary energy inputs to food production will be restricted to solar radiation, human labor, and biological waste-produced soil enhancers and fertilizers, with a greatly reduced supplemental input from fossil fuels.

The results of the three approaches to estimating a land area per person benchmark are summarized in Tables F-1 and F-2 below. Table F-1 presents minimum land area figures for completely vegetarian and animal product supplemented (e.g., goat milk) diets and Table F-2 presents minimum land area figures for a partially meat diet.

TABLE F-1:
LAND AREA PER CAPITA FOR CROPLAND ONLY -VEGETARIAN DIET

DATA SOURCE	DESCRIPTION	Hectares	Acres
CURRENT CONDITIONS	World average, developed regions	0.7	1 3/4
	World average, less-developed regions	0.25	5/8
	U.S., average, industrialized	0.7	1 3/4
	India, present condition	0.3	3/4
	U.K., average, industrialized	0.13	1/2
	U. S., industrialized, highest recorded yields	0.05	1/8
CASE STUDIES	Swidden, vegetarian, New Guinea	0.08	1/5
	Allotment garden, UK (extrapolated)	0.08	1/5
	U. S. community garden, labor intensive, all-year	0.04	1/10
	China small scale farming, labor intensive	0.02	1/20
	U. S. small-scale, raised bed garden, all -year	0.01	1/40
THEORETICAL STUDIES	Odum	0.4 - 4	1 -10
	Pimentel, et. al.	0.5	1 1/4
	Pfaundler	0.2 - 0.4	1/2-1
	FAO	0.2 - 0.4	1/2-1
	Clark	0.07	1/6
EXPERIMENTAL STUDIES	Biosphere II experiment. Arizona, USA	0.04	1/10

[Adapted from Borgstrom 1980, 72; Clark 1977, cited in Cohen 1995, 190-196; FAO 1983, cited in Cohen 1995, 196-209; Glenn, et. al. 1990, 1507-1512; Green 1978, 6-8, 180-182, 194; Jeavons 1974, 167; Leach 1976, 12-13, 116, 119; H. Odum 1971, 125; Pfaundler cited in Martinez-Alier 1987, 108-126; Pimentel and Pimentel 1979, 36-40; Pimentel, et. al. 1994, cited in Cohen 1995, 417; Randall 1996, pers. comm.]

Following are figures for the total amount of agricultural land - land required for food crops and livestock (cropland and pastureland or rangeland) - for meat supplemented diets.

TABLE F-2:
LAND AREA PER CAPITA FOR CROPLAND AND RANGELAND/PARTIAL MEAT DIETS

DATA SOURCE	DESCRIPTION	Hectares	Acres
CURRENT CONDITIONS	World average, developed regions	2.0	5
	World average, less-developed regions	0.8	2
	U. S., high meat diet - 100+ kg/year	2-4	5-10
	U. K. average	0.4	1
CASE STUDIES	New Guinea, Tsembaga (some hunting)	4.4	11
	Uganda, Dodo tribe	3.7	9
	U. S., self-sufficient small farm	0.4	1
	India, low meat diet - 2 kg/year	0.4	1
	New Guinea, swidden agriculture with livestock	0.2	1/2
THEORETICAL STUDIES	Clark	0.2	1/2

[Adapted from Borgstrom 1980, 72; Clark 1977, cited in Cohen 1995, 190-196; Durning 1992, 67; Green 1978, 6-8, 180-182, 194; Leach 1976, 117-118; Pimentel and Pimentel 1979, 28-35; Seymour 1975,17.]

For comparative purposes, these figures are being presented within the framework of a global view of human carrying capacity based on food production, both present and projected for the near future. A comparison between the minimum land area per person carrying capacity benchmark and the ratio of agricultural land per person at the global level will help to determine how close to the Earth's carrying capacity limits we actually are and, therefore, how critical it is for sustainable settlements to start reserving and utilizing land for agricultural uses. The global ratio requires both an estimation of the quantity of the world's land used for agricultural purposes - how much agricultural land currently exists in the world and how much it might increase our decrease in the future, and an estimation of the world's human population - the current level and the projected level resulting from future population growth. These figures are summarized in Table F-3 below.

To people who live in the less-densely populated areas of the world, especially North Americans, there seems to be a huge amount of available open space and agricultural land. The North American continent possesses vast areas of productive land - approximately 30% of the total area is cropland and pasture land, and in the United States lies the world's largest concentration of prime agricultural land. Agriculture is the largest use of land in the U. S. today with over 40% being dedicated to food and fiber production. Worldwide, there is a huge amount of land used for agricultural purposes. Food production has the greatest spatial impact of all human uses of the land on the Earth's surface. Cropland and animal grazing land are easily the most spatially extensive human activities on the landscape. Agricultural activities have become the dominant use on over one-third of the land areas of the Earth.

The simple fact that vast quantities of agricultural land presently exist gives no indication of either the condition of the land nor the rate at which it may be increasing or decreasing. The problem is twofold: the fruits of this agricultural land must be divided among more and more people who want more and more food, and both the quantity and quality of available agricultural land is rapidly decreasing.

An overview of the current and projected ratio between world agricultural land area and world population is presented in Table F-3 below. What is the amount of agricultural productive land per person today? At present conditions, 6 billion people supported by 22.0 billion acres of usable land - forest, pasture, and cropland - yields a density of 0.25 persons per acre, or, inversely, approximately 4.0 acres per person. Assuming that the world's forest land must be maintained for non-agricultural uses yields smaller areas of land available for food production. Cropland only is 3.7 billion acres which gives 1.5 persons per acre or 0.66 acres per person, pasture only is 8.4 billion acres which gives 0.67 persons per acre or 1.5 acres per person, and cropland and pasture combined is 12.1 billion acres which gives 0.46 persons per acre or 2.2 acres per person. If the population increases by 90 million each year and 27 million acres of arable land are lost annually (assuming, optimistically, that the amount of pasture land remains constant), then the changes in the ratio between world population and agricultural land shown in Table F-3 will result.

TABLE F-3:
RATIO OF WORLD POPULATION AND AGRICULTURAL LAND

TIME	WORLD POPULATION (MILLIONS)	CROPLAND		CROPLAND PLUS PASTURE	
		persons/ac	ac/person	persons/ac	ac/person
1995	5,600	1.7	0.59	0.50	1.98
+ 10 years	6,500	1.9	0.53	0.55	1,82
+ 50 years	10,100	4.5	0.22	1.00	1.00
+ 100 years	14,600	14.6	0.07	1.31	0.76

[Adapted from Burger 1994, 137-142; Myers 1984, 40-41.]

This table illustrates some thought provoking possibilities. For example, if some of the theoretical studies from Table F-1 are correct - 1 acre per person is the minimum required for life support on a vegetarian diet - then we have already exceeded the carrying capacity of the Earth based on available cropland by a wide margin. The lower number in the range of estimates gives us a little more time - a ratio of 1/2 acre of cropland per person will occur in about 10 years. Only two of the estimates in Table F-1 are less than 1/10th of an acre per person. If the population continues to increase at the rate of doubling every 40-50 years, then in only 100 years, with a total population of almost 15 billion people, that ratio will already have been surpassed and the ratio of all productive land will be about 3/4 acre per person, rapidly approaching the lowest estimated ratio for cropland and pastureland per person - 1/2 acre.

The most optimistic projections have indicated that it might be possible to double the amount of cultivated land area from today's 11% of the world's total land area to almost one quarter of the total. One limitation to doing so is that the new cropland would be in areas of less productive soils, less annual rainfall, or shorter growing seasons, or some combination of these three conditions. Moreover, the 'start-up' costs for new, less fertile cropland are relatively high, especially if irrigation is necessary.

Another limitation is that most of the land potentially suitable for food production is already designated for other uses. More cropland means less public land, parkland, forests, grasslands, and rangelands. Forests are habitats for wildlife, and grasslands and rangelands may be more productive for human use if they keep their function as livestock feeding areas. The amount of land area devoted to livestock production is great - 11% of the world's land area is used to produce crops, but an area twice this size is in rangeland - land that is either too dry or too steeply sloping to be cultivated. This 26% of the world's land area supports most of the world's 3.2 billion cattle, sheep, and goats - at least one for every two people in the world.

It is true that by cutting out - or drastically cutting down - intensive rearing of animals and poultry - restricting it to grazing of natural grasslands - would enable a country to more self-supporting. Grain for human consumption could be grown on arable land currently devoted to growing livestock feed.

However, in many areas of the world, grassland and rangeland may be the best use of the land. Animals can be raised on non-arable land that cannot produce any other kind of food for human consumption. These areas are appropriate for animal husbandry since humans cannot eat grass, and animals have the ability to turn it into human food. If these areas are not used to raise meat, they do not contribute to human nutrition.

Per Capita Vegetarian Diet and Meat Diet Ecological Footprints

This discussion points to the need to begin now the process of including the spatial requirements of food production as programming and design criteria in the shaping of sustainable settlements in order to preserve existing agricultural land, put into reserve agricultural land for future use, and utilize for food production vacant and vacated arable land. Accordingly, order of magnitude benchmarks for per capita food production in settlements and settlement regions are listed in Table F-4 below. These benchmarks are listed in order of smallest scale to largest scale.

The first and smallest benchmark is the recommended spatial footprint for home gardens. It is not intended to infer that a 400-500 square foot (1/100 of an acre) home garden will provide a person's entire annual food needs. Rather, it is a figure that can likely guarantee a certain degree of self-reliance and food security for individuals and their families.

The second benchmark is being proposed as the sustenance level, intermediate yield, vegetarian diet footprint icon. A per capita land area of 4,000 sq. ft or about1/10th of an acre of cropland under continuous cultivation is recommended at the neighborhood or community scale. This is not the lowest ratio documented in case studies (see Table F-1 above) and, therefore, represents a conservative and reasonable figure for food production assuming a total vegetarian diet can adequately provide a person's total nutritional needs. This ratio should be adjusted according to the geography of the locality and region for rainfall, soil quality, and growing season. For example, in the case of a six-month (half-year) growing season, the figure should be doubled to 8,000 sq. ft or1/5 acre.

The third benchmark recommends that, to provide animal product supplements to a vegetarian diet, an additional 1/2 acre of grazing land per person be reserved at the scale of the watershed or metropolitan region. According to the studies cited, this is the minimum spatial footprint area required per person.

The fourth benchmark is being proposed as the sustenance level, meat-supplemented diet footprint icon. It combines cropland and grazing land into one footprint and assumes slightly more cropland and grazing land per person than the minimum. It assumes a low-meat, animal product (e.g., milk, eggs, and cheese) supplemented diet. This provides a degree of self-reliance and food security at the scale of the bioregion, state, or nation.

TABLE F-4:
ORDER OF MAGNITUDE PER CAPITA FOOD PRODUCTION BENCHMARKS FOR SUSTAINABLE SETTLEMENTS [All figures by the authors and are derived from above data.]

LAND USE SCALE	PER CAPITA FOOTPRINT	COMMENTS
Residential Lot	0.01 acres 400 sq. ft.	• Home garden • argest area manageable by one person in spare time
Neighborhood or Community	0.1 acres 4,000 sq. ft.	• Average home garden size in U.S. • Can provide a large portion of a wide variety of vegetables consumed by one person • inimum recommended area assuming intermediate yields for local and community regional self- reliance (vegetarian diet)
Watershed or Metro Region	0.5 acres 21,800 sq. ft.	• Case study and theoretical study minimum (rangeland)
Bioregion	1.0 acre 43,600 sq. ft.	• Case study minimum with low meat diet (cropland + rangeland)

Per Capita Composting Ecological Footprint

Composting data required.

Per Capita Aquaculture Footprint

Assuming a 150 lb. person and a 0.24g/lb. body weight daily protein requirement results in a per person protein requirement of 36g per day and 13,140g per year. Assuming further that 25% of a person's protein requirement comes from fish yields a net requirement of roughly 3,300g per year of protein from fish.

A sustainable yield of fish derived protein from wastewater aquaculture systems is about 2,400kg per hectare per year or about 960kg (960,000g) per acre per year. Thus, one acre of aquaculture can produce the annual fish-supplemented protein needs of almost 300 persons. This yields a per capita land use footprint for aquaculture of almost150 sq. ft.

Lifestyle assumptions

Several lifestyle assumptions were made for deriving the food footprint icons.

Regarding the footprint icon for a vegetarian diet, a daily requirement of 2,000 kilocalories per day is assumed to be the minimum dietary needs for human sustenance. It is assumed that the vegetable content of the diet of the average American is the same as that of a complete vegetarian diet and that it is possible for a complete vegetarian diet to meet all of a person’s nutritional needs. Thus, the cropland footprint icon for all three lifestyles is assumed to be constant.

For a meat diet, it is assumed that the average American consumes ten times more meat than the sustenance level minimum. This assumption is based on statistics for meat consumption for various countries. For example, the average American consumes over 50 times more meat per year than the average Indian -75 kg (about 165 pounds) compared to 1.5 kg (about 3 pounds) - and at least 10 times more per capita than most European countries. Thus, for the average American, the cropland plus rangeland footprint icon for a meat diet is (conservatively) ten times the sustenance level. Assuming meat consumption can easily be reduced by 50% by eating more animal products to replace meat, the cropland plus rangeland footprint icon for the conservation lifestyle is reduced proportionately.

Integration potential

The cropland footprint icon can be nested within the following footprint icon(s):

- Cropland plus rangeland (meat diet).

It can be nested within or overlap the following footprint icon(s):

- Food production water harvesting (site runoff).
- Straw bale building materials.

The cropland plus rangeland footprint can entirely overlap the following footprint icon(s):

- Cropland (vegetarian diet).

It can be nested in or overlap the following footprint icon(s):

- Food production water harvesting (site runoff).
- Straw bale building materials.

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MATERIALS DATA SHEET

Sustainable lumber harvest

Under good management practices, the sustainable yield of a forest is approximately 400 board feet per acre per year. Using wood efficiently, a wood frame residence requires about 5-6 board feet of lumber per square foot of living space. Therefore, a sustainable harvest of lumber can provide roughly 65-80 square feet of living space per acre per year.

The healthy dense woodland at Peaceable Kingdom covers approximately 45 acres. According to the above figures, on a sustainable yield basis, this woodland can provide enough lumber to frame 2,925-3,600 square feet of living space per year. Assuming a living space footprint of 600 square feet per person (conservation lifestyle) yields a carrying capacity of 5-6 persons per year for wood frame building materials.

Straw bale walls

The dimensions of a straw bale are about 36-40" long x 18" thick x 14" high. Each bale provides an exterior wall surface area of 3.5-4 sq. ft.

At an American average of 750 sq. ft. per person (see biomass energy data sheet), the average person's living space is about 27'x27' x 8-10' high. If one wall is a common wall (shared with other living space) then the total exterior wall surface area to enclose one person's living space is about 650-800 sq. ft. or 160-230 straw bales. If 70 bales can be produced per acre, then about 3-4 acres per person is needed allowing for a waste factor. Assuming the lifetime of the wall is 40-60 years, then, on average, the straw bale output can be produced on 0.05-0.1 acres at the rate of one crop grown per year for 40-60 years.

However, a person rarely wants to wait 40-60 years to construct their house. Assuming that a 2 year construction schedule is acceptable, the house will require a straw bale output of 80-115 bales per year or 1.5 acres in production for two years. It is assumed that the average American, however, because of career constraints, must complete the house in one year. Therefore, the average American straw bale footprint is 3 acres (not allowing for a large waste factor).

Earth walls and floors

Using the figures above and adding a floor, the surface area requirement of an average American is 1,400-1,600 sq. ft. Assuming 24-30" thick walls and a 6-8" thick floor yields a building material volume of 2,000-2,800 cu. ft. of earth. If the earth is excavated to a depth of 4 ft. and 75-80% by volume is appropriate for use as a building material, then the surface area required is 600-900 sq. ft. for an average footprint of about 750 sq. ft.

A construction schedule that varies from one to two years has no effect on the earth building material footprint. It is assumed that the earth is excavated and cannot be replaced. The excavated area is then used as a retention pond for food production water harvesting.

Lifestyle assumptions

For straw bale wall and earth building materials, it was assumed for both the conservation and sustainable lifestyles that either the construction time frame could be extended to two years, or that the living space could be reduced to 500-600 sq. ft. per person, or both. These assumptions yield the following footprint icons:

- Straw bale walls: 2 acres for conservation lifestyle.
  1.5 acres for sustainable lifestyle.

• Earth walls and floors: 625 sq. ft. for conservation lifestyle.
500 sq. ft. for sustainable lifestyle.

Integration potential

The straw bale footprint icon can be nested within and overlap the following footprint icon(s):

- Food production water harvesting (site runoff).
- Cropland (vegetarian diet).
- Cropland plus rangeland (meat diet).
- Biomass for ethanol fuel.

The earth building material footprint icon can be nested within or overlap the following footprint icon(s):

- Food production water harvesting (site runoff).

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SOLAR ENERGY DATA SHEET

Photovoltaics for lighting and appliances

The U. S. average domestic electrical energy consumption for lighting and appliances (omitting electrical space heating, cooling, and water heating) is about 6 kwh per person per day. After accounting for system losses (e.g., operating efficiency, inverter power requirements, etc.), and assuming a 4-5 hour average daily charging period, the PV area required is approximately 1,000 sq. ft.

Photovoltaics for a passenger vehicle

The U. S. average vehicle miles travelled per year is 10,000-12,000 miles or about 30 miles per day. This distance is easily within the range of most electric passenger vehicles now available (e.g., Honda EV or GM Impact both have a range of about 100 miles before recharging is required). The PV system is sized for recharging the vehicle at home during the night from stored power (either from batteries or from a utility grid). This assures proper charging procedures and ease of operation and convenience for the consumer. Assuming an average of 4-5 hours of daylight and after accounting for system operating power requirements and losses, the PV area needed is approximately 250 sq. ft.

Lifestyle assumptions

For lighting and appliances, it was assumed that a 50% decrease in electrical energy consumption is easy to obtain with new energy-efficient hardware. In fact, many new light bulbs and appliances consume up to 75% less energy than older models (e.g., compact fluorescent light bulbs). The Rocky Mountain Institute "megawatt" house design reduces electrical energy consumption to less than 20% of state of California 1992 building energy standards.

The conservation lifestyle footprint icon, therefore, is assumed to be half, and the sustainable lifestyle footprint icon is assumed to be one-quarter, of the average American electrical energy consumption figure for lighting and appliances. The footprint icons do not include electrical energy for space heating, cooling, and water heating (except for low-watt appliances such as ceiling fans).

For the PV footprint required to charge a passenger vehicle, it was assumed that a conservation lifestyle could reduce energy consumption by 50% through a combination of two factors: a reduction in annual passenger vehicle miles travelled (e.g., less use of the vehicle or more passengers per mile travelled) and an increase in the fuel-efficiency of the vehicle (e.g., hybrid fuel-electric vehicles). Another assumption made was that for the foreseeable future, no further increases in efficiency could be made beyond the conservation lifestyle figures and that one vehicle per household would be the norm. Therefore, the sustainable lifestyle footprint icon is the same as the conservation lifestyle footprint icon.

Integration potential

Both photovoltaics footprint icons - for lighting and appliances and for a passenger vehicle - can be nested within or overlap the following footprint icon(s):

- Domestic water uses.

For example, roof-mounted PV panels can also harvest rainwater.

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WATER DATA SHEET

PER CAPITA PHYSIOLOGICAL ECOLOGICAL FOOTPRINT

Ecological Footprint Required for Household Water Use

In addition to drinking water, people need water for bathing, sanitation, cleaning, (i.e., hygienic uses) and cooking. These are usually called indoor or household uses of water. Indoor use combined with outdoor use - landscape watering is typically the primary outdoor use - is called domestic water use. Domestic water demands do not include offstream water demands for manufacturing, mining, commercial uses, and energy production, nor instream demands for fisheries, recreation, hydroelectric power, and transport. A detailed analysis of all these demands is beyond the scope of this inquiry.

Domestic demands are analyzed below according to three main categories: drinking water, household water, and landscape water. The definition of drinking water is self-explanatory. It must be the purest water. Household water includes all other indoor uses required for hygiene and sanitation: showers, baths, toilets, lavatories, sinks, and dish- and clothes washers. Landscape water is included as a possible substitute for food garden irrigation, assuming that the two amounts might be nearly equal and similarly distributed and used seasonally.

Drinking water is the smallest of the three domestic demand categories. For human sustenance, each person requires 1/4-1/2 gallon of drinking water per day. Using the larger figure, a surface area per capita benchmark for drinking water demands can be calculated as follows:

Sustenance level drinking water demand:

@ 1/2 gal./day x 365 days = 182.5 gal./year ÷ 7.5 gal./cu. ft.

= 24 cu. ft./year x 12 in./ft.

= 290 sq. ft. of surface area
for one inch annual rainfall and no on-site losses

= 360 sq. ft. of surface area
for one inch annual rainfall and on-site losses of 20%

= 9 sq. ft. of surface area
for 40 inch annual rainfall.

The estimated catchment area for drinking water demands is very small compared to the area of an average residential lot. It is therefore not included as a footprint icon at the scale of a Land Use Master Plan. It is more appropriate as a footprint icon at the scale of the house lot or building envelope, with the exception of aggregating catchment areas into a community-owned and operated facility. This estimate is assumed to be constant for all further calculations.

The minimum amount of water required for household demands is estimated to be 20-25 gallons per person per day (see references). A surface area per capita benchmark for sustenance level household demands can be calculated as follows:

Sustenance level household water demand:

@ 20-25 gal./day x 365 days = 7,300-9,125 gal./year

= 975-1,220 cu. ft./year

= 11,700-14,600 sq. ft. surface area

for one inch of annual rainfall and no on-site losses

= 14,600-18,300 sq. ft. surface area or 0.33-0.42 acres
for one inch of annual rainfall and on-site losses of 20%

= 365-460 sq. ft. of surface area or about 0.01 acres
for 40 in. annual rainfall.

The above estimate of approximately 400 sq. ft. or one one-hundredth of an acre (0.01 acres) is being proposed as a sustainable lifestyle benchmark for household water demands for any location with 40 inch average annual rainfall.

Ecological Footprint Required for Wastewater Treatment

Assuming a slightly less than one-to-one ratio of wastewater to household water use (cooking and cleaning losses), the sustenance level wastewater total is assumed to be not more than 20 gal./day (7,300 gal./yr.).

Forest mantle system

Utilizing forests for the treatment of wastewater sludge has advantages over other agricultural applications. There is usually a long period of time between the application and the removal of the crop. This gives greater opportunity for the organic compounds to decompose. Subsequently, there is less of a chance that organic or inorganic compounds will enter the food chain after harvest. In addition, forests benefit from sewage sludge through increased tree growth rates, increased productivity of understory vegetation, and increased quantity and quality of feed for herbivorous animals.

Wastewater sludge can be applied to all types and ages of forest. Sludge application may be done with permanent irrigation equipment (below the surface), a travelling irrigation system, or a tank vehicle with spray equipment.

At a sludge application rate of 2,000 gal./day per acre of forest (see references), the per capita land use footprint for sustenance level wastewater treatment on forest land is 20 gal./day ÷ 2,000 gal./day per acre = 0.01 acres or about 435-440 sq. ft. Coincidentally, this is the same footprint for household water demands for locations with 40 inch annual rainfall. (Household water demand footprints will vary with average annual rainfall.)

Grasslands

Sludge application rates for subsurface drip irrigation type on-site wastewater treatment systems in open spaces (recreational land, grasslands, and prairies) vary with soil type and slope. The range is 0.1-0.3 gal./day/ per sq. ft. of drainfield vegetation. Drainfield vegetation must be specified, established, and maintained and erosion control procedures must be followed to prevent topsoil loss while vegetation is being established. At a sludge application rate of 0.1 gal./day /sq.ft (see references), the per capita land use footprint for sustenance level wastewater treatment on grassland is 20 gal./day ÷ 0.1 gal./day/sq.ft. = 200 sq. ft. Assuming a one-to-one ratio of dryland grassland (native prairie) to irrigated grassland requires that the footprint be increased 100%. Therefore, the per capita footprint for wastewater treatment on grasslands is about 400 sq. ft. or almost 0.1 acres.

Per capita food production water use ecological footprint

Water demands for food production are much greater than drinking and household demands. Grains will be used as the source of food energy in the following analysis because they are the dominant food crops in all diets - vegetarian, lacto-vegetarian, and meat. Producing one ton of harvested grain consumes about 1,000 tons (235,000 gallons) of water just for the crop's evapotranspiration needs and not including losses because of inefficiencies. Hence, a 1,000 to 1 ratio of water weight to grain weight is the theoretical minimum water requirement for grain production.

In the field, water is lost in many ways, making the theoretical minimum almost always unattainable for most crops. To harvest one ton of wheat in Oklahoma, farmers use four thousand tons of irrigation water and for one ton of rice in a tropical climate, farmers use five thousand tons of irrigation water. The global average water consumed (not withdrawn) per ton of grain is estimated to be 3.3 thousand tons. Therefore, in the field, the actual water to grain weight ratio is about 3,300 to 1.

One kilogram (2.2 pounds or about 0.001 tons) of wheat flour, on average, supplies 3,500 kilocalories of food energy. In very round numbers, people need a minimum of about 2,000 kilocalories of food per day. To produce a wheat diet of 2,000 kilocalories per day requires about 0.6 kilograms (1.25 pounds) of wheat per day. If the water to grain weight ratio is 3,300 to 1, then 4,125 pounds, or about 2 tons of water are required to produce 2,000 kilocalories of food energy from wheat. Converting to gallons, about 485 gallons per day are needed if the above figures are accurate.

If efficiency improvements can reduce the water lost during irrigation, then this number can be reduced. Assuming a 50% reduction in irrigation water use (see Postel), such improvements can potentially reduce the water to grain weight ratio to roughly 2,000 to 1. If so, then 2,500 pounds, or about 1 1/4 tons of water would produce 2,000 kilocalories from wheat. Converted to a liquid measure, this is about 300 gallons per day. This is a theoretical minimum since food losses during harvest, production, and distribution have not been included. Assuming a 20% factor for food losses yields a total of 360 gallons per day.

This amount of water can be converted into land use terms. The amount of catchment area per inch of rainfall per capita, assuming a 100% runoff recovery rate, required to supply the water demands for a vegetarian diet can be calculated as follows:

Per capita water demands for a vegetarian diet:

@ 360 gal./day x 365 days /yr. = 131,400 gal./year ÷ 7.5 gal./cu. ft.

= 17,500 cu. ft./year x 12 in./ ft.

= 210,200 sq. ft. surface area or 4.8 acres
for one inch of annual rainfall and 100% runoff recovery

= 5,255 sq. ft. surface area or 0.12 acres
for 40" annual rainfall and 100% runoff recovery.

Before adjusting these estimates for runoff conditions, the same calculation procedure will be used to estimate the per capita water catchment area required for a meat diet.

Estimates of how many calories of plant food must be produced to obtain a calorie of animal food range from about 5 to 16. Using an average figure of 10 calories of plant food for every calorie of animal food and assuming that 20% of calories in our diet come from animal products yields a figure of 840 gallons per day for a daily diet of 2,000 kilocalories. These calculations do not take into account any food losses during production and distribution. A 20% loss would increase the water requirement per person for a diet of wheat and meat to about 1,000 gallons per day.

This amount of water will also be converted into land use terms. The amount of catchment area per capita, assuming a 100% runoff recovery rate, required to supply the water demands for a meat diet will be:

Per capita water demands for meat diet:

@ 1,000 gal./day x 365 days/yr. = 365,000 gal./year ÷ 7.5 gal. per cf

= 48,700 cu. ft./year x 12 in./ ft.

= 584,000 sq. ft. surface area or 13.4 acres
for one inch of annual rainfall and 100% runoff recovery

= 14,600 sq. ft. surface area or 0.33 acres
for 40" annual rainfall and 100% runoff recovery.

The water catchment areas must now be adjusted for runoff percentages. In estimating water catchment areas for household demands, rooftops provided the catchment surface and captured runoff was assumed to be quite high, around 90%. For estimating water catchment areas for irrigation, land covered by natural vegetation is assumed to be the catchment surface and the percentage of captured runoff will be much less. A figure of 20% has been estimated for the recoverable portion of global average runoff. Hence, the above figures for water catchment area must be increased fivefold. Some regions of the U.S. have only a 10% recovery rate, requiring a tenfold increase in catchment area.

A summary of water catchment areas for vegetarian and meat diets is presented below in Table W-1. The ecological footprint of the water catchment needs of a meat diet is almost three times larger than a vegetarian diet. The water catchment area for domestic water supplies can be provided by a building rooftop. The relatively large catchment area required for food production needs to be provided in large part by land surfaces for both vegetarian and meat diets.

TABLE W-1:
ANNUAL PER CAPITA WATER CATCHMENT AREAS FOR FOOD PRODUCTION

DIET / RUNOFF RECOVERY		CATCHMENT AREA 1" RAINFALL	CATCHMENT AREA 40" RAINFALL
VEGETARIAN	100% Recovery	210,000 SF / 4.8 AC	5,255 SF / 0.12 AC
	20% Recovery	1,050,000 SF / 24 AC	26,275 SF / 0.6 AC
	10% Recovery	2,100,000 SF / 48 AC	52,550 SF / 1.2 AC
MEAT	100% Recovery	584,000 SF / 13 AC	14,600 SF /0.33 AC
	20% Recovery	2,920,000 SF / 67 AC	73,000 SF /1.67 AC
	10% Recovery	5,840,000 SF / 134 AC	146,000 SF /3.33 AC

NOTE: Assuming 20% food losses.
[All calculations by the authors.]

Lifestyle assumptions

Domestic water demands per capita for three levels of consumption are summarized in the Table W-2 below. From lowest to highest, they are: minimum sustenance level, average American consumer level after water conservation measures have been implemented, and current average American level. Using these figures, the footprint for water conservation household demands is:

Water conservation level household demand:

@ 40-60 gal./day x 365 days = 14,600-21,900 gal./year

= 1,950-2,900 cu. ft./year

= 23,400-35,000 sq. ft. surface area
for one inch of annual rainfall and no on-site losses

= 29,200-43,800 sq. ft. surface area or 0.7-1.0 acres
for one inch of annual rainfall and on-site losses of 20%

= 730-1,095 sq. ft. of surface area or about 0.017-0.025 acres
for 40 in. annual rainfall.

TABLE W-2:
PER CAPITA DOMESTIC WATER USE FOR THREE LEVELS OF CONSUMPTION

DEMAND	WATER QUANTITY IN GALLONS PER DAY		
	SUSTENANCE	AVERAGE AMERICAN WITH CONSERVATION	AVERAGE AMERICAN
Drinking	0.25-0.5		
Household (hygienic)	20 - 25	40 - 60	75 - 100
Landscape	5 - 15	25 - 50	50 - 100
TOTAL	**25 - 40**	**75 - 110**	**125 - 200**

NOTES:
1. Distribution losses are not included.
2. Drinking water demands are assumed to be constant.
3. Sustenance level landscape demands are assumed to be about one-quarter of average American water conservation demands and one-tenth of average American demands.
[Adapted from Cohen 1995, 307-311; Clarke 1991, 19; Falkenmark and Lindh 1976, 22; Parfit 1993, 26; Postel 1996, 21; Texas Center for Policy Studies 1995, 10-15]

The above calculations indicate that the surface area requirement of an average American water conservation scenario is two to three times greater than the sustenance level surface area, the proposed benchmark. Hence, the ecological footprint of the water conservation scenario is a factor of two to three.

The same calculation procedure can be used to determine the ecological footprint of the average American level of household water demand. The demands are 75-100 gallons per day. The results of the same calculation procedure are:

Average American household water demand:

= 54,750-73,000 sq. ft. surface or 1.25-1.7 acres
for one inch of annual rainfall and on-site losses of 20%

= 1,370-1,825 sq. ft. of surface area or about 0.03-0.04 acres
for 40 in. annual rainfall.

The estimated ecological footprint of average American household water demand is a factor of 4-5 times more than the proposed benchmark. A summary of per capita catchment area requirements for domestic water demands is presented below in Table W-3. The water demands for landscape uses have not yet been included.

TABLE W-3:
ANNUAL PER CAPITA WATER CATCHMENT FOR HOUSEHOLD USES

LIFESTYLE	CATCHMENT AREA 1" RAINFALL	CATCHMENT AREA 40" RAINFALL
Sustenance	16,000 SF / 0.37 AC	400 SF / <0.01 AC
Water conserving	32,000 SF / 0.74 AC	800 SF / <0.02 AC
Average American	64,000 SF / 1.48 AC	1,600 SF / <0.04 AC

NOTES: Assuming 20% water losses. Figures are averages of above calculations. [All calculations by the authors.]

Several further lifestyle assumptions have been made for arriving at per capita footprint icons for food production water harvesting. Regarding the footprint icon for a vegetarian diet, a daily requirement of 2,000 kilocalories per day is assumed to be the minimum dietary needs for human sustenance. The footprint icon for site runoff must therefore be, at a minimum, adequate to provide the water requirements of a sustenance level diet. This minimum footprint icon is 210,000 sq.ft. for one inch of rainfall at 100% rate of recovery. Adjustments for climate and soils must be made using this figure as the minimum starting point.

It is assumed that the vegetable content of the diet of the average American is the same as that of a complete vegetarian diet. Thus, the food production water harvesting footprint icon for all three lifestyles is assumed to be constant.

For a meat supplemented diet, it is assumed that the average American consumes ten times more meat than the sustenance level minimum. This assumption is based on statistics for meat consumption for various countries. For example, the average American consumes over 50 times more meat per year than the average Indian -75 kg (about 165 pounds) compared to 1.5 kg (about 3 pounds) - and at least 10 times more meat than most citizens of European countries. Thus, the food production water harvesting footprint icon for a meat diet is ten times the sustenance level for the average American. Assuming meat consumption can easily be reduced by 50%, the footprint icon for the conservation lifestyle is reduced proportionately.

Integration potential

The domestic water footprint icon can be nested in or overlap the following footprint icon(s):

- Photovoltaics for household electrical energy.
- Photovoltaics for passenger vehicles.

For example, a roof surface can support photovoltaic panels as well as harvest rainwater.

The food production water icon can be nested in or overlap the following footprint icon(s):

- Trees required for carbon sink forests and woodlands.
- Cropland for a vegetarian diet.
- Cropland and rangeland for a meat diet.
- Biomass production for ethanol fuel.
- Biomass production for wood heating.

Water runoff occurs on the surface of all these land uses (although at varying rates) and can be collected and stored for food production in catchment areas and retention ponds located throughout the settlement site (depending, of course, on topography and percolation rate).

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SAMPLE OF EXCEL SPREADSHEETS FROM THE PREVIOUS

DATASHEETS

Some of the original formulas used specific ranges for values to calculate the ecological impact. However, for the sake of simplicity, I averaged those ranges so the formulas can be used to any situation for quick estimations. Some formulas were left blank when no information was provided for calculation.
The idea is that the user can copy these formulas into an Excel® spreadsheet leaving the "Value" blank. The formulas will refer to that cell (Value) and do the calculations according to the formulas written after the = sign, where the "Value" should be replaced by the corresponding blank cell. After obtaining the final results, the designer can have an understanding of the overall project's footprint and what are the most critical aspects of ecological impact to be addressed.

AIR

Ecological Footprint for O_2

# PEOPLE	A.D.I. (POUNDS)	A.D.I. (GRAMS)	# OF MATURE TREES	T.A. (ACRES)
Value	=1.84 * Value	=840*Value	=5*Value	=0.11*Value

A.D.I. = average daily intake

T.A. = Tree's area, assuming trees with 35' in diameter

Human Ecological Footprint for CO_2

# PEOPLE	OUTPUT (POUNDS)	OUTPUT (GRAMS)	LEAF SURFACE (FT^2)	T.A. (ACRES)
Value	=2.7*Value	=1225*Value	=430*Value	=0.18*Value

T.A. = Tree's area, assuming trees with 35' in diameter

USA Annual Ecological Footprint for CO_2

# PEOPLE	CO_2 (TONS)	CO_2 SINK P/C. (ACRE)
Value	=21*Value	=9.5*Value

LUMBER

Sustainable Lumber Harvest Footprint

FT^2 SPACE	BOARD FT. LUMBER
Value	=5.5*Value

Straw Bale Walls Footprint

# PEOPLE	ACRES	CONSERV. LIFESTYLE ACRES	SUST. LIFESTYLE ACRES
Value	=3*Value	=2*Value	=1.5*Value

Earth Walls and Floor Footprint

# PEOPLE	FT^2 SPACE	CONSERV. LIFESTYLE FT^2	SUST. LIFESTYLE FT^2
Value	=750*Value	=625*Value	=500*Value

CROPLAND

Land area per capita for cropland (vegetarian)

CURRENT SITUATION	# PEOPLE	HECTARES	ACRES
World average, developed regions	Value	=0.7*Value	=1.75*Value
World average, less-developed regions	Value	=0.25*Value	=0.625*Value
U.S., average, industrialized	Value	=0.7*Value	=1.75*Value
India, present condition	Value	=0.3*Value	=0.75*Value
U.K., average, industrialized	Value	=0.13*Value	=0.5*Value
U. S., industrialized, highest recorded yields	Value	=0.05*Value	=0.125*Value

Land area per capita for cropland and rangeland/partial meat diets

CURRENT SITUATION	# PEOPLE	HECTARES	ACRES
World average, developed regions	Value	=2*Value	=5*Value
World average, less-developed regions	Value	=0.8*Value	=2*Value
U. S., high meat diet - 100+ kg/year	Value	=3*Value	=7.5*Value
India, low meat diet - 2 kg/year	Value	=0.4*Value	=1*Value
U.K., average, industrialized	Value	=0.4*Value	=1*Value
U. S., self-sufficient small farm	Value	=0.4*Value	=1*Value

Estimations on Cropland/Population

TIME	WORLD POP.	CROPLAND		CROPLAND PLUS PASTURE	
	(MILLIONS)	persons/ac	ac/person	persons/ac	ac/person
1995	5600	1.7	0.59	0.5	1.98
+ 10 years	6,500	1.9	0.53	0.55	1.82
+ 50 years	10,100	4.5	0.22	1	1
+ 100 years	14,600	14.6	0.07	1.31	0.76

Per Capita Food Production Benchmarks for Sustainable Settlements

LAND USE SCALE	COMMENTS	# PEOPLE	FTP (ACRES)	FTP. (FT^2)
Residential Lot	•Home garden •Largest area manageable by one person in spare time	Value	=0.01*Value	=400*Valu e
Neighborhood or Community	•Average home garden size in U.S. •Can provide a large portion of a wide variety of vegetables consumed by one person • i nimum recommended area assuming intermediate yields for local and community regional self- reliance (vegetarian diet)	Value	=0.1*Value	=4000*Val ue
Watershed or Metro Region	• Case study and theoretical study minimum (rangeland)	Value	=0.5*Value	=21800*V alue
Bioregion	• Case study minimum with low meat diet (cropland + rangeland)	Value	=1*Value	=43600*V alue

Land area per capita for aquaculture footprint (fish)*

# PEOPLE	AQUALAND FT^2
Value	=150*Value

*Assuming further that 25% of a person's protein requirement comes from fish yields a net requirement of roughly 3,300g per year of protein from fish.

ELECTRICITY

Photovoltaic Panels Footprint (Light and Appliances)*

# PEOPLE	FT^2 SPACE
Value	=1000*Value

*Assuming a 4-5 hour average daily charging period

Photovoltaic Panels Footprint (Passenger Vehicle)*

# CAR	FT^2 SPACE
Value	=250*Value

*Assuming a 4-5 hour average daily charging period

BIOMASS

Biomass for Ethanol Footprint

# VEHICLE	ACRES
Value	=4*Value

Biomass for Wood Heating Footprint *

4,000 HDD	# PEOPLE	BTU/YEAR	ACRES AT 1 HARVEST P/ YEAR (5,000,000 BTU/ACRE)
20,000 BTU/ft^2	Value	=20000*750*Value	=3*Value
80,000 BTU/ft^2	Value	=80000*750*Value	=12*Value
160,000 BTU/ft^2	Value	=160000*750*Value	=24*Value

*Assuming a climate with about 4,000 annual heating degree days (Washington, D.C. and environs) and an indoor temperature of 68-72 degrees F with average winter wind speed.

WATER

Annual per capita water catchment areas for food production:

DIET / RUNOFF RECOVERY		# PEOPLE	CATCHMENT AREA ft^2 1" RAINFALL	CATCHMENT AREA Ac. 40" RAINFALL
VEGETARIAN	100% Recovery	Value	=210000*Value	=0.12*Value
	20% Recovery	Value	=1050000*Value	=0.6*Value
	10% Recovery	Value	=2100000*Value	=1.2*Value
MEAT	100% Recovery	Value	=584000*Value	=0.33*Value
	20% Recovery	Value	=2920000*Value	=1.67*Value
	10% Recovery	Value	=5840000*Value	=3.33*Value

Per capita domestic water use for three levels of consumption:

DEMAND	# PEOPLE	WATER QUANTITY IN GALLONS PER DAY		
		SUSTENANCE	AVERAGE AMERICAN WITH CONSERVATION	AVERAGE AMERICAN
DRINKING	Value	=0.375*Value		
HOUSEHOLD (HYGIENIC)	Value	=22.5*Value	=50* Value	=87.5* Value
LANDSCAPE	Value	=10*Value	=37.5* Value	=75* Value
TOTAL	Value	=32.5*Value	=92.5* Value	=162.5* Value

Annual per capita water catchment for household uses:

LIFESTYLE	# PEOPLE	CATCHMENT AREA ft^2	CATCHMENT AREA ft^2
		1" RAINFALL	40" RAINFALL
SUSTENANCE	Value	=16000*Value	=400*Value
WATER CONSERVING	Value	=32000*Value	=800*Value
AVERAGE AMERICAN	Value	=64000*Value	=1600*Value

Water conservation level household demand:

DEFINITION	# PEOPLE	AREA FT^2	AREA ACRES
1" RAINFALL, NO ON-SITE LOSSES	Value	=29200*Value	
1" RAINFALL, 20% ON-SITE LOSSES	Value	=36500*Value	=0.85*Value
40" RAINFALL	Value	=912.5*Value	=0.021*Value

Water demands for meat diet:

DEFINITION	# PEOPLE	AREA FT^2	AREA ACRES
1" RAINFALL, 100% RUNOFF RECOVERY	Value	=584*Value	=13.4*Value
40" RAINFALL, 100% RUNOFF RECOVERY	Value	=14600*Value	=0.33*Value

Water demands for a vegetarian diet:

DEFINITION	# PEOPLE	AREA FT^2	AREA ACRES
1" RAINFALL, 100% RUNOFF RECOVERY	Value	=210200*Value	=4.8*Value
40" RAINFALL, 100% RUNOFF RECOVERY	Value	=5255*Value	=0.12*Value

Average American household water demand:

DEFINITION	# PEOPLE	AREA FT^2	AREA ACRES
1" RAINFALL, 20% ON-SITE LOSSES	Value	=63875*Value	=1.475*Value
40" RAINFALL	Value	=1597.5*Value	=0.035*Value

Sustenance level household water demand:

DEFINITION	# PEOPLE	AREA FT^2	AREA ACRES
1" RAINFALL, NO ON-SITE LOSSES	Value	=13150*Value	
1" RAINFALL, 20% ON-SITE LOSSES	Value	=16450*Value	=0.375*Value
40" RAINFALL	Value	=412.5*Value	=0.01*Value

Sustenance level drinking water demand:

DEFINITION	# PEOPLE	AREA FT^2
1" RAINFALL, NO ON-SITE LOSSES	Value	=290*Value
1" RAINFALL, 20% ON-SITE LOSSES	Value	=360*Value
40" RAINFALL	Value	=9*Value
15" RAINFALL, 20% ON-SITE LOSSES	Value	=135*Value

APPENDIX 5

This appendix presents the main features of ake|Flato's sustainability toolkit with several recommendations that refer to manual calculations, the use of specific software, reference to databases, etc. The recommendations of this toolkit are presented in a concise manner and are considered as complementary material and guides to be used with DEPROSU.

ake|Flato's sustainability toolkit helps designers dealing with the following categories or tasks (in no particular order):

- Solar orientation and shading (climate analysis template and sizing overhangs);
- Energy (2030 Challenge, post-occupation evaluation, among others);
- Wind (natural ventilation strategies and calculation);
- Materials (VOCs, sustainably harvested wood, Living Building Challenge Red List, etc);
- Water (heating and rainwater collection/calculation);
- Glazing (properties, recommended light levels, etc); and
- Renewables (geothermal, PVs, etc).

The next paragraphs break down the aforementioned categories providing relevant information for each. Each category contains a list of steps and considerations to take while designing, as well as resources for estimations and recommendations for different design stages.

Overhangs dimensioning:

Architects prefer using 3D tools to interactively evaluate the performance of their designs (Attia et al., 2009). For this approach, some authoring tools already have embedded sun paths in a 3D model (e.g., Revit Architecture and ECOTECT) where the shadows are projected and the designer can evaluate their designs' capacity to allow or block sun radiation for specific dates and times.

Some heuristics are included here to help designers calculate overhangs dimensions without a 3D tool, based on ake|Flato's sustainability toolkit: before sizing overhangs, designers have to understand the concept of seasonal lag. For example, June 21st is identified (in the north hemisphere) as the day with the highest solar radiation. However, the hottest months in the year are usually July and August. Earth's thermal mass keep the heat generated in June and release it later on. For that reason, solar gain will never really match the Heating Degree Days and Cooling Degree Days. To overcome that issue, best practices recommend finding the mean of shading size to optimize its function, considering a month earlier to allow sun radiation in heating seasons and to start blocking the sun one month earlier for cooling seasons. Then, the designer can use solar path to look at sun angles for the time-range specified above. The optimized sun angle will be symmetrical over a sun chart, considering for example, March 21st and September 21st, which will appear as a horizontal line. The University of Oregon has a website to help creating sun path charts for any location:

http://solardat.uoregon.edu/SunChartProgram.html

The next step will be to draw a section view and project the sun angles with lines touching the edge of the overhang. Designers must select Summer Solstice, Winter Solstice and the optimized sun angles. The optimized sun angle and the Summer Solstice should block completely any solar radiation, while the Winter Solstice should allow sun radiation for passive heating.

Glazing

According to the ASHRAE Energy Design Guide, a window-to-wall-ratio (WWR) should be between 20-30% to provide adequate views to the outdoors. A formula is provided where WWR x VLT (Visible Light Transmittance) = effective aperture, and the effective aperture for daylighting should be between 1.5-3.0. Skylights' recommendation is to be limited to 5% of the ceiling area. Windows placed below 30" are not recommended. Instead, high and continuous horizontal windows are more effective than individual or vertical windows. The top of a window is recommended to be close to the ceiling, and the window's sill should be no higher than 4' to enable good views.

Daylighting Analysis

The use of software such as Radiance and Daysim enables designers to calculate annual/hourly performance of their design using 3D models, and to evaluate them under different parameters, such as Useful Daylight Index (UDI), Daylight Autonomy (DA) and Daylight Factor (DF). Radiance and Daysim are arguably the best and most used simulation tools for accurate daylighting analysis, however, these tools have limitations when dealing with complex shading devices (Reinhart & Herkel, 2000). For complex shading devices, the use of scale models and light sensors under natural sun exposition or a heliodon are a better choice for accuracy, but the model should have an accurate representation of materials in the room, with their respective transparency, specularity and reflectivity. For standards on daylighting, designers usually refer to the IESNA Lighting Handbook (http://www.iesna.org/).

PV - Electricity

The installed cost for PV is about $5-6/Watt (panels run between $2-2.25/Watt exclusive of labor).

Size

Panels are typically 3’ x 5’ = 15 s.f. Each panel produces approximately 200-230 Watts. A good “rule of thumb” estimate will be 3-4 Watts per square foot for 100% offset. You can also use this calculator by NREL (http://www.nrel.gov/rredc/pvwatts/site_specific.html).

Batteries

The minimum cost for storage batteries is about $10,000. Batteries must be installed in a battery enclosure. The enclosure should be very close to the inverters because the DC current requires large cable sizes, particularly as you get more than 10’ away. Batteries should be the sealed type, as the lead acid battery alternatives are problematic indoors – they require venting to the outside and cause rust.

Angle

Placing solar panels at latitude tilt angle and due south (in the north hemisphere) optimizes performance. However, for all practical purposes, deviating less than +/- 30 degrees from due south, and deviating less than +/- 10 degrees from latitude tilt makes no real difference in performance (less than 3%-4%). Depending on the climate and its HDD/CDD, it could be beneficial to have a flatter tilt. Sunny and hot/humid climates such as Texas usually consume more energy during the summer (cooling season), and a flat PV will be more exposed to the sun, hence, being more efficient.

Evacuated Tubes - Hot Water

Evacuated tubes perform better than PV in any climate, especially where it's cloudy. This technology has not been widely used for conditioning buildings yet, but its adoption is increasing. The main issue is that the number of collectors needed to heat and cool a home requires larger roof areas than most residential buildings.

Wind

Wind power is generally not suited for urban systems. You will need sustained winds of at least 10 mph for this to be a feasible option. The turbine should be mounted at least 25' above the nearest obstacle within a 500' radius. The higher the turbine, the better (less turbulence, and a better investment).

Ground-Source Heat Pump (Geothermal)

The installed cost for a geothermal heat pump in 2010 is about $7,200/ton before the federal tax credit is applied. This approximate cost includes the mechanical unit, ductwork, and boreholes. The price is expected to increase by about 15% each year from now on with the rising cost of materials (particularly metal and copper). This price is approximately $2,000/ton more than the highest efficiency dual-speed air-source heat pump system on the market, or $5,000/ton more than a conventional HVAC system. However, geothermal's efficiency does not slow down above 100°F and it eliminates the energy needed for water heating.

Heat removed from the building during cooling mode can be deposited to your water heater for “free.” If you have a geothermal heat pump, then you should plan to use a tank type water heater to take advantage of this.

Energy Model

Before creating an energy model, the designer needs to provide the following information (minimum), according to ake|Flato’s sustainability toolkit:

- Area of conditioned space and its perimeter
- Average ceiling height
- Foundation type (slab on ground, underground/basement, etc.)
- Area of above-grade wall and wall’s insulation and material construction
- Area of glazing for each orientation and an average overhang distance (if applicable)
- Mechanical equipment type and fuel used (water heating, HVAC, etc.)

Additional information should be discussed with the team, such as operating schedule, equipment/lighting schedule, etc. The use of software such as eQUEST enables designers to easily create their own energy model with a user friendly GUI, but the feedback from a specialist is always welcome to fine-tune the model and its equipment specification. The energy model would give designers a snapshot of the design's performance to compare against the performance targets (2030 Challenge, Energy Star, LEED, etc.). It is important to highlight the scope and limitations of BES as a way to measure approximate performance only.

Natural Ventilation (adapted from Lake|Flato's sustainability toolkit)

When considering natural ventilation, designers should not only rely on a wind rose chart because most likely, the weather station location has different obstructions to wind as your site, even more if your site is an urban site. Consider the topography, vegetation and neighbor buildings as obstructions. Nonetheless, there are several rules of thumbs for natural ventilation (Olgyay, 1963):

- Place inlets on windward walls related to the space you are trying to ventilate.
- Place outlets on leeward walls. The location of the outlet is insignificant unless you have obstructions to it.
- By creating a larger outlet compared to the inlet, a designer may exploit the Venturi effect, expediting air flow within the space
- Natural ventilation is effective up to 45 feet in depth from the window.
- The window type does direct the movement of air if it projects into the stream of air.

Rain water harvesting

Multiple tanks are a good approach, having one as a backup while the other is cleaned and or maintained. The base of the cistern usually has between 6-8” level sand pad extended 1’ past tank all the way, but designers need to add 2’ to the cistern diameter. The edges of tank should be lapped with large gravel. If collecting potable water, Cor-Ten steel should not be used.