Title: Green BIM Adoption, an Agile Approach

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Contents

Introduction:

The energy consumption issues of the United States cannot be discussed without the inclusion of the energy needs in the building sector. Currently there are approximately 76 million residential structures and 5 million commercial structures in the United States [1]. As the population grows upward of 311 million people, the need for additional buildings will correspondingly increase [2]. Currently, buildings account for approximately 40% of total energy and 70% of electricity usage [4]. Additionally, the cost of energy in the United States has also been increasing. As the rest of world develops and industrializes, the demand for energy is going to increase due to the economic elasticity in the energy sector.

When a consumer builds a structure, there is a formula that goes into the decision for the selection of materials, and construction technique. The formula is very similar to the purchase of goods or services, and can be described as the accumulation of fixed and variable costs. Using this technique the consumer bins the costs of purchasing a product into categories of either fixed cost (costs that are not dependent on usage or level of service) or variable cost (costs that vary with usage level). For example when a contractor is choosing products to occupy a commercial space, they may consider the cost of purchase and the installation cost multiplied by the quantity that is required.

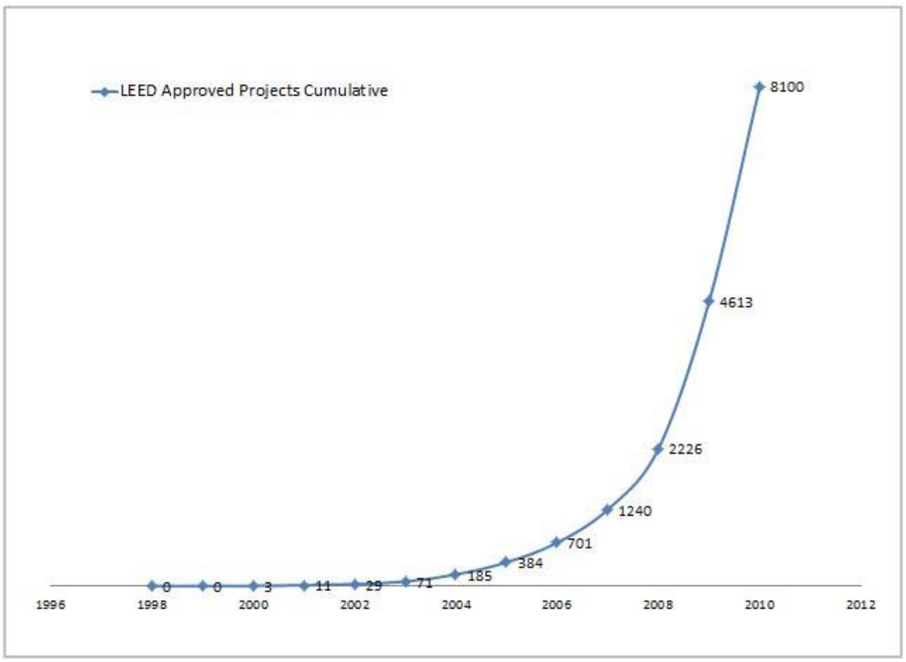
Given the current energy demands of the United States, and rising cost of energy it is in the best interest of companies to decrease the total lifecycle cost for a building and structure. In the building sector the user would take into account the operating cost of a structure with respect to energy usage and efficiency over the total life of the structure. This measure is critical to decreasing total energy usage in the United States because the median lifespan of a building is between 65 and 80 years [3]. Therefore, after a construction decision has been made the next opportunity to integrate a new decision or opportunity to implement an energy efficient option is lost until a replacement is needed. However, during the initial construction of buildings, there are opportunities for increased efficiencies and usage of decision models that encompass the total lifecycle cost.

Additionally, there are normalizing tools that can be used by contractors and builders that can help push industries in the correct path with respect to decision making. Some of these tools are rules of thumb, building codes, and third party certifications (such as LEED). Each of these tools, takes the decision making factors away from the user, and essentially disconnects the decider from the decision drivers. The contractor and architect must be fully engaged in the decision making process, and learn from the collective mistakes of the industry while concurrently striving for improvement. The industry must continually evolve their best practices to achieve the energy efficiency levels required for future efficiency requirements [5].

The growth of the Leadership in Energy and Environmental Design [6] rating system is a prime example of the interest in energy efficiency and environmental responsibility in the built environment. The U.S. Green Building Council's LEED program is indisputably leading in encouraging, evaluating, and recognizing energy efficiency and environmental design. From the inception of the program in 2000 recognition and adoption have been steadily growing. As interest and adoption has grown the rating system has also been evolving to include increasingly more efficient prerequisites and sophisticated technologies.

Figure #1 identifies the growth that LEED certified buildings have grown since the inception of the organization.

Figure #1 LEED Adoption



Interest in the movement represented by LEED has evolved from novelty to necessity. The relationship between the built environment, energy efficiency and energy generation opportunities fall in to the mercy of assisting technologies, specifically the proper utilization of Green BIM software. Such powerful tools will prove to be imperative to future successes.

Problem Statement:

Even though energy efficiency provides obvious benefits to new or retrofitted buildings and is widely seen as an appropriate approach to handle the increasing energy and the environment problems, the process of getting there is prohibitively complex and full adoption of energy efficiency in new buildings has been low. While the individual level of energy-efficient aspects like appliances and materials are progressing, the aggregate level of integrating these individual pieces to maximize the energy efficiency potential (Green BIM in particular) seems lagging. This report then aims to investigate major factors and introduce the use of Agile project management concept to enhance Green BIM adoption while ultimately increasing energy efficiency in new or retrofitted buildings.

Building Information Modeling:

Building Information modeling (BIM) is the process of using computer systems to develop computer generated models that can simulate the planning, design, construction, and operation of a building [7]. BIM allows all engineers participating in a construction project to fully and truly construct a building virtually, and in detail. In addition, BIM can be later used by building owners to manage the building throughout its lifecycle.

The use of computer systems is not new in the construction field. Computer aided design (CAD) software is still widely used in generating 2D and 3D designs for buildings. The main difference between BIM and CAD is that CAD describes different building views that are unrelated to each other. So, if one of these views is edited, then all other views must be updated manually, which causes high rates of errors and poor documentation. In addition, data in these CAD designs don't include intelligent semantic data. BIM models make use of object-oriented data structures, famous computer science approach, where objects are defined in terms of building elements and systems [7].

"A building information model characterizes the geometry, spatial relationships, geographic information, quantities and properties of building elements, cost estimates, material inventories and project schedule." [7] As a result, BIM provides an accurate representation of a building in an integrated data environment. With the integrated data environment, communications across different construction teams (such as plumbing, electrical wiring and air conditioning) can be performed in easier and more effective ways. The overall construction processes will be more effective due the accurate (just-in-time) design and cost simulations.

Accordingly the use of BIM eliminates up to 40% of unplanned changes. The time to generate a cost estimate is reduced by up to 80%. Additionally, clash detection can save up to 10% of the contract value [8].

Green BIM:

Green BIM is not a different system from BIM. It is the idea of utilizing BIM tools to develop more sustainable buildings. BIM has powerful analysis and simulation tools that can provide immediate insights into how design decisions may impact building performance during its lifecycle. Energy (performance) analysis, lighting analysis, building form analysis, water harvesting analysis, and renewable energy analysis are some of these analysis tools regarded as Green BIM. Typical CAD designs don't include these analysis tools. As a result, architects use semi-manual approaches to calculate building performance, which may produce inaccurate estimates and cost additional time and money [4].

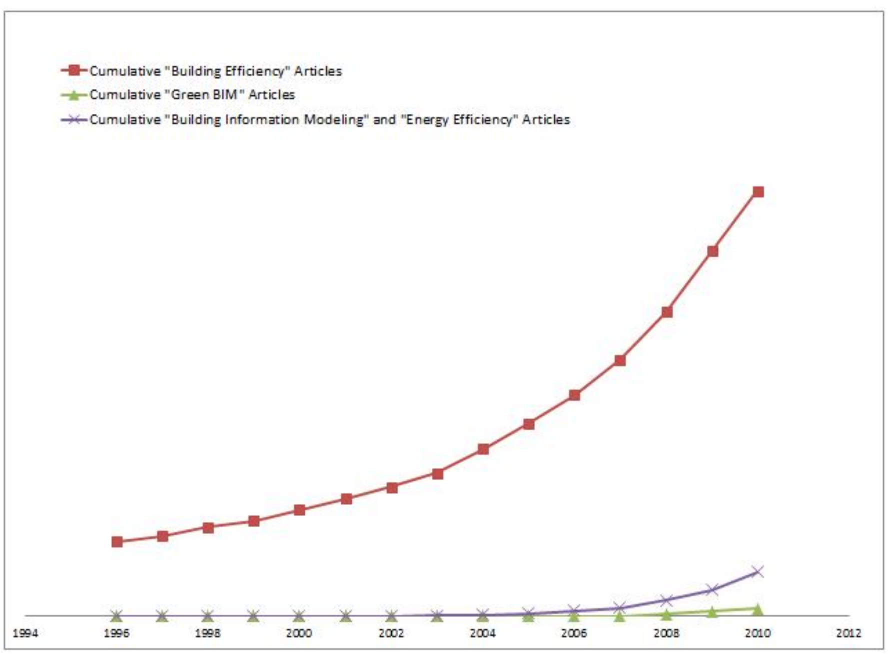
Green BIM also encourages the process of integrated design which is a critical strategy in making a building greener. Construction projects involve many building sub-systems' designs. With the use of BIM central database, critical design decisions (such as material type and quality) can be optimized based on other sub-systems decisions. This difference significantly improves the performance of buildings that are built using BIM as well as making them more sustainable.

Adoption of Green BIM:

Adoption of Green BIM is a complicated topic to discuss due to the scarcity of information. For example data for Green BIM usage and implementation during the design and construction processes are not available for analysis. Based on this lack of data, it was determined that the adoption of Green BIM could be analyzed utilizing a Biblio-metric analysis. The assumption being, that adoption would exist on an article basis before being accepted by the industry. Appendix A titled *Green BIM Search Criteria* identifies the methodology and search criteria utilized to collect the data analyzed below.

Figure 2 identifies the cumulative interest of Green BIM, and Building Information Modeling Articles that include the topic Energy Efficiency, from articles published online. The Term Building Efficiency was added to figure to compare the topic as a baseline perspective.

Figure #2 - Interest in Building Efficiency and Green BIM



As indicated by the above figure, the interest in building efficiency articles has grown steadily without sign of decreased interest. Essentially, this line indicated that professionals are interested in efficiency. The other two plotted lines in the figure are cumulative Green BIM articles, and articles containing both terms, Building Information Modeling and Energy Efficiency. As indicated by the above figure, the interest these terms is increasing and started in 2004. Based on this data it can be assumed that the interest in Green BIM will continue to grow in the future years.

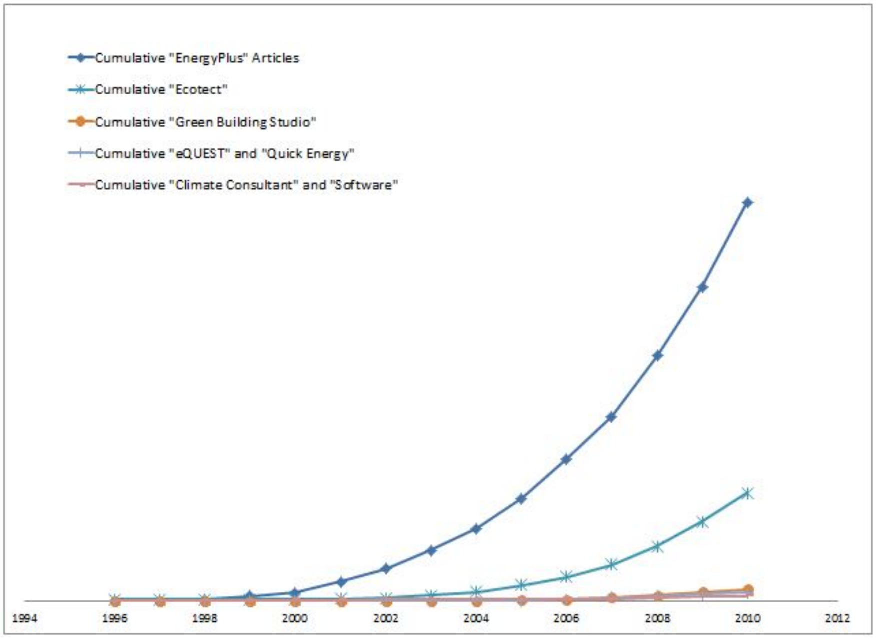
To go deeper into the adoption of Green BIM, an analysis of the specific programs is necessary. Currently, there are several prominent programs in this sector. The specific programs analyzed are identified below:

Table #1 - Green BIM programs

Program	Description
EnergyPLUS	Energy simulation program that can model heating, cooling, lighting ventilation, and water usage. Software is supported by the Department of Energy and has add-ons to improve usability and functionality [9]
Ecotect	Energy simulation program that can model thermal performance, water, solar radiation, shadows and reflections and carbon emission analysis. Software is owned exclusively by Autodesk [10]
Green Building Studio	Energy simulation program that can model natural ventilation, score energy star, day lighting, and weather analysis. Software is owned exclusively by Autodesk and is a Web based program [11]
eQuest	Energy Simulation program that is designed to be user friendly and free to download and use. Software is maintained by EnerLogic and James J. Hirsch & Associates and is mainly funded by the Department of Energy [12]
Climate Consultant	Energy simulation program that is specific to the California region, however it can link to EnergyPlus and used in other regions. Software is owned by the University of California Los Angeles[13]

Each of the above programs were analyzed using a biblio-metric analysis, Figure 3 illustrates the adoption of the specific programs that are used to complete Green BIM analysis.

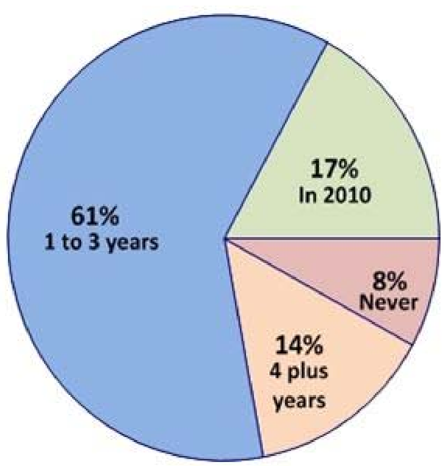
Figure #3 - Adoption of Green BIM Software



As indicated by the above figure, the growth in interest of all the Green BIM software programs has been increasing rapidly since the introduction of the programs. As indicated by the figure, EnergyPlus is exhibiting the largest amount of interest followed by Ecotect. From a market perspective these two programs make up a considerable amount of the interest from academics and publishers with respect to Green BIM.

Currently, the market is on the edge of industry wide adoption of Green BIM tools. A recent survey published by McGraw Hill Construction in the Smart Market Report on Green BIM published the following adoption information [15].

Figure #4 - Green BIM Adoption Statistics



This publication is currently forecasting an industry wide adoption with respect to a four year time frame. Although this data paints an extremely optimistic, we believe that the key take away is that Green BIM has a lot of interest from the industry. The same publication also identified a list of drivers for the adoption of Green BIM [15]. The adoption drivers are identified in sequence of importance in the following table.

Table #2 - Green BIM Adoption

Ranking	Percentage	Reason for Adopting Green BIM
1	›36%	Asked by Client
2	›28%	To be competitive
3	›18%	Improve Ability to do Green Work
4	11%	Generate greater ROI
5	›7%	Other (i.e. availability of BIM tools)

As indicated by the above table, the primary driver for a company to adopt the use of Green BIM software is from the request of the client followed by business related elements, and finally the access to BIM tools. Based on this information it can be justified that any actions that promote multiple drivers will increase the rate of adoption.

Barriers to BIM & Green BIM Adoption:

Despite the productivity and economic benefits of BIM has been increasingly acknowledged and the supporting technology has been rapidly maturing, BIM adoption in the building industry has been slow. It was identified that, besides the technology, the industry nature of being very fragmented and fixed in the work process majorly impacts the adoption rate of Green BIM [14]. In this section, barriers to BIM adoption identified according to the industry literatures [14] [16] [17] [18] are grouped into 3 categories; technical, organizational, and people/social perspectives.

Technical Barriers

Since BIM represents a new technique in dealing with information throughout the building project lifecycle, technological constraint can be viewed as an obvious barrier. According to the literatures, there are two major technical barriers. First, the computability of digital design information is essential in increasing productivity of iterative design process. Digital data used in traditional CAD system is fundamentally based on pictorial data, which is incomputable (despites being digital). The data is meaningful when read by human. However, the computer has no implicit knowledge of the information to be able to understand relationships and automatically calculate the results [14]. Second, the interoperability of the data between different parties is critical to bridge everyone involved in the building process. In addition, since BIM relies on many different purpose-built tools used by different parties, sharing meaningful design information is keyed for BIM to provide useful information flow throughout. Note that interoperability is not just the basic transactional-oriented business IT concept used in other industries like accounting and inventory control system. The application in building industry requires flexibility to deal with complexity of the design and construction process with a lack of fixed business protocols.

Organizational Barriers

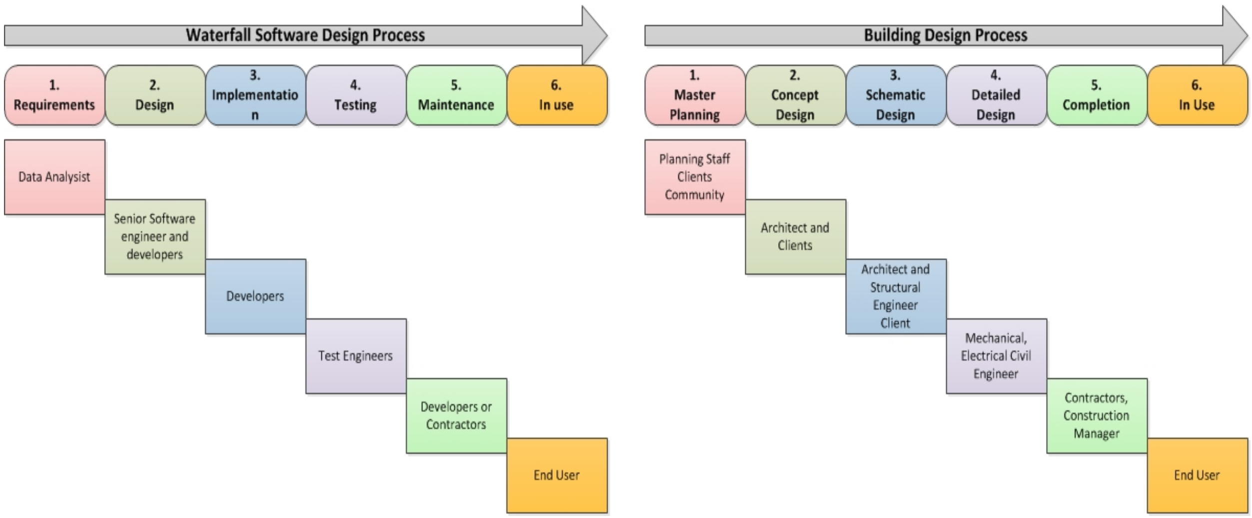
Current Project Management process for building design and construction that involves collaborations of multiple professionals is identified as one of the major BIM adoption barriers [16]. The current practice is defined as a very mature linear process, which is managed by a series of approval stages involving different functions [17]. Each function is typically from different units in the organization or from different organizations with different and many times conflicting objectives i.e. architects, structural engineers, system engineers, builders, etc. BIM, on the other hand, is introduced to work on the basis of integrated efforts among all parties. Then, there is a barrier of changing how the business has been done for decades to adopt BIM approach. Also, it was identified that there are discontinuities of risks and benefits of each party in BIM adoption that one party experiences a big cost while the other gain the benefits [14]. Thus, without the addressing this important issues, BIM would not be successfully adopted by every key player.

Personal/Social Barriers

People are identified as a major barrier according to the survey conducted in 2008 in the US and UK by Yan et. al. [18]. Most of the barrier is to allocate precious time and resources to the training process. Players in the industry including architects and engineers are by nature low margin. They are not willing to invest in BIM if there is not clear evidence of benefit that improves their bottom line profits. This is also consistent with the survey result conducted in Texas by Houston American Institute of Architects, which reported that the lack of experienced personnel, huge learning curve, and time to implement are of primary concerns [19]. In addition, the new BIM process requires changes to what they already are using and good at. There is a natural social and habitual resistance to change, as professionals are satisfied with traditional method to design their projects [18].

Traditional Building Design Process vs. the Old IT Design Process:

Figure #6 - Software vs Building Design Process



One of the major obstacles that faces the adoption of Green BIM is that the current building design “project management” process is linear and mature [17], which inadvertently conflicts with BIM (which is iterative). The principle benefit of BIM is that it overcomes most of the issues resulting from linear models such as communication conflicts and changes in later design stages. Due to the fact that the entire construction business model is based on the linear approach, BIM adoption will be very difficult with the current building design practices [16].

In order to overcome this major obstacle, a new design approach that utilizes an integrated design process should be introduced to the construction industry. After meticulous literature research, we found that similar issue was studied and resolved in the software engineering field. Waterfall lifecycle project management was one of the first software development approaches used in the software industry [19]. In this model, the software lifecycle is divided into five stages that are performed sequentially. The model starts with data gathering and analysis, the “requirement” stage, to identify user requirements. These requirements are then used to build the software in the initial design (user interface and database schema). Then developers will start building the actual product -- the “implementation stage”. Testing will be performed by a different group of engineers (test engineers) who set different test cases and validate the software results with client requirement. Finally, the maintenance stage which focus on resolving issues that are reported by customer [20].

Waterfall approach has been a good process for linear software development for certain applications that do not require change after their specifications have been defined. However, most software applications today have their specifications redefined during development because of client feedback and/or other factors. As a result, a linear development process, such as the waterfall model, is no longer appropriate. Many approaches were presented as a solution to waterfall model issues, including modified waterfall process, spiral development model, the evolutionary development model and the iterative and incremental approach [19][20]. However, none of these models were able to achieve the success that Agile development model has achieved. The main reason behind this success is that Agile has changed not only the process of developing software product, but also changed the entire culture and business model around software development [21]. In order to understand how Agile was able to achieve this success, we will discuss Agile development process, understand the key factors of success and apply them to building design process.

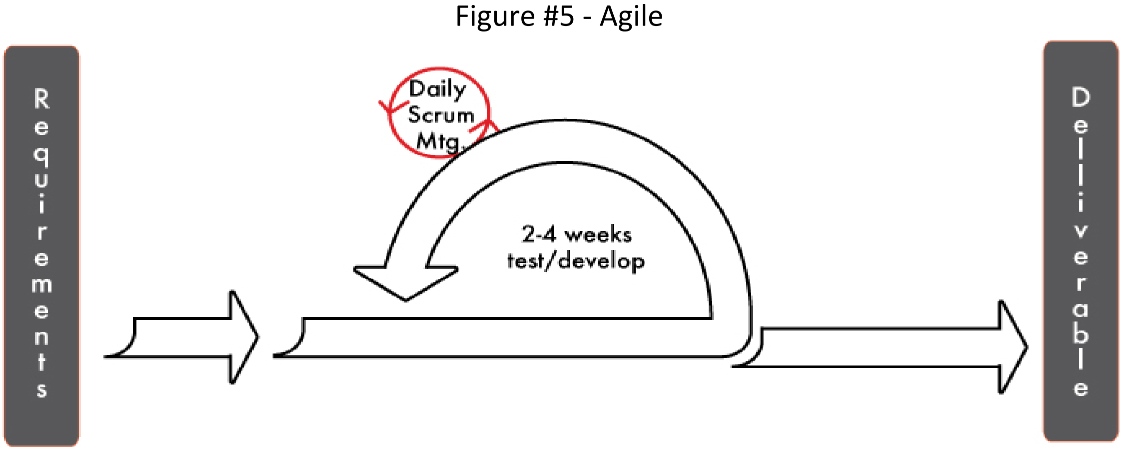
Agile Project Management Overview:

Agile is a lifecycle framework for software development processes. It's considered to be a revolution to the traditional development methods, such as Water-fall development process. Agile puts sets of engineering and management principles and techniques in a way that supports rapid and reliable software development. These techniques can handle different scale software projects. This framework fits perfectly with application domains that require development to be done in face of ambiguous and rapidly changing of requirements [22].

Since Agile focuses on delivering software products in the fastest reasonable period of time, it provides many evolutionary ideas about how to manage team communications so that it eliminates any extra work that can delay or distract software developers from their main tasks. Customers' involvement during Agile project development stages increases customer satisfaction and decreases change requests in the product lifecycle.

Agile methods agree on the idea of dividing the system features into simpler tasks that could be implemented in iterations. These iterations are delivered to the customer as working releases. The customer has an important role in ordering these tasks according to their business values.

Figure #5 - Agile



Design Process Analysis:

From the previous sections, we see that Green BIM is a great new tool that was created to help the building design industry efficiently integrate sustainable components (especially in energy efficiency application) into the building project lifecycle. However, the full capability of Green BIM (and BIM in general) is underutilized, which results in its having disappointing efficiency and full potentials unrealized [24]. Different barriers contribute to the poor adoption and under-utilization at different degrees. Among the identified barriers, the traditional linear building design and project management process is identified to have major impacts on the adoption and utilization of Green BIM [4]. As a result, the industry needs an integrated process that optimizes the use of Green BIM across all disciplines and activities ranging from planning and design to construction and operation [4] [24] [25]. The new process should be able to engage Green BIM not only in visualization of design interferences, but also in impacts of design decisions on construction, commissioning, close-out, and operation and maintenance activities.

Table #3 – Framework Comparison

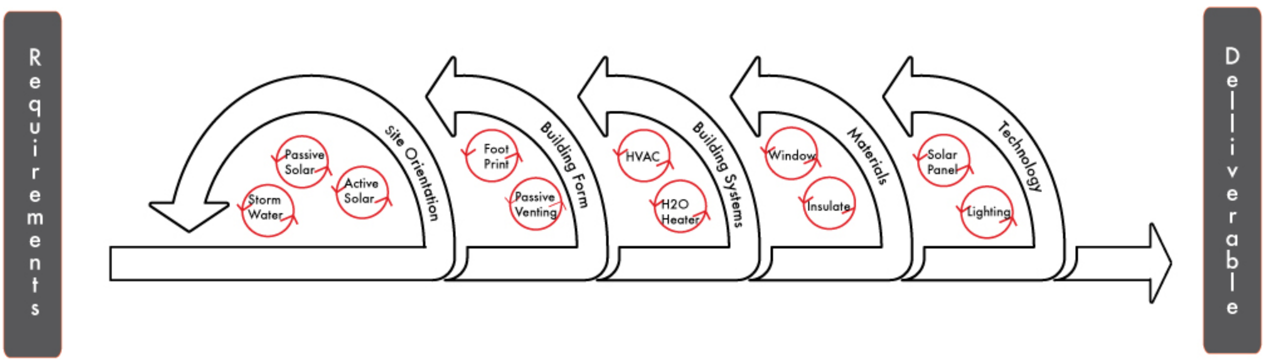
Referenced Framework: BIM-Optimized Work Procedures (Technology-enabled integrated practice model)	**Traditional (Linear)**	**AGILE**
Accelerated decision making (front-loaded) for all disciplines	*	***
Front-end involvement of stakeholders	**	***
Collaborative concurrent process (overlapping phases)	*	***
Task-based (not deliverable-based) focus	*	***
Schedule compression	*	**
Increased sharing of common sets of information	*	***
Reduced constr. change orders (design-related coordination Issues)	*	**
Reduced client-generated review comments	*	***
Reduced internal quality control review comments	*	**
Note: * indicates level of agreement with the referenced framework (* least , *** most agreed)		

This section considers the traditional linear design process and the proposed Agile framework with respect to the preferred BIM-optimized work procedures. The characteristics of the Technology-Enabled Integrated Practice Model presented by McDuffie [24] and the framework by Yudelson [25] are used as basis of comparison. The comparisons are shown in the above table. The results show that Agile satisfied all important dimensions of the preferred characteristics of the integrated design framework and that it has a great potential in being applied in the building design industry.

Agile Applied to Building Design Process:

Due the nature of architectural design, adopting the Agile management methods in the architectural design management strategy would lead to better resource conservation, design integration, and increased client satisfaction. Similar to the software design process, the architectural design process early requirements are sometimes undefined and plans need to be flexible to accommodate necessary changes.

Figure #7 - Agile Architecture



Incorporating the Agile methodology would allow for the early framework of the project to begin production, while iterative and incremental steps are developed for future implementation. Similar to Agile for software development, Agile for architectural development starts with all known requirements, resources, goals, and parameters.

From there, an architectural design will typically start addressing site issues such as building orientation opportunities and challenges. Green BIM programs offer designers the opportunity to analyze site conditions and simulate the building placement and orientation. These relatively fast feedbacks allow the designer to make changes, consult the client with measurable and options, and adjust the design as it relates to the site. This can lead to the absolute best placement and orientation of the building for the maximization of passive building system efficiency (i.e. increased day lighting, season dependent decreased and increased solar gain, and water management).

Once the site orientation is determined the green BIM software will also assist in designing the form of the building. Building form will have much impact on the efficiency of the passive opportunities inherent in the site and environment. This sprint cycle often analyzes the best size for a roof overhang, window sizes and placements, and efficiencies of various footprint sizes. With client involvement a form can be decided. This step may or may not require another site-based sprint to reevaluate the placement and orientation.

Building systems, such as heating- ventilation- air conditioning (HVAC), waste water management, irrigation management, storm water management, and on-site energy generation systems are each their own sprint, which can be run simultaneously or in an order. Running system options through the green BIM software will help in determining the most efficient options. Keeping in mind that each building-system sprint will inform other building-system sprints, a larger sprint should be run to analyze the combination of all of the building systems working in concert. This may lead to the revisiting of the building form analysis depending on the options determined by the designer and client.

Material and Technology options are the most often changing and updated. Technologies such as Energy Star products, CFL lighting options, and motion sensor switches are examples of ever expanding and increasingly sophisticated options to keep building energy consumption to a minimum. To determine the lifecycle costs for analysis in determining future returns on investment can be quickly and efficiently determined by green BIM software. Material-selection sprints are similarly used to quickly determine combined insulation values of material choice and light absorption/reflection. These options can be again, quickly analyzed, ROI determined and presented to the client.

Along the way production can easily begin regardless of the lack of completeness in the plans. As options are decided on an analysis of the chance for future change will determine whether or not it would be appropriate to begin on that phase of production. It is unlikely that choosing lighting options for an office will chance the building orientation on a site. It would be safe to begin site work while the client and designers are looking at materials and technology. Choosing an energy generation option might change the form of the building slightly to accommodate the feature. If there is a possibility of opting for energy generation the building frame should not begin production until the energy generation sprints have been completed.

Client involvements in architectural design processes vary depending on the client, the designer, expectations, and project scope. The Agile methodologies, with high levels of client feedback and consultation coupled with green BIM modeling will insure success and efficiency in production and product lifecycle. High client buy-in of the process and the project and the implementation of the steps laid out above will result in energy savings, resource savings, design integration, adaptability to changes, and high client and tenant satisfaction.

The adoption of Agile methodology to the architecture industry would promote three of the key drivers that were identified earlier. For instance it would enhance ROI for companies because the operations should increase in efficiency. The companies would have an advantage over their competition therefore they would be more competitive. And the simulation process could be used to market the companies' competency regarding energy efficiency evaluation.

Conclusion:

Introducing a building energy efficiency and sustainability concept, a new discipline that highly involves iterations and various project components, to the fragmented and linear practice process is not a simply straight forward task. New technology, Green BIM in this case, was invented to aid professionals in the building industry to incorporate such new discipline into the building project lifecycle.

Green BIM adoption is forecasted to be picking up in the near future by the industry optimists and our biblio-metric analysis, but a number of adoption barriers still exist. Among those barriers, the linear building practice is identified as a major barrier that causes disappointing results and inhibits the full potential of Green BIM technology.

It is noted that adoption rate would increase if value is realized. Then, the academic and industry literatures emphasize the need for a move from the existing linear building process to the integrated work procedures. Efficiency of the integrated work process in the early planning and design stages that result in improved overall project lifecycle encourage true value of Green BIM to be fully recognized by owners and professionals in the building industry.

The characteristics of the desired procedures of Agile methodology, to which the information system industry has successfully moved from the linear work process. With the objective of optimizing Green BIM value, combining Agile methodology with traditional design practices and the use of Green BIM can bring meaningful implication to the building industry.

Agile methodology requires major changes in work procedures in the building industry which is considered a big challenge. Also, the difference in the nature of the building and the information system industry does not allow a direct translation of successful adoption and performance of Agile methodology in the building industry. However, the Agile adoption experience from the information systems industry can provide significant insight to the key factors considered and implementation techniques to successfully launch Agile in the building industries context.

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Appendix A: Green BIM Article Data

In order to understand the future and adoption of Green BIM, an article search was conducted using data that is available on the Internet. The search engine that was used to data mine the information was Google Scholar. Through Google Scholar, data was collected using the following search criteria:

Table #A1 - Article Search Criteria

Find Results: with **all** the words	Date Start:	Date End:
"Building Efficiency"	January	December
"Green BIM"	January	December
EnergyPlus	January	December
Ecotect	January	December
eQuest and "Quick Energy"	January	December
"Climate Consultant" and Software	January	December

For each of the above searches the years that were analyzed were from year 1996 to year 2010. For each of the samples the issue date was changed for both the Start and End values to represent the year of interest. For each of the samples, the number of articles available was recorded in the responding data set.

To determine the Y-intercept of the data, start date was removed and the search year was changed to 1995. This procedure output the total articles that were available before the specified search window. The only search term that this technique was relevant for was, Building Efficiency, because all of the other terms and ideas were created during the specified time frame.