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Utilization and Justification of Generative AI Technologies For Schematic Architectural Design

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Utilization and Justification of Generative AI Technologies For Schematic Architectural Design

By

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ABSTRACT

Today, architecture is heavily assisted by computer programs. As technology advances, these programs will be more impactful in the design space and will become more inseparable as a result. It is nearly certain that architectural design will no longer be as time-consuming and reiterative as it is today. Computer software and AI-assisted tools will be able to interpret information and produce practical designs that architects otherwise couldn't. It may seem futuristic and a not-in-our-lifetime phenomenon, but it in fact already exists today. Algorithms are already developed to assist and in some cases take over design work. This thesis discovered existing AI tools and determined their effectiveness in the Schematic Design phase as articulated by the American Institute of Architects (AIA). Ultimately, 18 tools were selected to assist across four schematic design phase criteria; Analysis, Synthesis, Refinement, and Documentation. Through the research and use of these available AI tools, it was determined in this thesis that AI does have a role in the architecture industry. Although it is not yet capable for AI to completely overtake the design process, it can be used today to assist in design creation and help inform programmatic and contextual decisions. An assessment scorecard was generated for these tools, providing a ranked evaluation for each tools potential savings and productivity. While researching and analyzing these potentially industry-changing tools, the merit of using AI models in lieu of working-class architects was discussed. Given the intriguing promises yet glaring dangers of utilizing AI, as articulated in this thesis, there are a number of hesitations and unknowns surrounding its potential integration into the architectural practice. While the future remains unclear about the effects AI will have on our jobs and livelihood, there is no doubt about the coming AI revolution. To prepare for this, this thesis proposes the Collaborative Design Approach; a controlled integration of AI tools within architecture firms. Here, artificial intelligence will not take over design work or replace architects, but work alongside designers as digital assistants, helping to create more efficient and meaningful work.

1. INTRODUCTION

1.1 Background

The computer has assisted architectural design for many years, and this involvement can be broken wide open as technology continues to evolve. From the early days of AutoCAD, a 2D graphical representation tool in the 1980's to the BIM technologies, a 3D realistic modeling and computational software of today, the computer has remained an integral part of the design process. As technology advances and new software is developed, it should be expected that it finds its way into architectural design. The computer programming industry is seeing a rapid advancement of software development, specifically with advancements in artificial intelligence (AI) leading to machine learning (ML) becoming mainstream. ML is a combination of algorithms, all enabling AI to predict, learn, and optimize systems. The design practice could greatly benefit from adopting this tool. While it may be an asset in the design space, the implications need to be understood. There will need to be a balance between intuitive 'production machines,' that recommend and profile human behavior with reduced human control. Once ML embeds itself into the architectural design process, it can 'sketch' design solutions of the future (Armstrong et al., 2021).

Let's take, for example, a personal trainer competing with AI technologies. A personal trainer may start a session by talking to the client and deciding on a workout regiment that caters best to them. An algorithm utilized for physical training may take the client's information including goals and physical ability, then scan their dataset, the breadth of which is incomprehensible, to develop an optimized workout plan that should produce the best results. Is one option more right than the other or more likely to prove successful? The answer may not be so clear. Instead of having to choose between two alternatives, the best approach may be collaborative. In this scenario, the personal trainer could utilize the designated algorithm to receive client information and evaluate necessary criteria to suggest workout programs. The personal trainer can then choose, at their discretion, what workouts to schedule for the client. Using their experience and history of training multiple clients, the personal trainer can infer what exercises are best for a particular client, deciding when to push them harder or back off. This collaboration will prove to be a much better experience for both the client and the trainer. Where

the algorithm can analyze and compute the ideal system, it is inevitably the trainer who knows what's best for the client on a human-to-human scale.

AI integration into everyday professions is no longer a science-fiction story, and architectural design is not the exception. ML has already had an immense impact on design, using deep learning and evolutionary algorithms to produce design solutions. Designers can use particular ML programs for ‘generative adversarial networks (GAN) for form-finding, space layouts, and material-based learning (Ozerol et al., 2023). This is only a small fraction of what AI can do for the architectural design process. There is a time in the near future when AI development explodes, known as the ‘singularity’ (Campo et al., 2022). AI is fed through data; as more data becomes available to it, it gets more and more productive. This is an exponential reaction since data (think emails, Facebook posts, website interactions) is increasingly adding to the expanse of the internet. There are a lot of unknowns about this ‘singularity,’ however, when it does come to fruition, architectural design may see an immediate and historical turning point into AI integration.

1.2 Research Purpose

The current state of using AI, ML, or even GAN is not quite as prevalent as the traditional pen-to-paper or ‘modernized’ BIM technology. There exists a number of problems when it comes to integrating and actively using these technologies to produce results. Namely, there are too many alternative algorithmic programs that are not far enough developed to be properly utilized. Many technologies exist but are not yet established for traditional architecture use unless the user has a background in AI construction. In addition to the mess of technologies assembled by a variety of developers, these technologies address design tasks that require different design tools, meaning one program cannot be used for everything a designer may be looking for. This may result in the requirement of multiple design programs, at which point not using AI integration at all may seem simpler. The reality of this in a design practice is the lack of consistent design elements and access to the project among team members (Castelo-Branco et al., 2022). AI-assisted design has some glaring hurdles to overcome before it can be implemented, but the potential is worth the effort and research into the practicality of its integration.

2. LITERATURE REVIEW

2.1 Discovery of AI Tools

Although the quality of algorithmic design technologies is underperforming the demand, the quantity is not lacking. There are countless algorithms, AI-integrated tools, and generative software that exist for architectural design. Even simple algorithms controlling architectural configurations have been designed and implemented for single-use projects (Fuhrmann et al., 2006). These technologies are not advanced enough to be used by firms or everyday architects, instead, they are introductory programs to establish the means of design. This baseline of algorithms, of which there are hundreds if not thousands, will over time develop into practical design solutions that can easily be implemented into a traditional firm's design practices.

Existing algorithms today are independently developed and created without standardized policies in place. Since AI is available and relatively feasible to write and feed with data, design algorithms can be made by anyone with the means and desire. This creates a messy network of algorithms that do not communicate with each other and are likely redundant. The lack of clarity and acceptance of one singular algorithmic design solution has compounded this effect to encourage more developers to create even more algorithms in the hopes of finding the next big thing (As et al., 2018). There is also a disparity in ML and AI tools among the five AIA design phases, as the majority of those writing algorithms for architectural design tend to cater towards Schematic Design and Design Development. This leaves noticeable voids in other, equally important, phases of the design process.

The potential of breaking through in an industry that can evidently utilize predictive and generative algorithms has been the catalyst for many developers. Others still are entering the space from a different perspective; researching and understanding existing technologies to determine if the ideal algorithm is already developed. The Algorithmic Design [AD] sketchbook is one such idea (Castelo-Branco et al., 2022). This sketchbook is the culmination of research and design testing to assess algorithm viability. The team coordinated several existing algorithms to achieve several design tasks, primarily within the schematic design phase. Their work includes algorithmic development of both the façade and the building's pre-existing geometry and surroundings, the analysis and optimization of the façade design in terms of indoor lighting

performance, and the generation of fabrication schemes. While proven successful (actually producing tangible results), the process of achieving this feat was for research purposes and not for realistic design work. While it was successfully executed, the years of coordination it took is not a practical solution in real-world design. Additionally, as AI develops and algorithms become more advanced, if they continue to be built independently it may prove too difficult to coordinate and integrate for architectural design use similar to the AD. Understanding specific tasks and desired outcomes within architectural design is important to discuss the effect AI can have on the industry. For this, phases of architectural design will be identified, as defined by the American Institute of Architects (AIA), and used as a means to measure AI tool effectiveness and merit.

2.2 AIA Architectural Design

The use of the AIA Architectural Design phases establishes a standard for the design practice. AIA, founded in 1857, is a collaboration of architects across the United States, providing resources, connections, and standards for the architectural discipline. The organization has a unique influence to define and push standards used in daily architectural design. This includes their designation of six design phases; Programming, Schematic Design, Design Development, Construction Documents, Bidding, and Construction Administration (AIA, 2023). While bidding is not a consistent phase in every design project, as many projects have become more integrative with contractors being chosen prior to design, this phase will still be mentioned as a possible design phase that exists. This Integrated Project Delivery (IPD) is an advantageous evolution in the construction industry, providing better performance in communication, cost, scheduling, quality, and more (El Asmar et al., 2013).

It should be assumed and will be made evident that algorithmic design and other AI-assisted programs will be able to expedite, simplify, and possibly redefine these traditional architectural design phases. Currently, the design process will account for more than half of a total projects duration, which can be months or years depending on scale and complexity (Hayes, 2014). The schematic phase is the paramount focus for this thesis and while it may not be as lengthy as other phases, it is equally if not more important. Any introduction of AI assistance may help any of these phases get shorter and more profitable. These phases could see potentially a 10-15% reduction in costs, resulting in faster, cheaper, and more sustainable projects

(Ahramovich, 2023). The use of algorithms within the schematic design phase is no exception, and the time and cost savings may compound in later phases, making this the primary focus of AI integration.

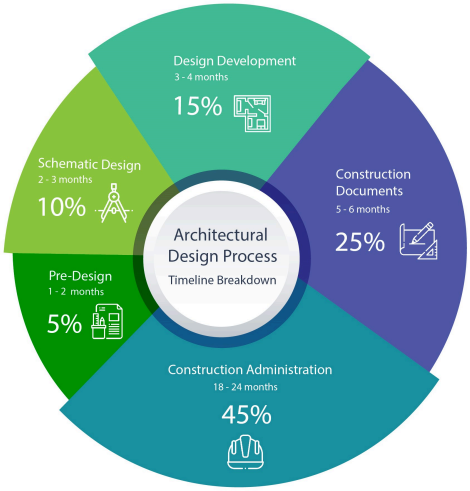

Figure 2.1 Architectural Design Process Credit: AIA

2.2.1 Programming

The programming phase is the only dedicated pre-design phase. Programming responsibilities vary based on the project, but in general involve the communication and understanding of the client requirements, known as Owner Project Requirements (OPR). Here, the architect will asses the given design goals as well as the site, if chosen, and other limitations that can involve code, zoning, or community restrictions. (Hayes, 2014)

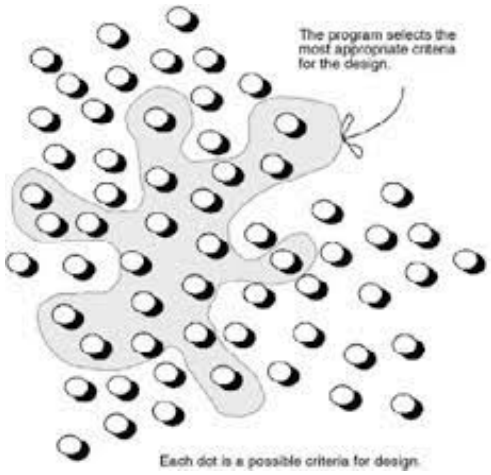

Figure 2.2 Programming Diagram Credit: AIA

AIA has identified many steps involved in the programming phase to assist in standardization and quality management. (Emerging Professional's Companion, 2013).

1. Research the project type
2. Identify project goals
3. Gather and analyze information
4. Diagram processes and relationships
5. Establish quantitative requirements
6. Synthesis the program
7. Document the program

2.2.2 Schematic Design

The schematic design phase is the first phase of basic design services and begins the articulation of the project's function, space, form, and detail. Where programming is an identification and understanding of project criteria, schematic design is the analysis of project information and synthesis of early design elements. This is an extremely important phase as it establishes the design that will be used throughout the remaining phases. Schematic design often gets held up due to differences in architectural articulation, client goals interpretation, and variances in code and zoning regulation. It is important during this phase to resolve unknowns and establish consistent design elements early. AIA has identified a number of steps involved in the schematic design phase (Emerging Professional's Companion 2A, 2013).

1. Analysis
    a. Resulting in the definition of the design problem
2. Synthesis
    a. Analysis is translated into a project concept
3. Refinement
    a. Concept is worked into a design solution
4. Documentation
    a. Design solution is graphically depicted.

2.2.3 Design Development

The design development phase is the progression of the schematic design phase, in which the level of completeness increases to demonstrate the project can be built. Architects in this phase will collaborate with other architects, engineers, and contractors to evaluate systems, material selection, coordinate detailing, and mature the project to include all necessary aspects of design. As the schematic, design development, and construction documentation phases are all distinct phases in the architectural practice, they have distinct project deliverables owed to the client. The design development deliverables are in most cases similar to schematic design deliverables but include much more detail, including structural connections, material choices, HVAC and other system integration, and inclusion of site and other civil involvement. While the AIA recognized design development will differ based on project sizes and scopes, they identify the expected deliverables and products for this phase (Emerging Professional's Companion 2E, 2013).

1. Site plan
2. Floor plans
3. Building elevations
4. Building sections
5. Typical wall sections
6. Integrated sections/plans
7. Schedules
8. Structural
9. Mechanical
10. Electrical
11. Plumbing
12. Outline Specifications
13. Visualization
    a. Including models, mockups, material samples, renderings, computer models, animations, sketches, and lighting studies
14. Other material

a. Including code and zoning analysis, floor area summaries, and LEED rating summary

2.2.4 Construction Documents

The construction documents phase is the final and most important phase within the design phases. This phase continues the work from design development and now improves the level of completeness to legal, procedural, and informative documentation. Architects in this phase will create documents in both written and graphical formats in order to convey how the project is to be built. It is of utmost importance that the documents have clarity and specificity, as these are the binding documents that will be used in construction and maintenance for the life of the building. While this phase will still include design decisions, it is recommended that the majority of design changes occur before the construction documents phase, as they will become more cost-inhibited. Since every project will require different documentation both feasibly and legally, AIA does not provide dedicated steps or requirements for this phase.

2.2.5 Bidding

The bidding phase is unique to architects in that it does not involve design or the execution of design. Instead, this phase involves the curated proposals and selection of contractors contracted to execute the design. Architects are responsible for the creation of a bid form, to be drafted specifically for each project's requirements, including contract arrangements and other specifications that will be legally bound within the contract. Outreaching to various contractors may not seem like a role for architects, although it is extremely important that those responsible for the design, i.e. architects, are also the ones choosing the professionals who know how to craft, assemble, and maintain construction elements.

Again, bidding is no longer a consistent design phase as it once was. Recently, the industry has been shifting towards a more collaborative and integrative approach, in an effort to save time and money through less changes during construction. In an integrative process, a contractor is chosen before any design phase. This eradicates the bidding process entirely, as there is no competitive element amongst potential contractors, the cost of construction is simply what the previously chosen contractor commits to during the design process. While it may not be

as relevant in today's architectural practices, the bidding phase is still regularly used and thus still an important benchmark established for many architectural projects. Similar to the construction document phase, there are no explicit steps from AIA within the Bidding phase. There are, however, a number of subphases that every bidding phase will incur (Emerging Professional's Companion 3A, 2013).

1. Preparation of bid package
2. Choosing qualified bidders
3. Bid engagement and interpretations
4. Contractor selection
5. Negotiation
6. Contract execution

2.2.6 Construction Administration

The construction administration phase is the longest phase and involves the most stakes in terms of legal responsibility and overall project success. The construction of any project will involve issues and in-field disparities, both resulting in changes that need to be seamlessly made and recorded. It is the architect's responsibility during this phase that construction follows the design detailed within the construction documents. Any changes that occur, due to any combination of material procurement issues, client preference, lack of design specification, or contractor adjustments, will require architect intervention, approval, and record-keeping for as-built purposes. The construction and management of the construction documents and changes are both time-consuming and carry significantly more legal barring than previous steps. AIA includes several subphases that occur during construction administration, all of which are typical for a project of any size (Emerging Professional's Companion 3B, 2013).

1. Preparation
    a. Including the establishment of a project management tool and the inclusion of all necessary team members for access to construction documentation and tools
2. Construction start-up
    a. This subphase is self-explanatory
3. Documentation

a. This will involve managing document control, managing and reviewing submittals, clarifying construction documents, updating schedules, RFI's, approvals, and maintenance of meeting reports and transmittal letters

4. Project closeout
    a. Once construction is complete and the project is ready to be turned over to the client, a punch list will be created, final change orders will need to be resolved, and closeout documents will be drafted and provided for all parties involved

2.3 Repetitive Design Tasks

With all aspects of the design process carefully detailed by the AIA, a distinction in architect involvement can be made. In some instances, particularly in design concept synthesis, an architect will utilize their years of experience and understanding of the discipline to make decisions. In other instances, like code review and document drafting, these become mundane and repetitive tasks that do not require particular architectural influence. This is the haven for algorithmic intervention. One simple AI tool can completely change the way firms operate. Where one firm may employ entry-level architects to spend weeks of billable time on rudimentary tasks, another may subscribe to an AI tool or employ an algorithm coder to complete these tasks in mere minutes.

It should not - and with the privilege of technological advancements now does not - require an architect to spend hours completing tasks that do not require their experience. Updating redlining for example, a task that may or may not require the architect to understand the forms or details they are manipulating, can be accomplished with the help of an algorithm scanning and adjusting existing documents with ease. Altering parameters on multiple existing instances would previously require an architect to spend hours performing the same clicking and dragging motion to complete. This can be offloaded to an algorithm that will do it faster and significantly cheaper. The time savings will free up firms to employ architects to perform work that does require their expertise, resulting in more meaningful, creative, and passionate work. The cost savings that firms will realize from utilizing AI technologies in lieu of salaried employees can shift the industry to a more cost-friendly model (creating more access and

therefore more design in projects) or conversely see that cost savings trickle down to employed architects, who now can be more productive when not working on repetitive tasks.

2.4 AI Utilization Within Schematic Design

While all design phases could be analyzed for the potential of AI integration, this thesis is only considering the schematic design phase. As stated, this phase is one of the most important steps in the design process as it is necessary to clearly define the design elements as early as possible. As the design effort curve in Figure 2.3 articulates, the ability to impact cost is highest early in the design process. This means the cost of design change is lowest early in the design process, emphasizing the importance of curating a successful design as early as possible (Illozer et al., 2012). Using specifically chosen algorithms will ensure a comprehensive and well-documented design. Therefore, the use of AI technologies will have the most impact during the schematic design phase.

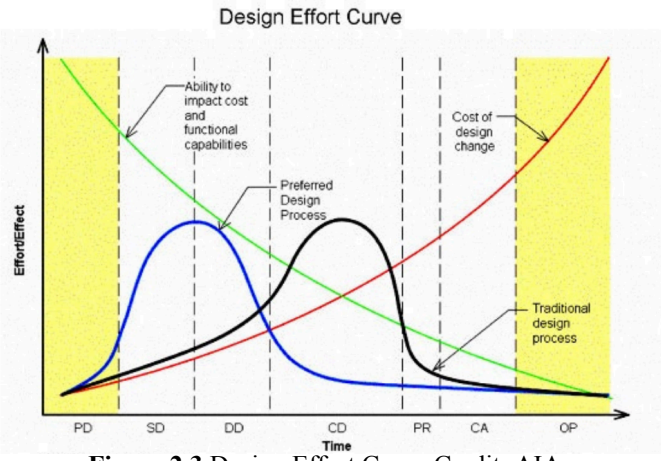

Figure 2.3 Design Effort Curve Credit: AIA

Given the significance this phase holds, as well as the general broadness of necessary design elements, finding tools to assist in schematic design should prove impactful. There may exist many algorithms useful in this phase, assisting in every step from analysis, synthesis, refinement, and documentation. As computing power increases and algorithmic programs advance, it is likely one singular algorithm could assist the schematic design as a whole, however, there are currently a multitude of various programs that can assist in particular processes. An algorithm for form creation will not have the same capabilities as an algorithm for

document creation, and neither will have the ability to check for code compliance. This is the reason for the extensive research into existing algorithms. It will need to be determined what algorithms exist for what task, when they can be utilized, and when it is better to forgo AI intervention entirely.

As the architectural industry shifts towards a more integrative and data driven process, the acceptance of AI technologies may be the catalyst the industry needs, either easing the process or enabling the process entirely. To minimize design change costs and encourage more sustainable and meaningful design, the preferred IDP process places more emphasis on schematic design. Here, the industry seeks collaborative processes - including input from clients, contractors, and architects - and seamless - quick designs that are successful from inception. As access to technology becomes more commonplace in firms, the schematic design process, per Figure 2.4, is the collaboration of concepts, including analysis from the programming phase, and criteria, the quantitative data that is derived from assessments and design evaluations (Chiavaroli, 2022). Algorithmic solutions may be just what the industry needs to accomplish this, aiding in the integration and acceptance of these programs.

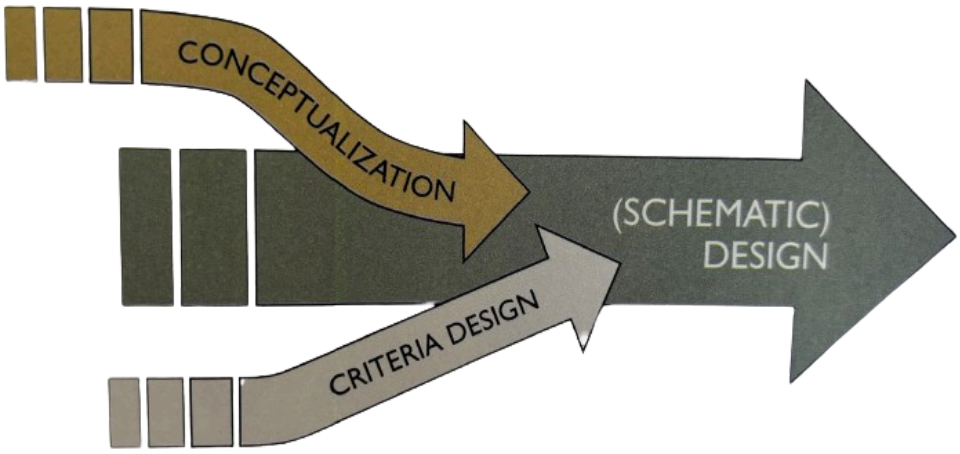

Figure 2.4 Schematic Design Process Credit: Julius Chiavaroli

Firms will have more and more projects utilizing AI and will adjust resources and personnel accordingly. Today, firms employ BIM Managers to administer and oversee projects using 3D modeling software. This position will likely need to adapt towards an Algorithm Drafter, someone within the firm designated to write and issue algorithms to assist in the

everyday schematic design process. This position may create algorithms for common processes seen in every project or more advanced algorithms for specific processes on one project. A position that generates AI may itself be automated by generative AI soon, but that is a discussion beyond this thesis (Becker et al., 2017). This shift in personnel will surely revolutionize the industry and create a standard of AI integration within every project.

The market size for AI use in the architecture and construction industry is looking to increase by 1500% over the next 10 years (Precedence Research, 2022) and nearly 92% of the construction and architecture industry intends to use AI technologies (Potter, 2022). The use of architectural algorithms is not a fad, it is a real and imminent development. Architecture firms will become acutely aware of AI presence within the next few years, and the transition towards an integrative and now algorithmic approach will become critical. This transition will make the most sense in the schematic design phase with the influence of AI technologies assisting in early design decisions.

2.5 Merit of AI Use

Integrating AI technologies with architectural design has demonstrated real, optimized results and the attempts to assimilate algorithms in firms have been successful. The question now turns to whether the architecture industry should allow AI to be so involved. The fear of ‘robots’ taking over is not new, and it has become even more relevant today. The worry many people within the industry have with integrating AI is that it may take away their jobs and remove the personal touch of design that makes it unique and beautiful. After all, the computer can’t design with the passion or understanding of human experiences like an architect can.

Using algorithms for design assistance would be a groundbreaking step in the history of architectural design. On one hand, it could compute data and produce optimized results in unprecedented numbers, a hundredfold what an architect could do in a day (Campo et al., 2022). What happens then if the algorithm becomes too involved and architects lose all control in the design process? It’s highly unlikely that AI technologies could be used without architect intervention, at least in our lifetime. If anything, the architect's capacity to extrapolate this utilization of ML or other design algorithms to produce design ideas or concept inspirations is

the limiting factor (Campo et al., 2022). Even when design algorithms advance to need architects less, researchers have little fear of the 'robot takeover.'

Similar to sophisticated grammar and spelling checkers, like Grammarly, an AI assistant could not impact choices unless prompted. Where Grammarly requires an initial dataset (words, sentence structure, subject context) and suggests alterations to this dataset, so too will architectural algorithms (Grammarly, 2023). These algorithms will require an initial dataset (project criteria, location, limitations) and will suggest results given this dataset. The intervention from AI will still require human input, and even the results provided will be meaningless until architects embrace them and articulate them further. There is no concern about Grammarly controlling the book industry, only the industry-wide acceptance of its practicality and ease. The architectural industry will similarly have the advantage of algorithmic assistance and should similarly embrace the opportunity. Research done by the Pew Research Center found that about 19% of the American workforce will be affected by AI intervention and in almost all instances they project that AI to help more than it will hurt. Most of the top professions affected, see Figure 2.5, are in data analysis and technical drafting. These areas are within Architecture but are not the sole makeup of the industry (Kochnar, 2023).

Jobs with high exposure to AI that employ the most men and women

Among the U.S. jobs most exposed to AI, the top 5 that employed the greatest number of men and women, 2022

Men	Number employed (thousands)
All jobs with the most exposure to AI	*12,962*
Sales representatives, wholesale and manufacturing	825
Lawyers	731
Computer occupations, all other	720
Couriers and messengers	690
Accountants and auditors	682
Women	
All jobs with the most exposure to AI	*14,572*
Secretaries and administrative assistants, except legal, medical and executive	1,775
Office clerks, general	1,060
Receptionists and information clerks	1,059
Accountants and auditors	973
Bookkeeping, accounting and auditing clerks	964

Figure 2.5 AI Exposure in Jobs Credit: Pew Research

Architecture is in a unique position when it comes to computer-aided design. Unlike many other professions, emerging technologies have always been utilized and embraced for architectural design. The earliest examples of computer-aided design date back to 1963 with SKETCHPAD, and since then new practices have evolved to bring the industry to the standard it is today; inseparable from 3D modeling and BIM integration. Since architects have historical precedents for adopting these emerging technologies, the advancements of AI will not hinder the design or drive out architects. Instead, it will improve the quality of the work and allow architects to concentrate on making practical decisions for their clients with unprecedented ability (Rotman, 2013).

The design solutions from AI integration may not outcast architects or end the position of a designer as we know it, but what about the quality of the results? ML design solutions may have been run through algorithms to optimize for design tasks, but if people aren't happy with the way the solution looks or feels then it is a failure. In a realistic scenario, the architect can adopt the design solution into the architectural language established, controlling aesthetics and interaction with existing systems. However, the principle remains, if an algorithm cannot produce beautiful results then it has no place in an architectural capacity. But then again, what is beauty?

A subjective quality like beauty cannot be articulated by computer programs, nor can it be assumed to exist in every design solution it creates. In the event AI integration becomes void of architect intervention and algorithm designs are forwarded without improvement or manipulation from a human source, then the fear of a mundane, optimized maybe, but lacking future for design articulation becomes reality. Louis Sullivan, however, may disagree. In his 1896 assertion that form follows function, he wrote that the beauty of a building derives directly from a design that practically and effectively meets design requirements; fitness for purpose equals beauty (As et al, 2018). Who's to say a world of AI-generated buildings isn't beautiful, after all, they would be the most efficient product possible. Further exploration of these topics will be made in the justification section of this thesis. Actually using and assessing AI tools that have promised an industry revolution will help inform the merit of their existence. In the following sections, a determination will be made on how AI can be used within an architecture firm and whether the industry should continue to allow it.

3. RESEARCH METHODS

3.1 Overview

In assessing the viability of algorithmic utilization within the architectural design process, existing tools will need to be obtained, tested, compared, and ranked. This process involves combing through databases and online guides in search of algorithmic design programs and software. The bibliometric system will partially be utilized for categorizing and comparing these existing algorithms. This system can easily store metadata for each algorithm and harbor a statistical dataset that can be used for organization and comparison. A bibliometric analysis will likely be most productive from databases with large amounts of data, like the Web of Science (WOS) and Cumulative Index about publications in Computer Aided Architectural Design (CUMINCAD). Other resources including the Open Source Architecture Community and Art & Architecture Source will also be researched. Here, algorithms and other AI-assisted design solutions (including ML and GAN) can be searched and cataloged relatively seamlessly (Ozerol et al., 2023).

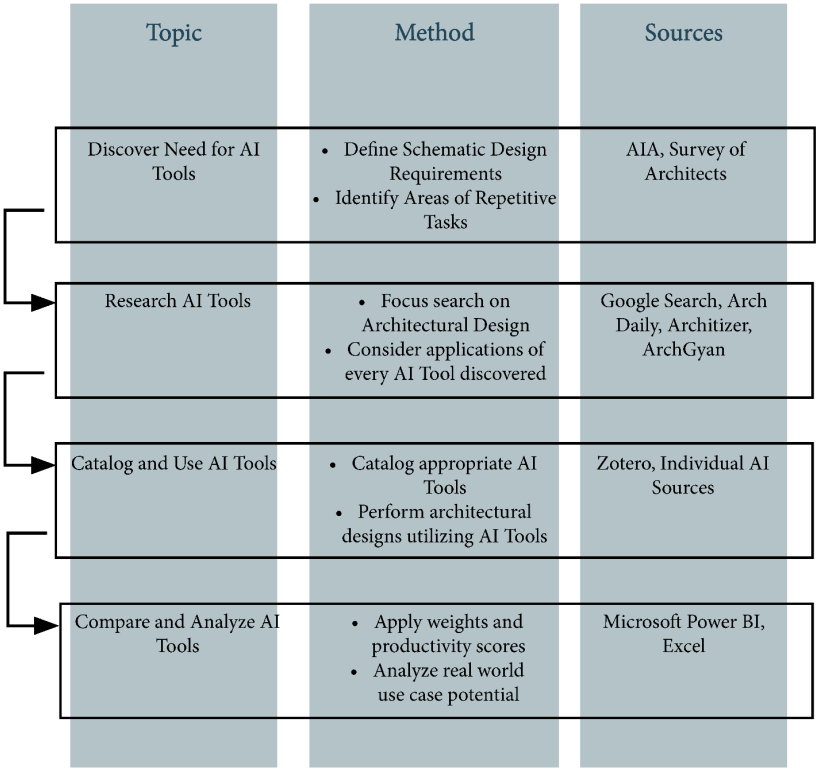

Figure 3.1 Research Procedure Credit: Author

The research procedure in Fig. 3.1 lays out the procedure for discovering and analyzing AI tools. Tools will need to be compared and assessed due to 1) the sheer quantity of algorithms that exist will hinder results in each of the design phases and 2) some algorithms are likely to prove redundant, as there are likely many design solutions for each design task. Before searching for these algorithms, an assessment of the need for AI tools will be required. Understanding the role of an architect and the deliverable requirements they are responsible for within the schematic design phase will assist in what AI tools should be researched. Previous articulations of the typical schematic design process will be used here, specifically one from RIT professor Julius Chiavaroli. Per Figure 3.2, the expected outcomes and deliverables in the schematic design phase will be the best source for any schematic design requirements that could potentially utilize AI assistance. These objectives include in particular plans, elevations, renderings and program data, and a preliminary schematic design outline specifications, detailing information about materials, equipment, and finishes.

Schematic Design	
Goal:	To fully experience and appreciate the architectural design process.
Objective:	To complete an architectural design and present it for evaluation by others.
Outcome:	A complete set of schematic design drawing panels prepared for physical or digital presentation.
Deliverable:	A professionally created presentation to the proper depth and completeness that contains the following: • Graphics/ models that accurately represent the design intent. The presentation should be able to illustrate the design without a presenter's explanation. The presentation should exhibit generally accepted layout standards, e.g. drawing orientation, panel layout, title bars, lettering hierarchy, etc. • Verbal communication that supplements the above. The explanation should be at the macro level explaining the parti pris and how it satisfies the program. • The design itself satisfies the program and specifically the problem statement. It demonstrates the use of form, space, and ordering systems to emphasize the design intent. • Data is provided that demonstrates that the design has met the criteria. This may be met with the use of diagrams, performance modeling, and massing studies. Optional elements include a physical model and/or a fly-through of a digital model.

Figure 3.2 General Objectives of Schematic Design Phase Credit: Julius Chiavaroli

Researching AI tools will be the next requirement in this research. After identifying areas of need in the practice, finding and researching as many AI tools that cater to these needs will result in the most productive programs. A simple internet search for AI tools resolving specific issues may provide minimal results. Instead, there are multiple resources available that have

found many architecture-relevant algorithms. There are platforms like ArchGyan that provide dialogue between architects and direct links to AI tools they find useful (Arch Gyan, 2023).

Some websites are also releasing multiple publications about AI and specific AI software, Architizer for example compiling a list of 15 AI Tools that architects can utilize today (Frew, 2023). These valuable resources, as well as any specialized algorithm discovered via Google Scholar or RIT Libraries Catalog, will help to find every relevant AI tool currently available.

The cataloging and use of these AI tools will be the bulk of this research. The programs will be cataloged into bibliometric systems within Zotero. Once all redundancies and inefficiencies are worked out, the remaining AI tools can actually be tested. This procedure will be a continual practice, using programs multiple times to understand the nuances and particular human intervention requirements within each new tool. The result of this procedure will be an assessment of each tool. A utilization score will be given to each tool tested, assessing its viability in the architecture practice. This last procedure should result in a general understanding of AI's use within architecture, and positive or negative experience of using them in lieu of traditional design practices.

Once algorithms are properly analyzed and compared within their respective design subphases, which will be presented in the Utilization section, the final determination can be made for the practicality of algorithm use in the architectural field, as well as the merit of using them. Simple graphical representations may be used for this organization; Sankey diagrams are common when using bibliometric analysis (Ozerol et al., 2023). However, given the complexity and expected quantity of this research, more advanced tools will likely be needed. A comparison tool can be created in addition to the bibliometric analysis dataset as an accompaniment, simply pulling algorithm results into a graphical approach. Analysis from Microsoft Power BI should be able to interpret this data and provide valuable information about the algorithms and their relationship to other programs. Other comparison tools exist currently, including a Model Comparison Tool that compares the performance of one or more predictive models (Alteryx, 2022). In the end, a collection of AI tools will be analyzed and an expected design outcome can be produced using the now-established hierarchy of AI utilization.

4. UTILIZATION

4.1 Utilizing Generative AI Technologies

While the AI takeover has not been as profound in the architecture industry as it has in other industries like Law and Finance (Konrach, 2023), there are still countless generative AI technologies that are currently available for use in an architecture firm. The intent of this work is to ideally find enough AI tools to fully execute a schematic design. Multiple solutions were discovered and in the end, 18 tools were finalized and analyzed for utilization within architectural practice. These tools have been selected due to their potential functionality, availability for access and continual use, and their relevance to the schematic design process. It should be noted that all of these tools are widely available to the public and are mass-marketed programs. There are proprietary algorithms that can be written for individual firms that seek AI assistance; algorithms that can cater to exactly what the firm requires for every project (Garfinkel, 2017). While these algorithms are extremely enticing, they would be most relevant for design development and construction documentation due to their specificity. For the purposes of this thesis, only mass-marketed AI solutions will be considered and tested moving forward. Similarly, no tools specifically assisting in repetitive design tasks, including editing and picking up redlines or altering parameters on multiple instances were assessed as these tasks fell outside of the scope of schematic design. Also, after extensive research, there were no tools available to assist in the creation of an outline specification, an objective previously identified for this schematic design phase.

Distribution of AI Solutions

Criteria	Sub-Criteria	Tools/Methods
Analysis [A]	Program Analysis [A.1]	Fireflies, SGE, ChatGPT[A]
	Context Analysis [A.2]	UpCodes, Forma[A], Archistar*
Synthesis [B]	Establish Design Goals/Parti [B.1]	ChatGPT[B], ChatUML, Vondy[B]
	Design Creation [B.2]	DallE, Midjourney, Architectures*
Refinement [C]	Functional Refinement [C.1]	Forma[C], CodeComply*
	Aesthetic Refinement [C.2]	Photoshop, AI Home Design
Documentation [D]	Schematic Design Documents [D.1]	Maket, PlanFinder*, Hypar*
	Schematic Renderings [D.2]	Vondy[D], LookX

*Solution is not available at the time of testing

Table 4.1 Distribution of AI Solutions Credit: Author

In following the AIA Schematic Design Phase procedure, the criteria for schematic design are identified as; Analysis - Program and Context Analysis, Synthesis - Establish Design Goals/Parti and Design Creation, Refinement - Functional and Aesthetic Refinement, and Documentation - Schematic Design Documents and Schematic Renderings. The 18 tools studied are categorized into these subcategories, seen in Table 4.1, with some tools being utilized across multiple subcategories. After completion of each subcategory, the collective use of these AI tools should accomplish a majority of the identified General Objectives of Schematic Design Phase.

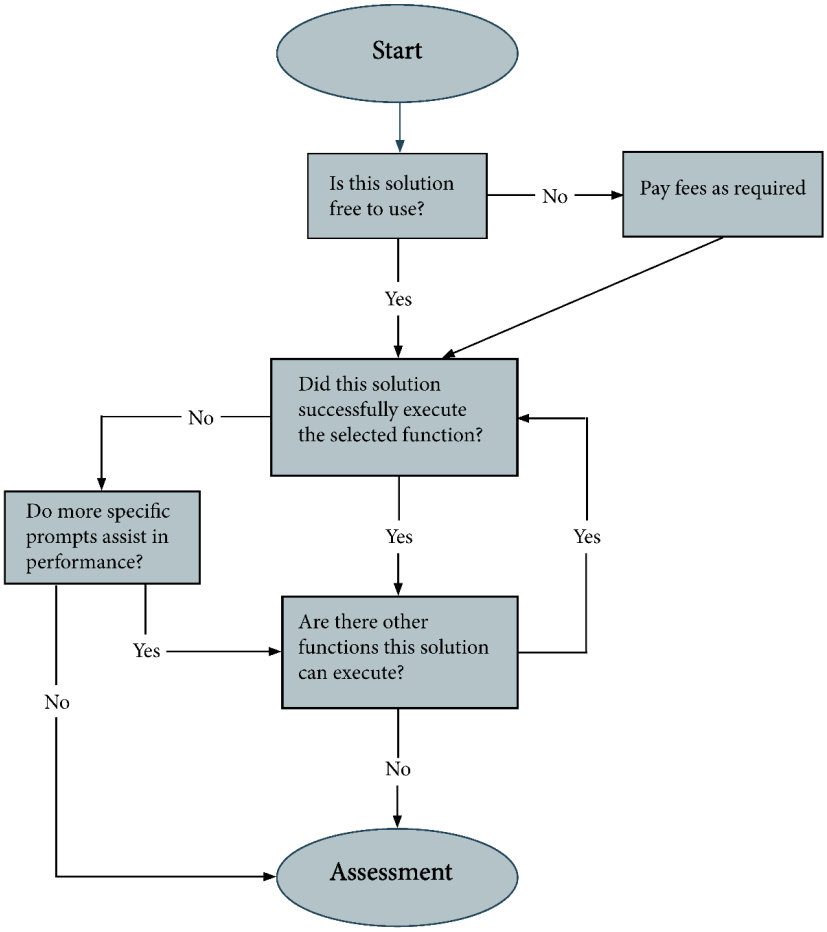

Figure 4.1 Decision Flowchart Credit: Author

To properly assess all solutions wholistically, each AI tool will be tested following the decision flowchart in Figure 4.1. This flowchart will ensure the necessary qualities of each solution are considered; namely the price associated with the tool, the success rate of the tool,

and whether specificity in the prompts plays an important role. Only after each tool is tested and passes the flowchart can they be finally given an assessment. These various AI solutions will be tasked with completing the function within their respective subcategories, all of which will be used for a case study project; a new home build in Albany, NY for one of the authors clients. This case study is an example of a real-world project architects might see in the firm. The given criteria for this example case study project are below. Five of the 18 tools identified were either not available for testing or not able to be tested using this thesis' hypothesis. The remaining 13 AI tools will be tested under this same project and evaluated using the same flowchart before given a final assessment for comparison and analysis.

Case Study Project Criteria:

> *A client, Ms. Smith, has a vacant lot located at 222 Briarwood Court Albany, NY 12203. They want a 4-bed, 3-bath house, ideally 2 stories and around 3,000 sf. They want a connected 2-car garage, a pool and a shed in the backyard, a spacious living room and kitchen, and a dedicated room for their books and wine collections. They want the house to be beautiful and feel like a welcoming home. They are not set on cost, although are looking for a reasonable price for the area.*

Figure 4.2 Site Map Credit: Realtor.com

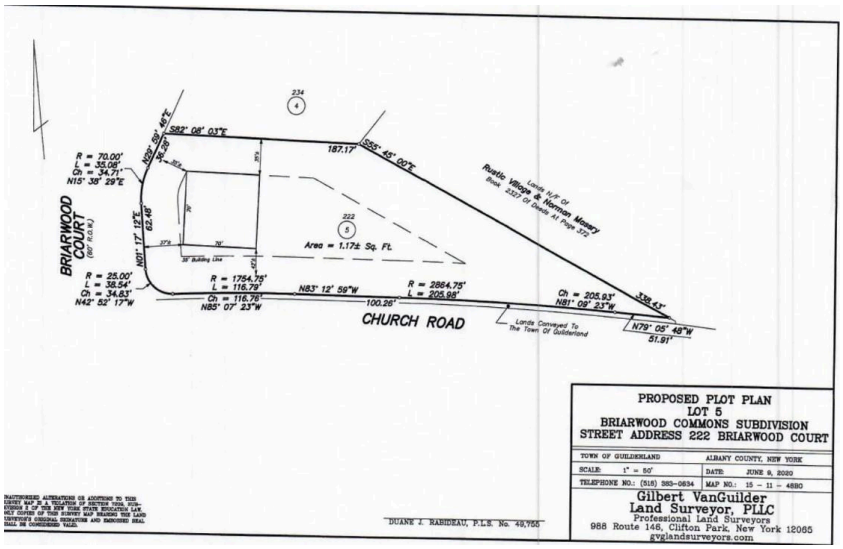

Figure 4.3 Site Survey Credit: Realtor.com

A. Analysis

A.1 Program Analysis

The intention in the program analysis design phase is to receive and understand the project criteria. This first stage in the design process is when the program is conceptualized, intentions are elaborated, and a 'geometric logic' is settled upon (Kwok et al, 2007). The architect is to listen to the client's goals and visions, then analyze and construct a program from this information and contextual data. According to the AIA standard, this phase requires time for the architect to familiarize themselves with the project, converting dialogue from the client into clear and usable design information (Emerging Professional's Companion, 2013).

Fireflies

Fireflies was started in 2016 by Krish Ramineni and Sam Udotong in San Francisco, California (Crunchbase, 2023). While it is not an architectural design program, this website utilizes AI to capture, transcribe, and summarize meetings. Fireflies will join any meeting on any platform (Zoom, Google Meet, Outlook, Skype, etc.) and record everything, providing useful information from the meeting within 3 minutes (Fireflies, 2023). This capability almost

eradicates the need to take meeting minutes, allowing employees to utilize their time more effectively.

The Fireflies program was used in this thesis to record and interpret the initial meeting with the client. In this meeting, the client presented information to the architect. This information, including project location, client goals, and budget/scheduling restraints was all a necessary first step to begin this project. The Fireflies bot, named Fred, was invited to sit in on the meeting, so long as both the architect and the client consent. This bot sat muted with their camera off, listening and recording the entire thing. At the end of the meeting, both parties left the meeting as usual, and within 3 minutes the entire interaction was digitized and summarized on the Fireflies website.

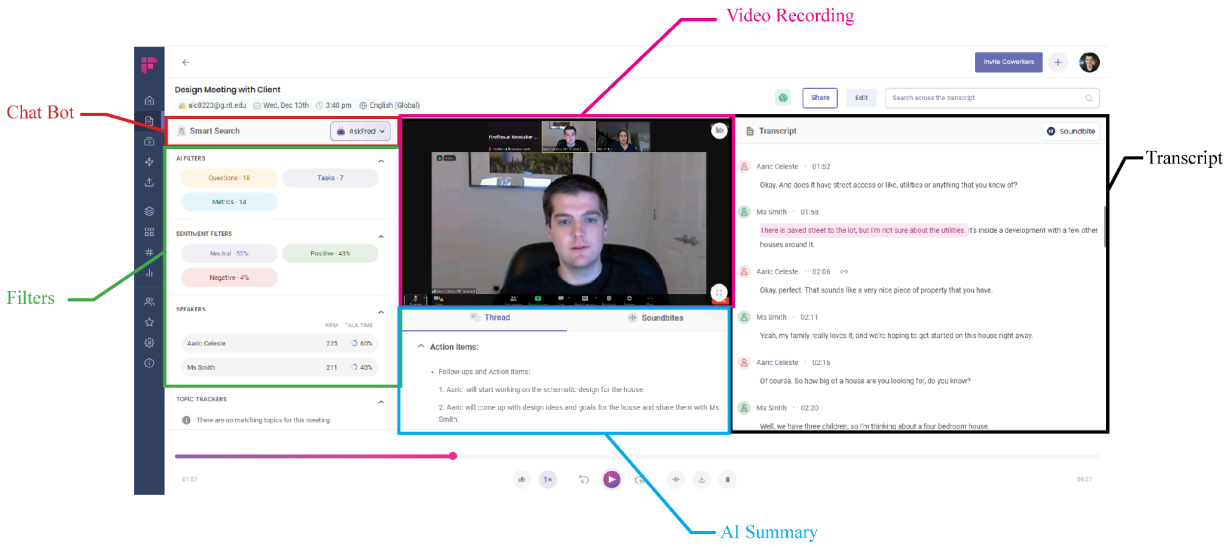

Figure 4.4 Fireflies Interface Credit: Author

The interface has many features and advantages in understanding and synthesizing information from meetings. For starters, the website records and downloads all video and audio from the meetings, storing it for the project duration or longer. The AI bot also transcribes the meeting with incredible accuracy; for this design meeting with the client, there were no errors. This transcription is live and will highlight the text as it is spoken during the video, it can also be scrubbed and any snippet of dialogue can be selected and played immediately. Another feature is the AI filters that are created, one set for metrics, questions, tasks, and dates/times mentions. Selecting one of these features will isolate the parts of the meeting that mention the relevant

information. For example, selecting metrics will show in the transcript any mention of numerical quantities. The filters also number the instances in each filter, informing the user that for this meeting there were 18 questions asked, 9 tasks detected, 21 metrics used, and 1 date/time discussed.

Similarly, there are AI filters created for sentiment, categorizing the meeting into either positive, neutral, or negative dialogue. For this engaging and aspiring meeting for both client and architect, the meeting was 43% positive, 53% neutral, and 4% negative. The negative interactions are isolated events when either the client or the architect dropped their tone, although the words spoken were not negative in nature. The filter also identifies speaking time and cadence, identifying that in this meeting the architect spoke at 225 words per minute and talked for 60% of the meeting, with the client speaking at 211 words per minute for the remaining 40%. This information is very interesting and can be useful for project meetings, although for the most part, these filters will likely not be used as often as the AI summary.

The AI summary is the principle feature of this program, taking all the dialogue from the meeting, understanding the concepts and information discussed, and synthesizing new and relevant data for the user's benefit. For this project meeting, the client and architect talked for approximately 5 minutes about the house the client is looking to have designed. From this meeting, Fireflies was able to create a meeting summary, notes about the meeting, outlines of the meeting discussion with timestamps, and a list of 10 action items that are to be taken as a result of the meeting. Figure 4.5 showcases the meeting summary portion, and the complete list of AI-generated text is provided in a supplementary appendix.

AI meeting summary:

Aaric Celeste confirms that the meeting is being recorded and asks if everything is good on Ms Smith's end. They discuss Ms Smith's new plot of land in Albany, which she wants to build a house on. Aaric asks about the location and size of the land, as well as street access and utilities. Ms Smith provides the address and mentions that there is a paved street but she's unsure about utilities. They talk about the desired specifications for the house, including four bedrooms, three bathrooms, a connected two-car garage, a pool with a shed, space for books and wine collection, and a large kitchen/living room area. Budget-wise, Ms Smith wants it to be comparable to other houses in the area. The style of the house is undecided so Aaric will come up with some design

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ideas later. They agree to reconvene in a few weeks to review progress on schematic design plans that Aaric will provide along with floor plans and renders for consideration by Ms Smith.

Figure 4.5 Fireflies Summary Credit: Author

This summary information came straight from the Fireflies interface, it did not need to be edited or filled in at all. This information is extremely helpful to the client and the architect, not only for preserving information from the meeting but also for creating progress items that the client and architect can look to for the next step, including any timeline information that was discussed. While it was not needed for this meeting, this summary as well as the transcript could all be edited prior to downloading and sharing if needed. The summary and transcript work together to create a 'library' of keywords, audio snippets, and individual action items for the project. The following meetings within this project will continue to add data to this library, further informing the AI bot and also creating stored and searchable data for both the client and the architect.

In addition to all of these features, Fireflies also gives users access to a chatbot that was trained using data from the meeting. Users can engage with this chatbot and ask prompts about information from the meeting. The bot has the ability to comb through the information and provide real-time responses. This saves users even more time from having to comb through potentially multiple meetings to find information. For example in this meeting, the bot can be asked '*Why did Ms. Smith want 4 bedrooms?'* to which the bot responds '*Based on the conversation, Ms. Smith mentioned that she has three children. It can be inferred that she wants a four-bedroom house to accommodate her family members.'*

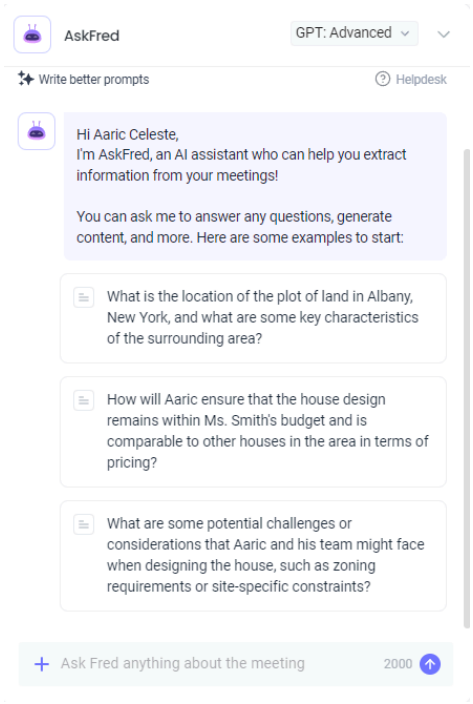


Figure 4.6 Fireflies Chatbot Credit: Author

There are many advantageous features about the Fireflies interface. It should be noted that this information can be sent to all parties of the meeting, not just the meeting host. It can also be sent to other employees, anyone who missed the meeting or comes onto the project late and wants to catch up. This program also works for in-person meetings, requiring someone in the room to use the Fireflies app to record the meeting. This AI even works on previously recorded meetings, allowing users to upload recorded meetings to the website and letting Fred interpret the information from that. The utility gained from this program transcends just client and architect meetings, showing potential for in-house design meetings as well as future design and contractor meetings. There is no use case where these features are not an efficiency boost to the project.

The collaboration on Fireflies is a significant attribute. As collaboration both within the design team as well as with the design team and external clients/contractors, a tool that can be shared and utilized across multiple devices is necessary. Fireflies works with all common meeting programs, Zoom, Google Meet, Outlook, and Skype, as well as multiple project management softwares and digital storage companies. This program has been extremely useful at

the inception of this project and it will be even more so later in the design process and construction. The tool costs $29/month for the business subscription, any company that utilizes this for project efficiency will require a business tier. The schematic design phase may only take 1 or 2 months, costing the project a total of $58 for the meeting minutes and information tracking, a fraction of what an architect would charge per hour to write the same information.

Perhaps the best attribute of using this tool is that there is no additional time expense to use it. Users do not need to engage with or spend time drafting within this program at all. Using Fireflies doesn't save time in project management, it cuts it out entirely. The program is extremely intuitive and easy to use with very little trouble getting it initially set up for this project. The results speak for themselves, this tool seems very productive and worth the subscription cost. The summary created by the AI will be used to wholistically start the design process, with the action items setting the framework for expectations from the client. This tool will be used for every meeting as well as continually throughout the project to confer with project information.

Google's Search Generative Experience (SGE)

Search Generative Experience (SGE) is a generative AI update to the Google search. The beta for SGE was released in May 2023 and seamlessly integrates with the already powerful Google search engine (Google, 2023). This functionality provides results from Google's trained generative AI chatbot in addition to conventional search results. This essentially takes the 'searching' out of the Google search, providing instantaneous and predictive results. The SGE tab will appear above the search results, sometimes being hidden behind a '*Get an AI-powered overview for this search?'* with a Generate button. This tab can be expanded to show all results for the given prompt, which can range from simple questions to complex and highly detailed cues that require SGE's predictive capabilities. The prompts can be layered, meaning context can be continued from prompt to prompt to continue building the AI to provide the desired responses.

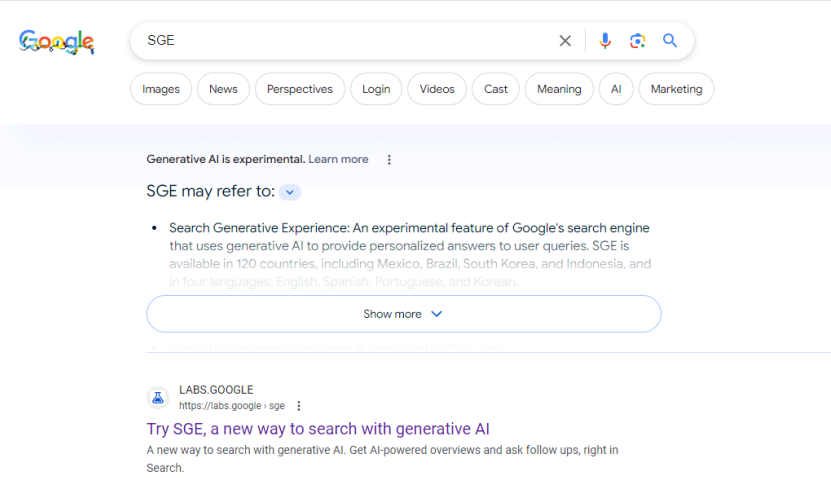


Figure 4.7 SGE Search Results Credit: Author

For this project, this program can be used to help the architect familiarize themselves with the project. This can include any information the architect did not previously know that would be useful to the design process, including information about Albany, NY, certain elements that are going to be added to the house, as well any specific client expectations the architect is unsure about. For example, simply searching in the Google search bar *'New build housing prices per sf in Albany, NY'* will provide results as expected with additional information. Here, SGE responds '*In November 2023, the median listing price for homes in Albany was $249,900, or $176 per square foot. The median sold price was $277,000. Albany's housing market is considered competitive. In June 2022, the vacancy rate was 12.2% and is expected to increase in 2023.'*

While this information would be relatively easy to find without the use of generative AI, the additional information is useful to provide the architect with more relevant data to make informed decisions. These kinds of searches, which take almost no time to run, can help inform the architect more about what the client's expectations are, and further if the project is worth taking on from a financial perspective. SGE can also be useful for more complex and specific prompts. To get more information on the scope of this project, the architect may use SGE to study examples of wine cellars and library rooms, both in style and functionality.

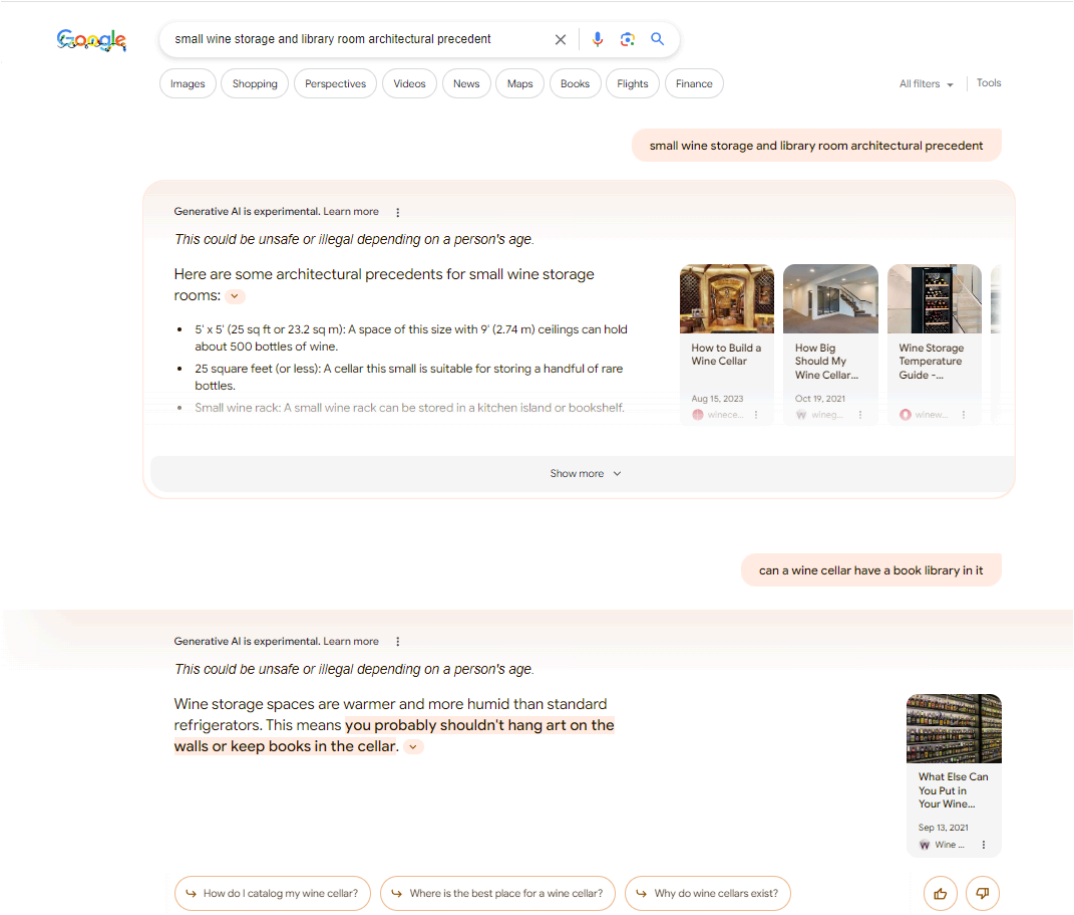


Figure 4.8 SGE Specific Prompts Credit: Author

In this example, the architect is looking for information on the client's goal of having a wine cellar and a library in their house. The prompts typed into the Google search are displayed on the right of the results as a text bubble. The results are then a collapsable tab with suggested prompts at the end. Continuing the conversation extends these bubbles and result tabs down the page. After asking about wine cellar and library precedents, SGE provided results about wine cellar floor plan standards. To get the results the architect is after, a second, more specific prompt to add onto the previous was needed. Here, SGE concludes that a wine cellar should not be host to a library as well, due to the higher humidity requirements in the cellar.

This information will end up being useful for the architect to inform the client. These results establish a better understanding of the project scope and will assist the architect in designing the project more efficiently from the beginning. While the generative AI did little

beyond a typical Google search, it did provide results faster and upfront compared to combing through thousands of results to get the same information. The results were seemingly subpar; however, the action of searching and researching proved useful to the progress of the design. The program itself is intuitive, there is no learning curve, being integrated with Google. Since this program is isolated to the individual user, there are no collaborative qualities.

As a digital Google product, this is a free integration that can be used by anyone. Utilizing SGE solely for developing the design will not be productive or efficient. However, since it is free and seamlessly integrated, it is worth engaging in for times when the architect needs to quickly search for something. As this is in beta at the moment, it is likely that this feature will become a standard on all Google searches, at which point there will be no choice whether to use it or not. With the fast advancing of AI technologies, it is very likely that generative searches like SGE will be the only option for searching for information. These 'oneshot' implementations will be common in all search engines on any device, but will be reliable, fast, and intuitive (Colton et al, 2021).

ChatGPT[A]

ChatGPT is perhaps the first thing that comes to mind when AI is mentioned at this time. It is one of the first useable mass-market AI tools, being made available from Open AI in November of 2022. This AI program is similar to Google's SGE in that it responds to given prompts and can continue to have a conversation with the user, adding more detail to its response. When it became available, it revolutionized how people interact with technology, utilizing machine learning algorithms to communicate with users on a conversational level while comprehending context, intent, and sentiment to provide real and fast results (George et al, 2023).

While SGE can provide any conventional Google search result (images, maps, shopping recommendations), ChatGPT will only provide text information. This text can be formatted in any way after copying and exporting it but within ChatGPT it is only lines of text, this means you cannot ask ChatGPT to create documents or diagrams. Despite its limited production value, the results from ChatGPT are impressive and the early release to the public is the reason for its sustained popularity.

For this project, similar to SGE, an architect can use this generative AI to ask questions and receive valuable project information, for example, requirements for pool installation or wine cellar conditions. The difference, however, is that ChatGPT synthesizes its own information from Open AI's extensive data set. SGE does provide valuable information, but it takes snippets from websites from Google searches. Chat GPT interprets information from the prompt and produces an original response, giving the user useful and practical lines of text. Therefore architects should not use ChatGPT for common questions that a Google search or SGE could answer, ChatGPT is best used for idea and design scheme synthesis.

It should be noted that ChatGPT does not allow architects to ask about code or zoning regulations, no matter how specific the prompt. Asking for the zoning considerations of an R-1 zone in Albany, NY will result in the AI telling the architect there are many considerations and to consult local ordinances. Other design criteria relevant to this stage of the design process can be solved and accomplished by ChatGPT relatively easily. The architect can ask the AI to draft an architectural program document for the given scope. This scope uses the summary from the Fireflies meeting, as well as information retrieved from a few SGE searches. The result is a comprehensive and actionable program that can be formatted onto a document, printed, shared, and used by both the architect and client for the duration of the project. Figure 4.9 includes the design considerations and final program conclusion, with the complete architectural program included in an appendix.

Architectural Program Document: Residential House at 222 Briarwood Court, Albany, NY 12203

Design Considerations:

- *Aesthetics and Ambiance:*
- *Focus on aesthetics that promote a welcoming and comfortable environment.*
- *Use warm colors, natural lighting, and comfortable furnishings.*
- *Functional Design:*
- *Ensure the layout promotes easy navigation and functionality.*
- *Emphasize energy efficiency and sustainable design practices where possible.*

Conclusion:

The architectural design should focus on creating a spacious, functional, and aesthetically pleasing residence that meets the client's desire for a welcoming home. The design should incorporate all specified features while being mindful of cost considerations.

Figure 4.9 ChatGPT Program Credit: Author

This program of course can be edited as needed after the fact, or more specific prompts can help focus the AI chatbot to include more information. For example, the architect could return in the prompt to include space planning and square footage of each space in the 3,000 sf proposed house. This, however, is beyond the program analysis design phase. In this current phase, the intent is for the architect to interpret, understand, and plan a program based on the initial client meeting. By utilizing information from Fireflies and SGE, the creation of the program from ChatGPT was seamless and elementary.

It's interesting that the program written by ChatGPT included elements that were explicitly written in the scope, including the need for a pool, shed, garage, etc., but also created additional requirements, like ensuring the layout promotes easy navigation and functionality. This was not an underlying theme in the scope, nor was it written in the prompt to include. The AI included this likely since the prompt stated it was for an architectural program, something ChatGPT knows typically includes a discussion on accessibility and navigation functionality. The intuition in ChatGPT makes it a very successful tool by both providing the expected results as well as additional information previously not thought about. Although the interactions are isolated so there are no collaborative capabilities, this will assist the architect in drafting a holistic project program, ensuring everything is considered and documented.

ChatGPT is a free to use, open-source program. There are additional tiers with more sophisticated features, like advanced data analysis, for $20/month, however, the free base tier is more than capable of proving useful. Utilizing this AI will save architects time not only on program drafting and preliminary design research but also for a multitude of implications that can be explored in later design phases. The results are optimal enough to warrant immediate use

in any firm and can boost productivity for design ideas and document drafting. Using ChatGPT (i.e. writing a prompt and copying the results) takes almost no time at all, and the iterative process ensures the results are exactly what the architect is looking for. The time and cost savings make this a viable AI solution, and the results can help push the design to the next phase effortlessly.

A.2 Context Analysis

Beyond the need to understand the client's goals and objectives of the project, it is the architect's responsibility to understand the context surrounding the project. This context will always include site considerations, zoning and code review, as well as the inclusion of budget and scheduling constraints, local construction industry practices, and architectural precedents (Emerging Professional's Companion, 2013). The objective of this phase is the complete understanding and analysis of the project requirements, both abstract and physical.

UpCodes

Up.Codes is an AI-based website that provides useful code information for a project in any phase. Since starting in 2016, UpCodes has been a reliable database for all building and zoning code inquiries. In May 2023, founders Garrett and Scott Reynolds launched Copilot, an AI assistant to UpCodes (Crunchbase, 2023). Copilot is a research companion within UpCodes, providing real-time analysis and comprehensive solutions to regulatory constraints for projects.

For this residential project in Albany, NY, UpCodes can be used to give necessary context to the project, informing the architect of zoning and building code limitations. Through the use of Copilot, this process should be much faster and more integrated than ever. The database that UpCodes has been building since 2016 is impressive enough without the use of AI. They have a library of every code book, for this project specifically the Residential Building Code, Building Code, Fire Code, and Energy Code of NYS was researched as well as the 2010 ADA Standards. These codes can be easily bookmarked and stored within project data and can be compared to other jurisdictions or versions of the same book. UpCodes also has an extensive catalog of diagrams for structural members, ADA accessibility, and countless assemblies that can be used for any phase of construction.

Project information, like height, area, and construction type can be inputted and stored as project metadata. UpCodes will then utilize its database to output regulatory information, like egress requirements, fire safety, and plumbing minimums. This information can be extremely useful, both for data synthesis and project management, however, it is not pertinent to this stage of design. Within the context analysis design phase, the architect needs to research and review existing considerations. This includes regulatory requirements, but the input of project-specific data would be an unnecessary specification to consider.

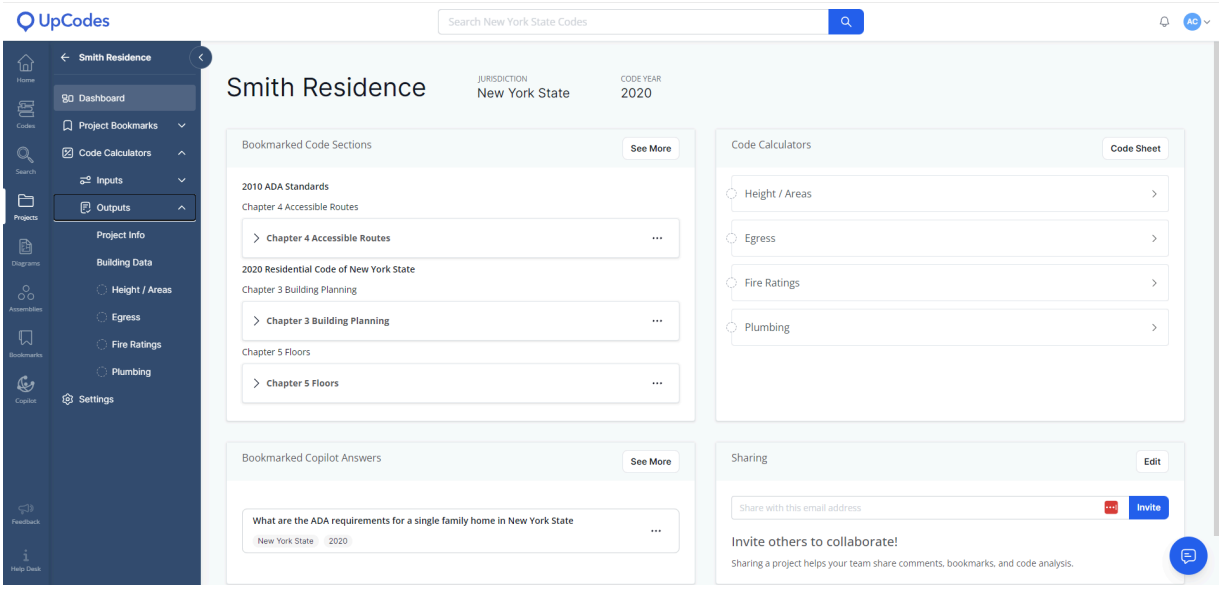


Figure 4.10 UpCodes Interface Credit: Author

Utilizing Copilot would be the best use of UpCodes for this early schematic design phase. Copilot operates similarly to any chatbot, with a line for the prompt and an area for Copilot's response. The response will consider any line of code from the jurisdiction specified and will include the referenced code pages and diagrams if applicable. For this project, researching the zoning requirements for 222 Briarwood Court Albany, NY would be a sensible place to start. After a few failed attempts, it is clear that the prompt needs to be as specific as possible, otherwise the response will be vague and incomplete. However, even with specificity, the results are subpar and mostly worthless.

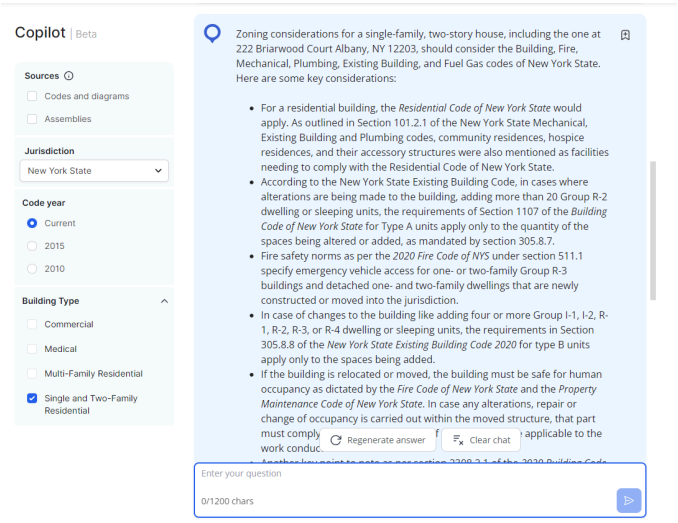


Figure 4.11 UpCodes Copilot Interaction Credit: Author

Hyper-specific prompts tend to provide actual results; however, they are incomplete broken snippets of text from the code chapters. Complex prompts do not seem to be worth the time to draft and iterate as the results are ineffective. Simple prompts, like minimum stair widths for example, do provide easily digestible answers including any diagrams, exceptions within the code, and the code resource itself. However, the process to type out the prompt and wait for a response is likely comparable to searching the physical code book in the firm, or if the architect is practiced enough they may already know the information, making Copilot also ineffectual for simple prompts.

Interestingly, every response from Copilot includes the disclaimer '*Copilot is the starting point for code research. It is often wrong; make sure to validate everything.'* This is considerably alarming, not only does Copilot not produce valuable results, but the results it does produce are untrustworthy. As a test of Copilot's accuracy, it was tested on text-based code questions. It scored 74% on the Project Development and Documentation section of ARE 5.0 (UpCodes, 2023). Copilot is accurate more times than it isn't but any inaccuracies at all means every response needs to be doubted and confirmed. This requires the architect to perform additional research to fact check the AI, adding more time to the process.

The intended use of AI within architectural design is to provide results faster and cheaper. Copilot did not produce results particularly quickly, nor were the results worth waiting for. If

anything, the AI is advantageous to use because it provides sections of code relevant to the inputted prompt, serving as an advisor leading the architect to the desired code book. UpCodes charges $68/month, and while the non-AI database and diagram catalog would be extremely useful in any firm, the AI capabilities have too many flaws to warrant the added expense. There are multi-user capabilities, encouraging collaboration between users. While UpCodes would add to any firm's productivity with its semi-intuitive breadth of regulatory information, the majority of its features are either useless in schematic design or too unreliable to consistently use.

Autodesk Forma[A]

Forma is an Autodesk program that uses AI to help projects in early-stage design. Forma, formally known as Spacemaker until it was adopted by Autodesk in 2023, can study any site in the world, and can use specific or generalized massing for contextual studies. Utilizing this program will give architects insight into their project's site and surrounding buildings. As a part of the Autodesk family, it can be easily integrated with Revit to use existing project buildings for this study. In the context analysis phase, this AI program can be used to study various masses and consider all physical contextual relationships.

For this single family house, the address of 222 Briarwood Court can be inputted into Forma, resulting in a navigable 3D view of the site. Through add-ons, most of them free with the Autodesk subscription, elements like roads, terrain, and neighboring buildings can be automatically added. The 3D viewfinder allows the architect to view the site from a variety of different perspectives, informing them about the considerable slope that exists on the east half of the property. Additional site elements can be manually added, like vegetation and neighboring buildings that were not previously added. More project specific information like site setbacks and height restrictions can also be added, this information being provided by UpCodes' Copilot and the existing site survey.

Once the site is updated with as much relevant information as the architect wishes to add, a conceptual mass can be added anywhere on the site. This is also the time an existing project building can be inputted to the site. Here, a 2 story mass about the scale of a house is modeled. The architect may use Forma's AI to convert and manipulate the mass as desired. This mass will be used for contextual studies but can always be changed prior to another study. This enables the architect to consider many different forms, scale, orientation, and geometries.

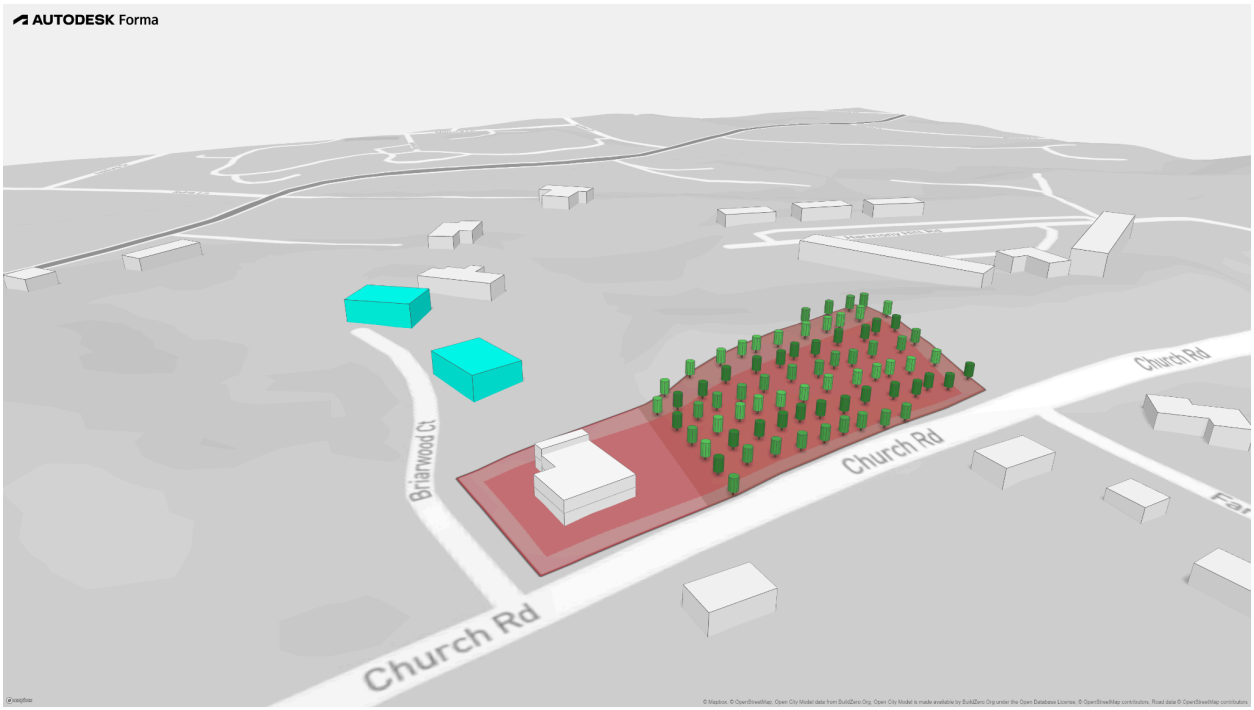


Figure 4.12 Forma Site Integration Credit: Author

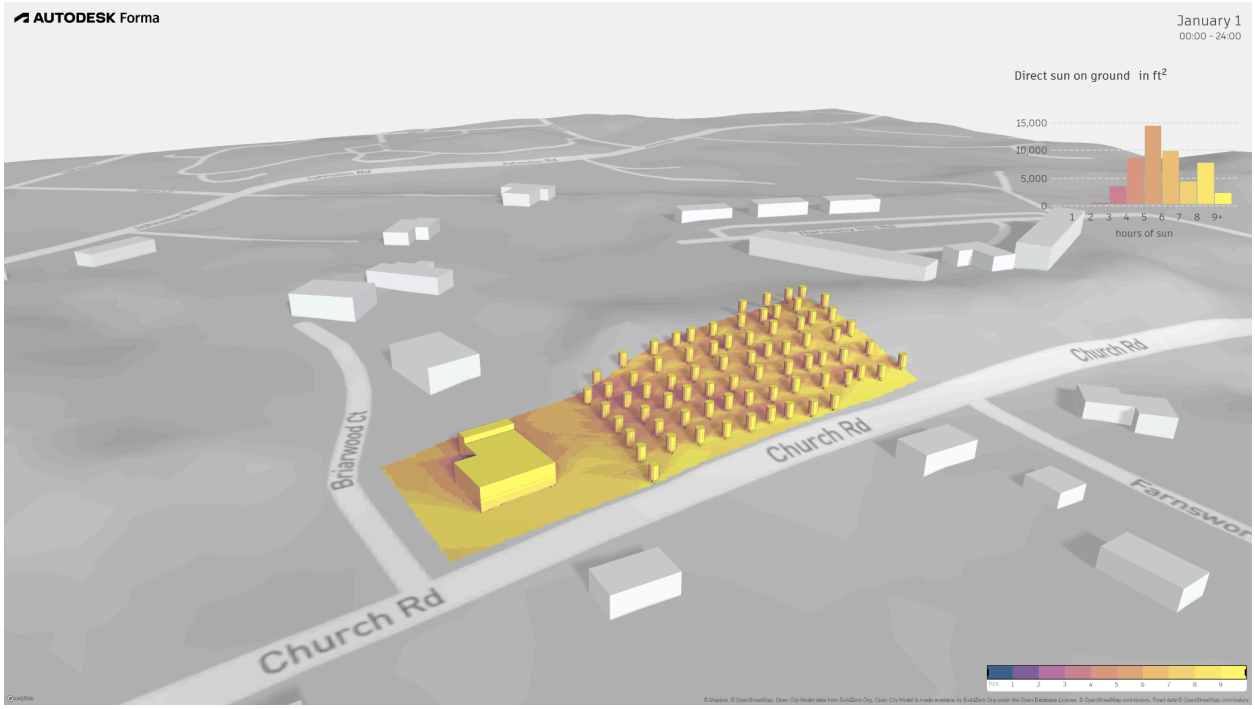


Figure 4.13 Forma Sun Analysis Credit: Author

The contextual tests that Forma can run include a sun study, daylight potential, wind study, noise, operational energy, solar energy potential, a microclimate analysis, and more with the capability of third-party extensions. Architects should run all of these tests for the project mass they are considering. Using these tests on multiple masses would prove even better results, ensuring that the final conceptual mass chosen is most optimal for this exact address. Forma uses predictive analytics to aid in this process, utilizing AI seamlessly to provide the best integration for architects and planners (Autodesk, 2023).

Autodesk Forma can be extremely valuable in this early design stage, allowing the architect to understand the site terrain more comprehensively, inputting and testing certain design opportunities, and visualizing the project's scale and orientation in relation to the surrounding context. This tool can even be better utilized once a project model is drafted in another Autodesk software like Revit. The capabilities in that instant would be similar but can inform the refinement of design elements to best utilize for solar, wind, and energy.

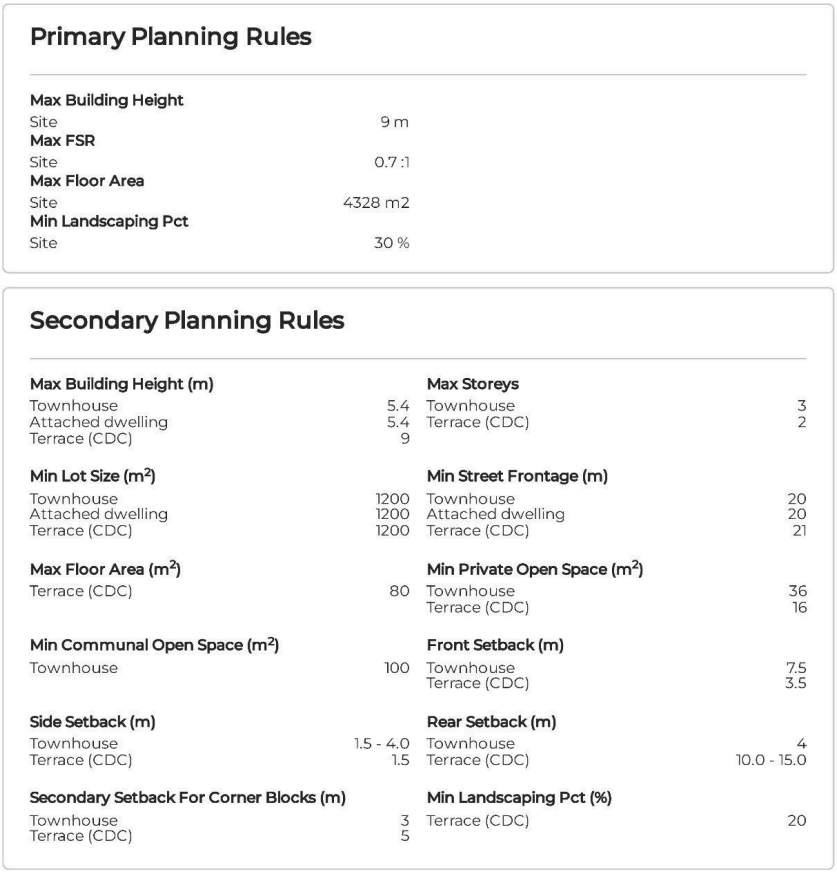
The integration of Forma within the Autodesk ecosystem makes it a valuable tool architects should continue to use, with a similar intuitive interface and collaborative capabilities. Autodesk prices Forma at $185/month, similar to many other Autodesk software. While the price is considerably higher than other AI tools, it’s important to note that the price is not solely for the AI integration assistance, but for the whole tool and its BIM integration with existing project models. Value in Forma shines with the time saved, being able to run multiple tests on a variety of masses in a matter of seconds. Each test took less than 10 seconds to complete, a noticeable difference compared to similar non-AI tools. The results were particularly useful and specific to the exact project specifications.

Archistar*

Archistar is an Australian-based company developing programs that utilize AI to study and test site data. This program is only available for Australian cities, therefore it will not be used or considered for this Albany, NY house and will not be included in the utilization assessment. The tool is exceptionally productive and should at least be mentioned when considering AI tools for context analysis. Archistar has been in development since May 2022, providing architects and property developers with an invaluable tool to assess site conditions.

This program has planning and market data, aerial photography, feasibility study, as well as design generator and analysis (Archistar, 2023).

This AI tool would be revolutionary for the context analysis phase, providing every instance of valuable information required. After selecting a site, in this example a randomly selected parcel in Australia, a multitude of data becomes available and downloadable. Archistar can instantaneously create a site report including zoning and building code information like permitted uses and minimum/maximum building limits, flood and fire maps, topography, vegetation, contextual demographic data, and critical shadows. The report also includes potential site designs, mostly for commercial developments, but can include feasibility for residential houses as well. This report created after simply selecting a site is paramount, saving the potential architect countless hours of research from a variety of sources.



Primary Planning Rules

Max Building Height
Site 9 m

Max FSR
Site 0.7 :1

Max Floor Area
Site 4328 m2

Min Landscaping Pct
Site 30 %

Secondary Planning Rules

Max Building Height (m)
Townhouse 5.4
Attached dwelling 5.4
Terrace (CDC) 9

Max Storeys
Townhouse 3
Terrace (CDC) 2

Min Lot Size (m^2)
Townhouse 1200
Attached dwelling 1200
Terrace (CDC) 1200

Min Street Frontage (m)
Townhouse 20
Attached dwelling 20
Terrace (CDC) 21

Max Floor Area (m^2)
Terrace (CDC) 80

Min Private Open Space (m^2)
Townhouse 36
Terrace (CDC) 16

Min Communal Open Space (m^2)
Townhouse 100

Front Setback (m)
Townhouse 7.5
Terrace (CDC) 3.5

Side Setback (m)
Townhouse 1.5 - 4.0
Terrace (CDC) 1.5

Rear Setback (m)
Townhouse 4
Terrace (CDC) 10.0 - 15.0

Secondary Setback For Corner Blocks (m)
Townhouse 3
Terrace (CDC) 5

Min Landscaping Pct (%)
Terrace (CDC) 20

Figure 4.14 Archistar Report Credit: Author

B. Synthesis

B.1 Establish Design Goals/Parti

The main idea and organizing principle, or parti, will need to be defined early in the design process. This parti should utilize information from the analysis phase to synthesize the optimal and primary design goal that will be used throughout the remaining design phases. This parti can be textual or diagrammatic. Parti diagrams are an especially useful tool to iterate and define the massing, program, circulation, spatial hierarchy, public/private zoning, and transparency/solidity (Bibo Studio, 2023).

ChatGPT[B]

As mentioned, ChatGPT can be an invaluable AI tool within the firm. After proving its utility in the program analysis design phase, ChatGPT can continue to contribute to the synthesis of a parti. Since ChatGPT is a conversational chatbot with a sophisticated database, it can produce results for any textual design element. The primary design goal and organizing principles would be the perfect role for this AI tool. While an architect may utilize their experience in the discipline to incept a new and inspired parti catered to the client, ChatGPT can assess millions of projects and propose a parti specifically written for the client.

For this project in Albany, the client asked for a 2-story, 4-bed, 3-bath house with a pool, garage, wine cellar, and library. The client did not articulate a particular style or budget, so long as both as consistent with the area. The architect can take this in multiple directions; choosing a primary design goal for this project is not so straightforward. Using ChatGPT can provide the architect with the exact parti they are looking for, or at the very least provide iterative parti examples that the architect can piece together. For the prompt, writing '*Give me an architectural parti for a 2 story house in Albany NY with a pool, shed, garage, wine cellar, and library. The focus of the design should be nature and consideration of the forest in the backyard*' results in plenty of usable and productive examples. Figure 4.15 highlights a snippet of the results; an opening idea of the design, as well as some architectural features, and an overview of the design's intent. The full parti, including space layout with square footages, is included as an appendix.

Conceptual Idea: "Harmonious Retreat"

Form and Function:

The L-shaped design maximizes both indoor and outdoor space, embracing the natural surroundings while providing privacy. The house is divided into public and private zones, with the public spaces oriented toward the pool area, creating a seamless indoor-outdoor connection.

Architectural Features:

- *Modern Aesthetics: Clean lines, large windows, and a mix of materials like wood, stone, and glass complement the tree's aesthetic, enhancing the connection between built and natural environments.*
- *Integration with Nature: The design focuses on seamlessly integrating the house with the forest landscape. Large windows and sliding glass doors throughout the house offer panoramic views of the lush greenery.*
- *Backyard Oasis: The backyard features a pool strategically placed to blend with the natural environment, perhaps using natural stone or wood decking. It's surrounded by native plants, creating a serene and private oasis.*

This parti focuses on creating a harmonious retreat that balances luxurious living spaces, functionality, and a seamless integration with the natural landscape of Albany, NY.

Figure 4.15 ChatGPT Design Goal Credit: Author

This ‘parti’ is quite long but provides useful information. For one, it gives the house a name; ‘Harmonious Retreat.’ This is a bit tacky and probably won’t be seriously used for the project, but it establishes the design principle that is used throughout the parti. ChatGPT played with the idea of an L-shaped house, writing how it can further integrate indoor and outdoor spaces, built environment with natural, and create a ‘backyard oasis’ with a pool overlooking the backyard forest. ChatGPT knows about the forest in the backyard and the need for a strong connection with nature because of previous conversations it had with the architect. ChatGPT

again also included elements not explicitly asked for, like the intended tones of the material - in this case, earthy to compliment the tree's aesthetics - and spatial organizations, like an open plan first floor with a lounge and private space on the second.

The 'parti' produced by the AI is comprehensive and will prove useful to the architect when considering a design. To simplify the idea of this project into a snapshot of its design, the parti should be reduced to a singular paragraph or sentence. Responding to the chatbot to simplify the parti to a sentence will provide results the architect can share with the client when presenting the idea and use in-house to focus the design team on the primary goal throughout the design.

An L-shaped modern sanctuary in Albany, NY, seamlessly blending indoor-outdoor living around a central pool, with private wings housing a library and wine cellar below and serene bedrooms above.

Figure 4.16 ChatGPT Parti Credit: Author

This is a strong and usable parti from ChatGPT. Not only does it sum up the extended text it previously provided, but it also includes keywords the client and architect can grasp when envisioning this project. '*An L-shaped modern sanctuary*' established the general shape of the project as it wraps around the '*central pool*' proving its significance in this design while '*blending indoor-outdoor living*,' evokes a beautiful open first-floor plan. The '*private wings*' is a new concept in this design but works perfectly, with '*a library and wine cellar below and serene bedrooms above'* serving as a functional and elegant solution to the project layout. This textual parti will be used by the architect to inform the design in later stages and can be utilized to create diagrammatic tools to further enforce the design.

ChatUML

ChatUML is a diagrammatic AI tool that started in 2023. It uses AI to interpret prompts from users to generate diagrams, tables, and charts (ChatUML, 2023). This program could be useful for architects looking to visualize and synthesize their parti into diagrammatic form. These

diagrams can indicate adjacencies, spatial scale, or occupancy. If done properly, like the example from BiBO Studio, the diagram will enforce the idea of the design and enlighten designers and clients about the overarching theme of the project as a whole.

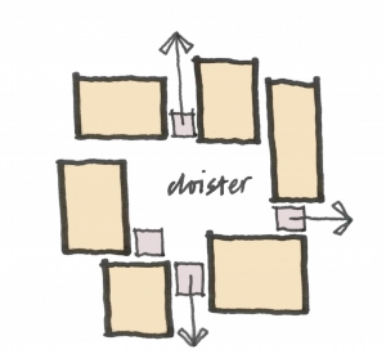


Figure 4.17 Conventional Parti Diagram Credit: BiBO Studio

The diagrams created by ChatUML are to replicate as closely as possible to the traditional parti diagram. By using AI, this process should occur faster and with more complexity and sophistication given the trained AI model. However, the results are anything but. Firstly, the architect could not insert the parti retrieved from ChatGPT nor the extended design principles as a ChatUML prompt. Any attempt to use more than a few words would produce an error. ChatUML requires a prompt to begin with '*create an entity relationship diagram for…'* with only a few diagram or chart options. For architects, the entity relationship diagram is the closest option to the traditional parti diagram.

After many attempts of iterating and specifying the prompt, the results are still a simple, incomplete flow chart. Not only does ChatUML require the architect to spell out exactly what spaces occur where and the relationship between them, but the results are extremely minimal and miss the majority of the prompted content. Writing explicitly that the living room is to be integrated with indoor and outdoor access to the pool and forest in the backyard will only yield an arrow pointing from 'living room' to 'indoor/outdoor access.' In addition to the subpar results, the visualization is underwhelming, with no option to add a hand-drawn element, or even change shapes, color, or size.

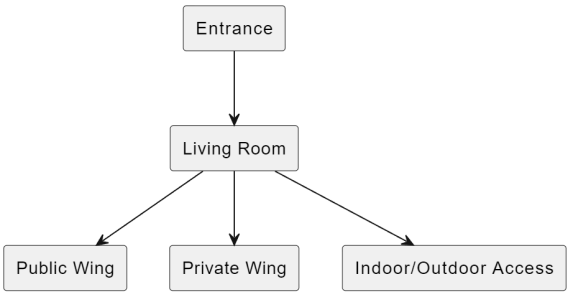


Figure 4.18 ChatUML Diagram Credit: Author

It's evident that the extended duration, upwards of 4 hours, to troubleshoot and manipulate this AI tool to produce these results is not worth the architect's time. Not only do these results not save the architect time, but it does not produce results at a higher quality or with more complexity than with traditional means. To ChatUML's credit, the service is relatively cheap with a cost of $3 for 25 credits, or $0.12/credit. These credits allow for one response, and given the issues with this project's prompts, it should be assumed that upwards of 50 credits will need to be used. It appears the best way to create parti diagrams is still to hand draw. While chatbot AIs like ChatGPT can provide ideas and textual parti's for the project, the physical drawing of these textual results are lacking, perhaps an telling forecast for what's to come.

Vondy[B]

Vondy is a database of existing AI tools that started in 2022. Vondy itself is not an AI tool, although it does use AI machine learning to find the most applicable AI tool to the user. The website is pretty intuitive, allowing users to search their library of AI tools that Vondy created. These tools range from a variety of services, most of them text-based; essay summarizers, joke generators, speech writers, etc., but some include image generation and even code script generation, allowing the user to create their own AI chatbot within the Vondy chatbot.

For this project, the architect is again trying to find a tool that can help visualize and conceptualize the parti into diagrams and images. Using Vondy's advanced database of over 100 AI apps, surely there is some program that can be used in this design phase. Unfortunately, there is not strictly a diagram generator or anything close. The best examples an architect can use for this instance are image generator tools, specifically ones like '*Sketchify*' which makes pencil

drawings, '*Doodle Maker*' which creates playfully artistic shapes, or '*Line Art Maker*' which generates simple line art images.

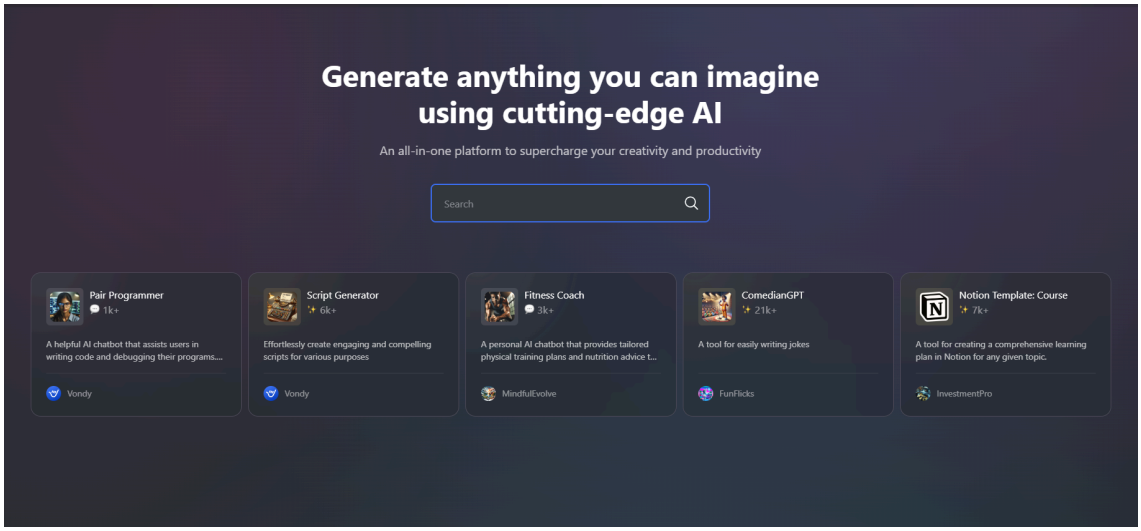


Figure 4.19 Vondy Interface Credit: Author

Similar to the success in using ChatUML, Vondy's apps were not productive at generating a diagrammatic parti. Regardless of the AI tool used, all of Vondy's solutions were incoherent and irrelevant to the intended purpose. The interaction with the app is only a text prompt, and entering a prompt requesting a diagram of the parti from ChatGPT was futile, only producing full-scale images of the app's idea of what the house might look like. The results were interesting but not what was intended. After manipulating the prompt to spell out exactly what the image generator should produce; '*a bubble diagram with an entrance and living in the center, branching to public, private, and outdoor spaces'*, the AI is still trying to generate images of a house, not a diagram.

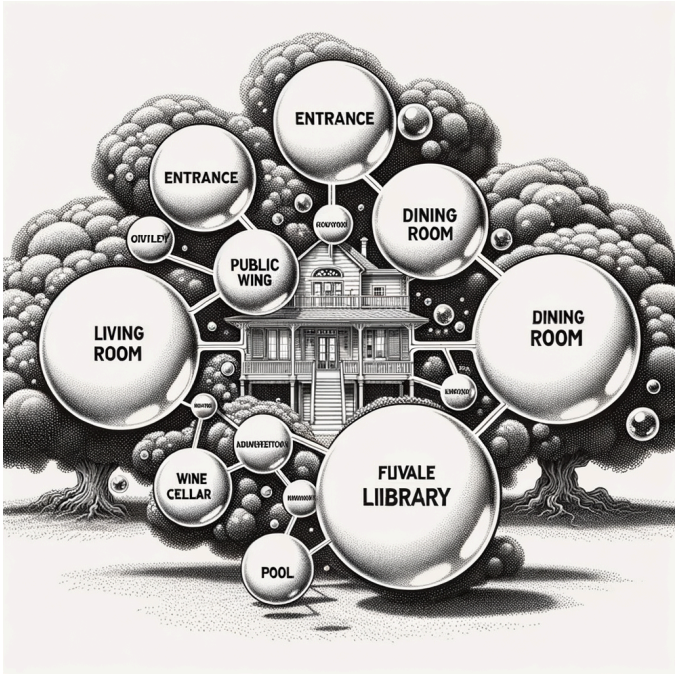


Figure 4.20 Vondy Parti Diagram Credit: Author

This rendition of what a spatial organizational diagram looks like is evidently off and not aligned with industry standards. Although, if AI continues to be used and trained this may be the new standard for parti visualizations. Again, it seems apparent that AI is not ready for diagram creation, it does not save the architect time and does not produce results anywhere close to what an architect can do with a pen. The intuition and multiple use cases within Vondy make the tool potentially viable for later phases of design, however, it should not be used to synthesize parti goals at this stage. Vondy is subscription-based, costing $19/month for full access to its catalog, with an additional $49/month tier for an increased generation limit. The tool is powerful on its own and should be considered when looking for AI assistance in design, however in practice, at least in this early schematic design phase, the architect is better off without it.

B.2 Design Creation

Within the synthesis design phase, it can be common for a multitude of design options to be drafted and evaluated. The purpose here is to find the best design concept without getting lost

in detail prematurely (DSA Architects, 2023). After understanding the project's design goals and parti, these early designs can be assessed given the architect's understanding of the client's goals. At the end of this phase, a singular design language should be chosen and the design team should be in agreement on general space planning and the project's relationship with the site and occupant. Lewis Davis, architect and founder of Davis Brody Bond asserted that the strongest ideas are often the ones developed early (Emerging Professional's Companion, 2013).

DallE

DallE is an OpenAI program that was released in January 2021. This tool takes text prompts and generates realistic images using text-image pairs, a neural network that associates images to text (Heaven, 2021). DallE started as a program to generate images never before seen, like a koala dunking a basketball, a proof of concept of how advanced machine learning was getting in 2021. DallE-2 was released in 2022 with more advanced comprehension abilities and high resolution photos. DallE-2 now can build upon created images, creating an iterative process to generate the user's desired image. This revolutionary tool by OpenAI was released to the public partly to allow users to create functional and practical images to support their interests, but also to help OpenAI learn more about the program, whether it comprehends prompts are is simply repeating previous protocol (OpenAI, 2023).

OpenAI has recently, in October 2023, released DallE-3, now with more nuanced understanding and advanced text translating capabilities thanks to more comprehensive and rigorous training (Betker et al, 2023). DallE-3 is integrated with a newer version of ChatGPT which was also released in October 2023. For the purposes of this thesis, the previously used ChatGPT model (ChatGPT-3.5) will remain to be used as well as DallE-2, still a functional and productive AI tool.

In the design synthesis phase of an architecture project, the architect is expected to generate a number of conceptual design ideas. Given the progress AI tools have made for this project, the architect should have all the information necessary to create a preliminary design. Using the site analysis and program understanding from the analysis phase, as well as the strong parti from the design goal synthesis phase, the architect should be capable of rendering several design choices for this Albany, NY house. The interface of DallE is clean and simple, with a

prompt bar and some example images DallE produced. The generation time is not immediate, maybe 15 seconds to run, and produces 4 images at a time.

To get the best results for a conceptual image, multiple attempts at writing the prompts are required. Since DallE can edit existing images, it seamlessly allows users to select a generated image and rerender it with additional prompt cues or simply provide variations of the image as is. Although the capabilities and potential uses are profound with DallE, the practical uses for design inspiration and synthesis are almost non-existent. Even after countless iterations of prompt construction, the results are largely incoherent or incomplete. The algorithm analyzing the prompt and pairing text to images works, but only partially. It's clear that adding specificity to the prompt assists DallE in adding more detail, but adding too many specifics clouds the model and tends to leave more elements out than it includes.

For example, the intention at this stage in the project is to produce conceptual renderings for the house as articulated in the parti. Writing the prompt '*L-shaped house with pool in the backyard'* not only doesn't result in a house in an L-shaped plan with a pool tucked in the corner, but the images are attempts at houses, sometimes blurring the roof line and sky, other times adding the pool inside the house. The multitude of failed examples requires the architect to add more specificity. Here, the prompt may read '*traditional 2-story L-shaped house with white siding and large windows, with attached garage, in the backyard there is a pool, further in the backyard there is a forest, in a hand-drawn schematic rendering'*.

Figure 4.21 DallE Exterior Concepts Credit: Author

The prompts can include a rendering style, without clarifying the style would be photorealistic. The architect will likely want a more loose and schematic image at this stage, and adding '*in rendered style'* tends to remove the realism from these images. The term '*traditional house'* or in other cases '*craftsman house'* or '*ranch house'* is required to be added, otherwise DallE defaults to hyper-contemporary houses not typical for Albany, NY. Interestingly, the order of details and breaks in these prompts are extremely important. The order of a specifying detail or sentence break will change the results from '*a house that is [2 stories with pool and forest]*' to '[*a 2 story house], [in the backyard there is a pool] and [in the background a forest].*'

With the introduction of more specificity, however, such as describing the shape or location of the pool, or clarifying the roof shape and form, the model falters significantly and leaves portions of the prompt out. In some cases resulting in a house without a pool, a house floating in space with no context around it, or a pool next to a blurry and confusing mass. For the sake of the thesis, inputting the exact parti from ChatGPT also does not produce valuable results. The prompt is a bit too vague and leaves too many unusable details like '*modern sanctuary'* and '*private wings.'*

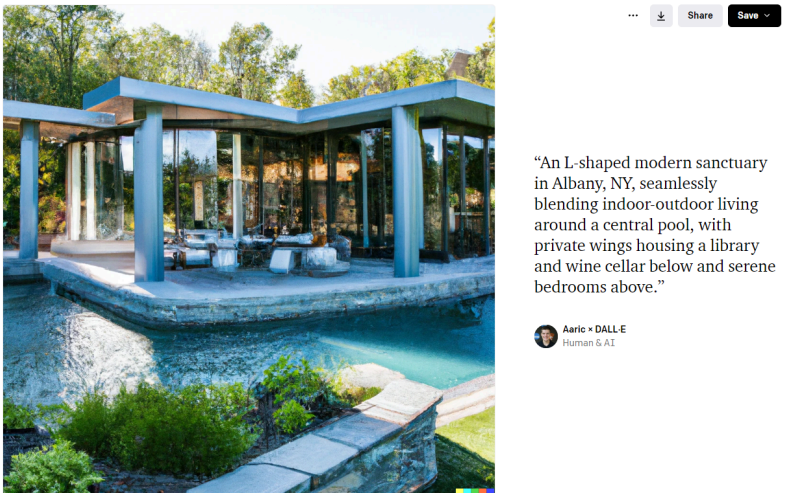


Figure 4.22 DallE Parti Concept Credit: Author

Given the challenges of depicting an exterior design language, the architect can also use DallE to consider interior spaces and finishes. The prompts again need to be generalized enough for the AI model to interpret individual elements (kitchen cabinet, vaulted ceiling, expansive windows) but with particular details added to achieve the architect's intended results. For this house, given the importance of the living room size, connection to the outdoors, and specialized

rooms like the wine cellar and library, the architect could choose to highlight a few examples of these spaces to gauge the client's opinion.

Figure 4.23 DallE Interior Images Credit: Author

The process of engineering prompts and attempting to edit and create variations of several images is an exhaustive process. It is certainly likely that the intention of the architect is to produce design considerations rather quickly to continue the project. Going through hurdle after hurdle just to generate subpar images might not be in the architect's or client's best interest. For the purposes of this thesis and the residential project in Albany, NY, two exterior renderings were generated that can be used for further design development. The combination of interior renderings can be used from previous iterations for future design considerations if needed. These 'final' two generated images best highlight the organizing principle and parti of the house and should be optimal examples of what the client is looking for. The quality of the results is related to the amount of time put in by the user, but for this preliminary design synthesis phase, DallE might not be as effective.

Figure 4.24 DallE Backyard Concept Credit: Author

Figure 4.25 DallE Front Yard Concept Credit: Author

Obtaining these AI-generated images did require more time and maybe more resourceful problem-solving than expected. The results, however, will serve utility in progressing the project and was accomplished in less time than it would take for an architect to draw or model and rendering the multiple design variations. OpenAI charges $15 for 115 DallE credits, or $0.13/credit, a comparable price to other similar models. DallE is a complex model that provides the best results when the user is experienced and able to construct the optimal prompt. If AI is to be integrated within architectural design in the near future, hand-drawing and model-making classes may soon be replaced by prompt engineering classes (Velásquez-Henao, 2023).

Midjourney

Midjourney is an AI program that was released in July 2022, generating any imaginable image from natural language prompts, similar to DallE. Instead of other image generators that operate from their website, Midjourney's generative AI uses Discord, a communication platform that allows users to communicate through text, voice, and video chats. By using Discord, Midjourney does not need to design its own user interface, running its sophisticated program through a Midjourney bot that communicates back and forth with the user (Midjourney, 2023). Access to Midjourney's discord server is behind a paywall, but once users get access there are plenty of opportunities for collaboration and inspiration.

In the Midjourney interface, via Discord users can enter prompts into the text box. Midjourney has a few features beyond text prompts, giving the option to type 'Imagine\' to construct a text prompt to generate images, 'Blend\' to upload 2 images to combine together using a clarifying text prompt, and 'Describe\' to upload an image for Midjourney to generate a prompt off of. These features can prove extremely useful both in this preliminary schematic design phase but also in further design development phases.

The utilization of AI to blend two images can serve to visualize a physically built model, or regenerate an existing image or sketch into a full rendering or style of another image. The prompt generation feature also alleviates a lot of issues in prompt engineering. When the user may not know exactly what to type to achieve results, Midjourney can take an image similar to what users are trying to generate and produce a text prompt, giving insight into how the AI articulates and understands a variety of text-to-image relationships.

Using Midjourney for this residential project will generate similar results to DallE, however, the quality of the results is far more advanced and usable. The ease of use is similar to DallE's interface, but the results are much more comprehensive and seem to be based more in reality. Instead of the random blurring and incomplete massing of DallE's images, the generations in Midjourney are complete and usable for client and architect use. Controlling the style of these renderings was also easier, with Midjourney more responsive to a variety of prompted style choices.

Figure 4.26 Midjourney Exterior Concepts Credit: Author

Once the architect types and submits the prompt, the Midjourney bot will respond in a matter of seconds with four image options, similar to Figure 4.26. Each of the images can either be enhanced, increasing the production quality, or used to create variations. Variations on these images rarely change the content itself of the image, rather making small adjustments in color, focus, and even the angle the image is taken. To adjust significant elements within the images, the prompt can be regenerated easily enough or a new prompt can be constructed with new detailing attributes.

All images remain in the Discord chat within the Midjourney server and are uploaded to the Midjourney website for the user to view and download at any time. Also on the Midjourney website is an ‘explore’ tab with thousands of AI-generated images from previous users. These images are constantly updated and are searchable, meaning any architect using Midjourney has

access to an endless catalog of AI images. The images can either be used as is, or can be used as examples for the architect to use with the ‘Blend\’ feature. Images in this tab also include the prompts used to generate them, assisting users even more to understand what exactly can be written in the prompts to generate desired results. For example, searching for ‘architecture’ in the explore tab results in countless architectural drawings in a variety of styles. Researching this tab will provide insight into how to articulate the desired style, scope, and content of the images.

It is evident when reviewing the generated images just how superior this AI program is. The results are ultra-high definition and are clearly based in reality. Using similar prompts to DallE, the results are just more practical and usable. Every space and massing generated by Midjourney are completely feasible and can likely be designed and built. The results of these images may very seriously be used to inform design decisions and drive the project based on the client's opinions.

The model that is used to generate these images is evidently more trained and understands text prompts at a more advanced level. The model is so good that there is a discussion of Midjourney being an architect's anti-hero, as it is so productive at creating impactful renderings that an architect’s creativity may be stifled over time and be no longer required (Radhaskrishnan, 2023).

Figure 4.27 Midjourney Interior Concepts Credit: Author

Adding more specificity to the prompts does significantly help generate more detailed results, although there was not nearly as much specificity required. Even using the exact parti created by ChatGPT produced more real and usable results. Even with a vague prompt that mentions '*modern sanctuary'* and '*private wings'* instead of the more productive '*house'* and '*additions,'* Midjourney had no trouble creating a few options. While the architect will never solely use this AI-generated parti to draft design ideas, inputting this parti provides a more direct comparison and is an enticing example of this project's design principle.

In an attempt to synthesize early design ideas based on the program and parti, Midjourney is distinctly a useful tool. At the very least, these images can be used by the architect to inspire the project's design, but can also be used to discuss design choices with the client or even serve as the project's design moving forward. Midjourney is extremely easy to use, with collaborative capabilities both within the firm using the same discord account, across the industry using the explore tab, and across all users within the live discord server.

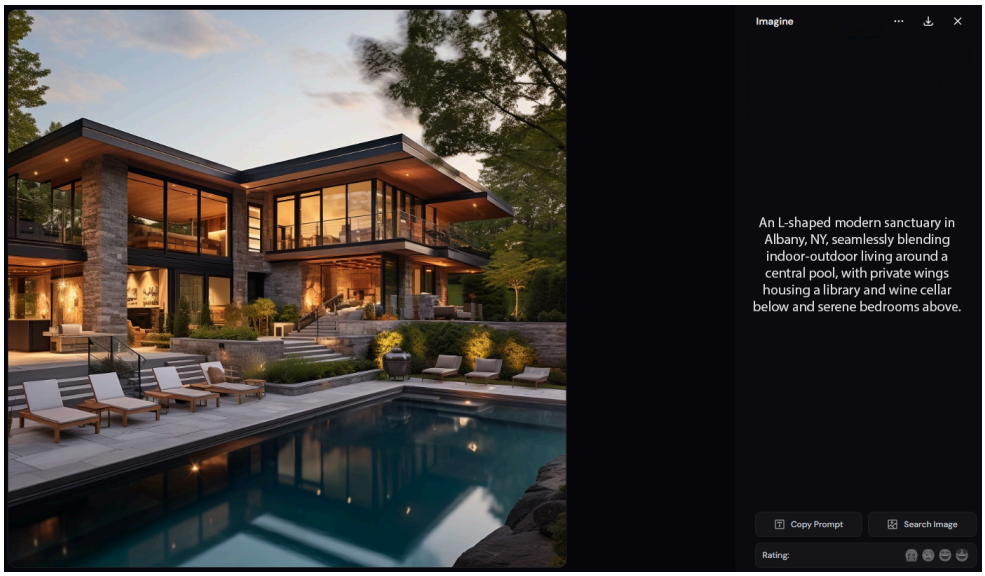


Figure 4.28 Midjourney Parti Concept Credit: Author

Midjourney is a subscription model, charging $30/month for standard unlimited generations, or upwards of $120/month for more commercial and mass generation needs. While a subscription is not the norm for AI image generators, it is actually favorable here. Since there are so many useful features within the program, it is advantageous to pay a reasonable fee for

unlimited generations as opposed to a pay-as-you-go model that may rack up extensive fees. The results speak for themselves and are realistic enough to assist or even take over this phase of design.

Architectures*

Architectures is a 2022 Spanish-based company that integrates AI and BIM, generating schematic design layouts for apartment complexes. With almost all architecture firms today using BIM technologies, it's important to begin building within the BIM ecosystem as early as possible. Utilizing AI should not hinder this initial generation of the project model. With tools like Architectures, AI can design and build 3D models within seconds for the architect's use. Unfortunately at this time, this program only functions for apartment buildings, not single-family homes.

While this program needs to be mentioned and could prove revolutionary in the integration of AI into architecture firms, it cannot strictly be used to progress the house design of this thesis. If architects utilize this AI tool for apartment building design, it is moderately intuitive but unbelievably useful. To begin the project, a site can be imported from a previous CAD source or can be drawn within the web-based tool. After drawing an outline of where the building is to be placed, or simply a perimeter where the building is allowed, the project building is created. That is it. The machine learning generates an apartment building within 5 seconds, complete with floor plans, 3D views, and endless reports of project data.

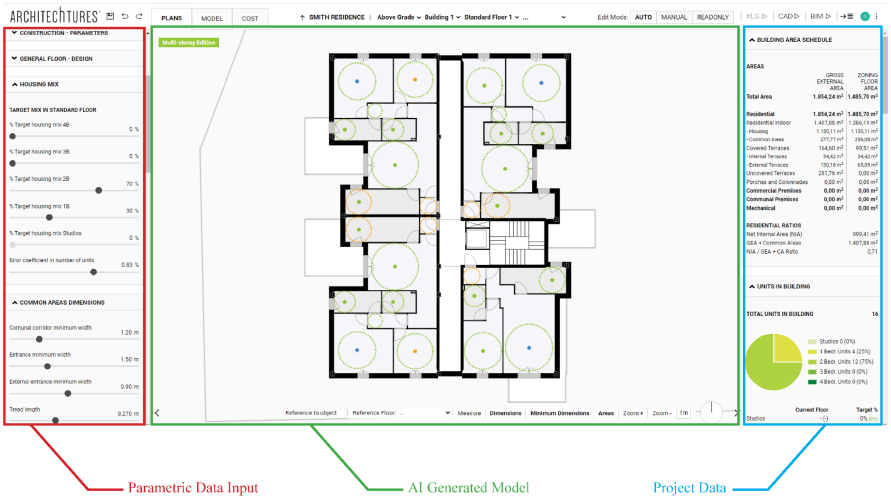


Figure 4.29 Architectures Interface Credit: Author

After a few uses, the interface becomes familiar and ever more useful. Architectures allows for every element of the project building to be parametrically detailed. Within the data input tab on the interface, everything from building dimensions, number of units, accessibility and code compliance, and even construction details can be adjusted with easy-to-use text boxes or sliding scales. The tool allows for any number of commercial floors to be added, or a percentage of floors to be commercial, mechanical, or multi-floor atriums. The resultant model is automatically updated, with the AI generating a new and revised building with each iteration. Architectures also provide updated project data, calculated in response to any parametric changes. This data includes building and unit areas, unit count and percentages, and advanced cost analysis, immediately totaling the entire project and breaking it down into floors, units, rooms, and materials.

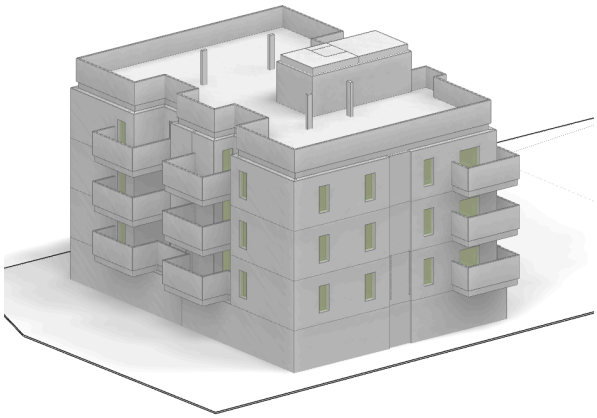


Figure 4.30 Architectures 3D Model Credit: Author

The 3D model generated from Architectures is useful to both the architect and the client. The visualization proves that the AI tool is considering more than just unit configuration, showing HVAC integration, structural considerations, and fenestration articulations. For less than 2 hours of learning the program and inputting project data, the results are more than expected. The entire design can be exported to any BIM software. With this, the architect can take the floor plans and 3D model to adjust as needed and begin the process for construction documentation. The assistance of AI with Architectures is almost the perfect tool for schematic design synthesis; generating countless iterations of a design specifically catered to the architect's parameters. Utilizing this tool can accelerate the design process exponentially, cutting countless hours - potentially days - of design work down to mere minutes.

C. Refinement

C.1 Functional Refinement

The refinement design phase is established to enforce the singular design choices made in the previous phases. There should be no more alternatives in this phase, as a consensus should be reached with the client about their preferred design option (Emerging Professional's Companion, 2013). Within the functional refinement phase, the preferred design option will be iterated and developed to ensure proper functionality. General functionalities can include proper structural capabilities, moisture drainage, code compliance, zoning compliance, and allotted space for required building elements like parking, lighting, and utilities. These functionalities should also cater to project-specific components such as activities occurring in each space, as well as the size and adjacent relationships of spaces (John Hearn Architect, 2023).

Autodesk Forma[C]

Autodesk Forma was used in an earlier design stage to study the site conditions and environmental effects on various massing models. Now that the design has progressed and the architect is ready to finalize and refine an ultimate design choice, Forma can once again be used. In this stage, Forma can serve best as a functionality tool, studying the site and environmental effects of one specific model. To assist in refining the project design and concluding this schematic subphase, Forma will provide valuable and necessary project information before the design can continue, all made faster and more accessible with the help of AI.

In this phase of design, the architect has a general idea of what the design looks and feels like. This design will need to be integrated into BIM soon, and utilizing Forma to facilitate that could improve efficiency. Within Forma, instead of allowing the AI to generate various models for preliminary site analysis, the AI can also assist in 3D massing creation. Here, the architect can input shapes, vertices, and points to create the project design to scale right on the site. This design is based on information received from previous phasing, including the program and site analysis, code review, and design synthesis.

When drafting the model in Forma, the architect should include as much detail as possible in this stage of the design. This includes the wing extension forming the L-shaped house and the pool in the backyard. Intricacies like the roof layout and volume extrusions on the front

and back face can also be included although not necessary for this refinement phase. Adding the relevant project conditions like the house shape and pool add contextual functionality to the model, and will ensure the analysis of this project is comprehensive. Forma can also categorize spaces, in this project useful to denote public versus private spaces and understand the access and connection between them.

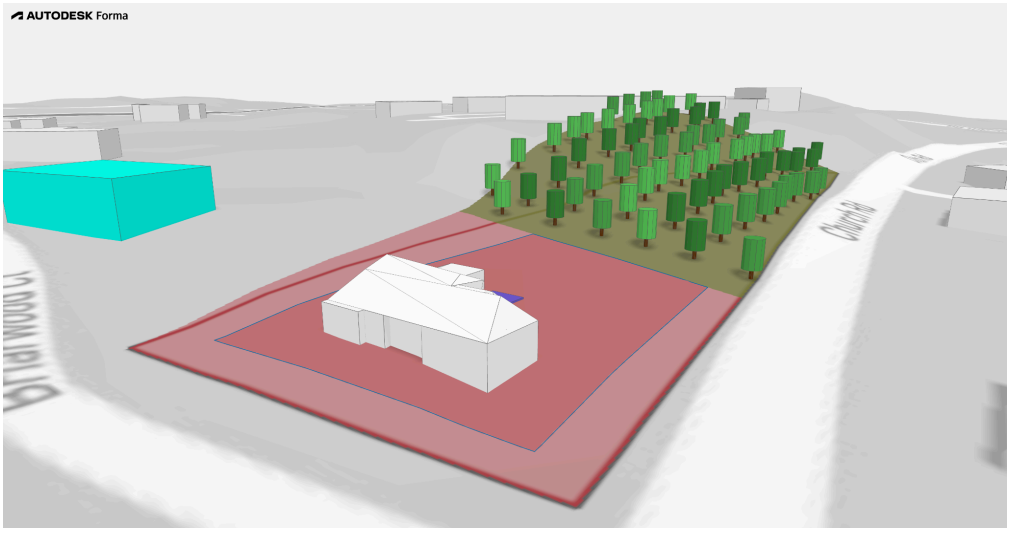


Figure 4.31 Forma Model Creation Credit: Author

Drafting in Forma is complex as it is all done within the 3D viewer, making it easy to pan and view what is being drawn but hard to actually draw. Drafting in 3D has its challenges, but these are overcome after working in the space for enough time to understand the best practices and keyboard shortcuts. Since generating the model in Forma is only volumetric masses, it takes considerably less time to develop than a similar model would with walls and floors. These elements will be essential in the design but do not need to be introduced at this time. Exporting the completed model into Revit for example will still maintain the scale and form of the model, making it easier to continue the design in later phases.

Once the model is complete in Forma, it can be easily analyzed similar to the massing studies in the context analysis phase. Now that the mass is close to the preferred design option, the analysis will become more useful in informing design decisions. The refinement in this phase will be based on the successes and failures of environment analysis, at the end ensuring the optimal design is chosen.

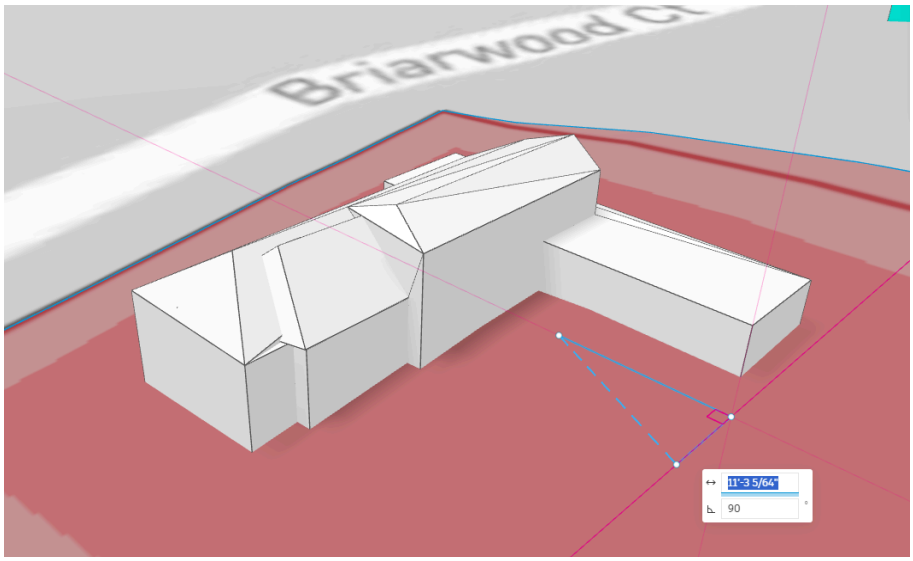


Figure 4.32 Forma Drafting Process Credit: Author

Utilizing AI assistance in Forma accelerates this process significantly. Not only was the drafting easier and quicker, but the analysis was intuitive, efficient, and very data-heavy. The architect can effortlessly run the analyses, adjust the design, and reanalyze to confirm the design is the best choice for the site.

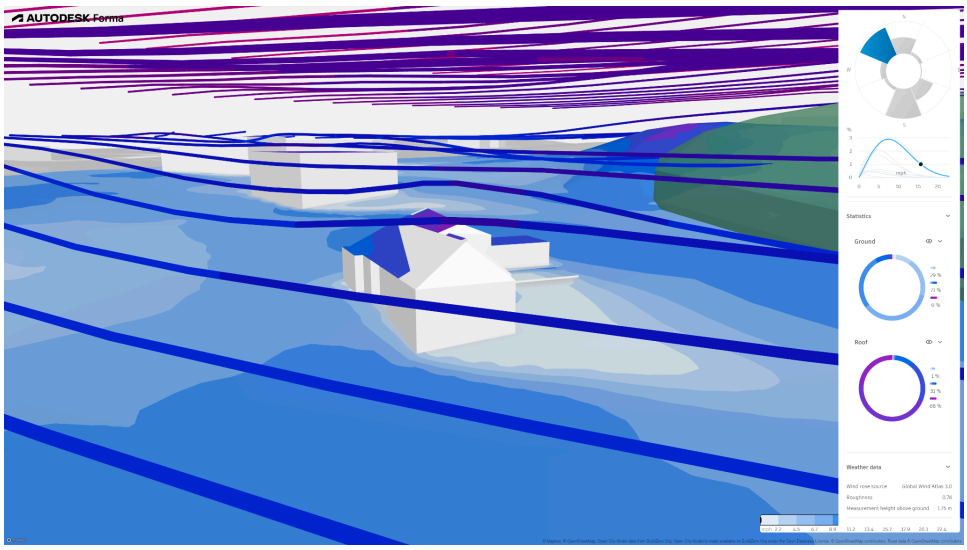


Figure 4.33 Forma Wind Analysis Credit: Author

Most impactfully, Forma can run analyses for sunlight, wind, and noise exposure, as well as operational energy. Additional analyses like solar energy potential can also be completed but would be better served later in the design process. Running each of these analyses takes less than

30 seconds and provides more than enough data to help the architect make a decision. This can include rotating parts or all of the house to better block wind from the backyard, or increasing the floor area ratio (FAR) to minimize energy usage. After running the analyses, the architect can be assured that the design is comprehensively optimal for all environmental conditions on that specific site.

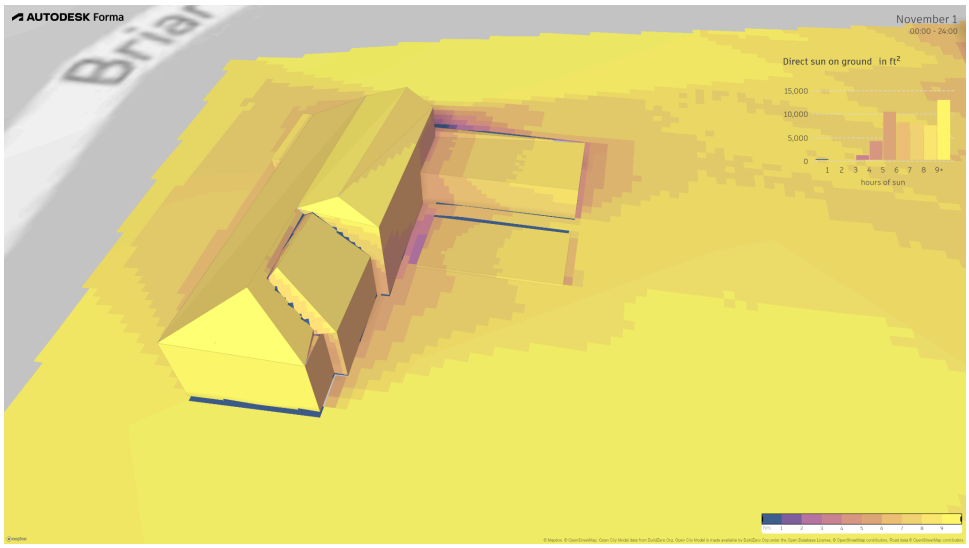


Figure 4.34 Forma Solar Analysis Credit: Author

Despite the learning curve in using Forma, the functionality of the program makes it a very valuable tool that architects should use when refining the project's schematic design. As mentioned, Forma can link projects to Revit, adding collaborative functionality for the project team. This will also add efficiency when first drafting the model in the Revit software, as it can be used as an underlay. The ability to add contextual information like surrounding buildings, roads, and vegetation makes the analysis more complete and helps inform the architect of relevant site conditions. While the cost is more than other AI tools, at $185/mo, it does include many features that are both impactful and necessary at this stage of design. The productivity and advanced design refinement allowed by using Forma make it an invaluable tool that architects should utilize.

CodeComply*

CodeComply is a web-based AI service that verifies project drawings are code-compliant. Unfortunately for this thesis, CodeComply is not yet available to the public, but the promising features of the tool make it worth talking about, especially in the functional refinement subphase of schematic design. Architects can use this AI program to input floor plans to test for code deficiencies. This can and would be used in all phases of the design process, but is best used early in the design to minimize design-based changes and save the project time and money.

Instead of taking time out of developing the design to redline, or worse ignore the code deficiencies entirely, architects can utilize an AI tool like CodeComply to irradicate the redlining process and ensure a more compliant design. Instead of continuing design work with potential errors, verifying the compliance of the design early and often in the design can prove effective in saving time and money. CodeComply verifies using the International Building Code (IBC) and the NFPA 101: Life Safety Code. The machine learning behind CodeComply has been trained using millions of examples of construction drawings, ensuring as accurate as possible results (CodeComply, 2023).

Figure 4.35 CodeComply Interface Credit: CodeComply

Although CodeComply was not explicitly used for this thesis, the program promises an easy-to-use interface. Architects can begin the process by uploading plans at any stage of design. For a project at this thesis' stage, the floor plan would be very minimal and created from the

mass generated in Forma. CodeComply then uses its trained AI to interpret lines, areas, and objects, generating a comprehensive list of all non-compliant items. The AI specifically looks for occupant load, egress capacity, exit separation, travel distance, common path, and dead-end compliance.

While a trained and experienced architect may be aware of these code conditions and create drawings that are already code compliant and thus do not require an AI tool to asses them, there are many applications when utilizing CodeComply would be beneficial. Firstly, even if the architect is confident in the design's compliance, there is no harm in running it through the AI to confirm there are no deficiencies or errors. It is also likely that projects get very complicated with multiple occupancy uses, resulting in convoluted and possibly wrong code-based design decisions.

CodeComply states that the tool can be used for architects and designers to create code-compliant buildings more efficiently, but also for building departments to more swiftly and accurately review submitted designs (CodeComply, 2023). While the program is not yet operational for use in this thesis, the applications of CodeComply make it an enticing and worthy tool that should be mentioned in the schematic design phase. Given the implications of AI assisting and potentially taking over code verification both in the firm and in permitting offices, it's important for architects to become familiar with AI tools like CodeComply. These tools will require millions of drawings as data to feed the machine learning algorithm, more than CodeComply or any other AI compliance tool currently has (Sun et al, 2022). It may take years for AI to fully enter the code compliance discipline, but the process of feeding the programs to make it better starts today with architects and designers utilizing programs like CodeComply.

C.2 Aesthetic Refinement

Refining the aesthetics of the project in this phase may seem premature; the design is bound to change and there is no need to articulate every design element at this stage. Refinement, however, is not for final design rendering, it is for the architect's and client's agreement of how the design is to be developed now and in the final stages. Juhani Pallasmaa, the renowned Finnish architect and professor wrote that a profound design process eventually makes the patron, the architect, and every occasional visitor in the building a slightly better human being

(Archtalks, 2010). This aesthetic refinement is necessary to discover the project's aesthetics and establish the language used throughout the design process.

Adobe Photoshop

Adobe Photoshop is a well-known program that is used across multiple disciplines, with architects using it to edit and render project images. In May 2023, Adobe released a generative AI tool integrated with Photoshop. This tool is an included feature native within Photoshop 2023 and later and includes the generative fill ability. This ability takes any selection within the image and can generate edits based on the user's prompts. The CTO of Photoshop, Ely Greenfield intends for this tool to accelerate productivity when using Photoshop (Nellis, 2023). For this thesis, while the previously generated renderings were great and usable for schematic design, they were not perfect. Using Photoshop's AI tool can let the architect easily edit individual elements throughout the image, adding site-specific and comprehensive details that the previous prompts could not include.

To use generative fill, architects can begin editing any image in Photoshop as usual. After using any selection tool, like the rectangular marquee or lasso tool, the generative fill tab will appear with a list of options. This is a floating tab that can be moved or dismissed based on preference. In the generative fill tab, the architect can type in a prompt, asking the AI to edit the selection as they see fit. The architect also has the option to leave the prompt blank, allowing the tool to use predictive generative AI to generate an image edit. By and large, the architect is better off using prompts specifying exactly what they want to be edited as the predictive fill is highly variable and mostly irrelevant. Photoshop will then produce three variations of the edit, which can be seen by cycling through one by one. These variations can either be chosen by dismissing the generative fill tab or deleted by deleting the selected edit itself.

The AI-generated edit appears as a new layer above the existing image. This creates a timeline of edits within the layers menu and allows for each edit to independently be hidden, edited, or even moved around the image if desired. In addition to the generative fill tab, the generative fill feature appears on the right side of the properties menu, giving the same options for prompts and displaying the history of edits for that selection. Each edit takes less than 10

seconds for Photoshop to generate the three variations, and the results can be as detailed as the prompt.

The results of Photoshop's generative fill once again require exhaustive prompt engineering to produce the desired results. The quality of the edits is mostly subpar and has little to no context to the rest of the image. Even after multiple iterations of drafting the prompt, there are some instances where Photoshop will just not produce the desired results. When the results are close to the subject and scale that the architect is looking for, they are often in a different style and not entirely well blended with the surrounding image. Using Photoshop's native features like the magic wand selection tool makes selecting subjects and intricate objects in the image easy. The interface and usability of the generative fill is very familiar and intuitive, but the quality of results is just not there to progress this design adequately.

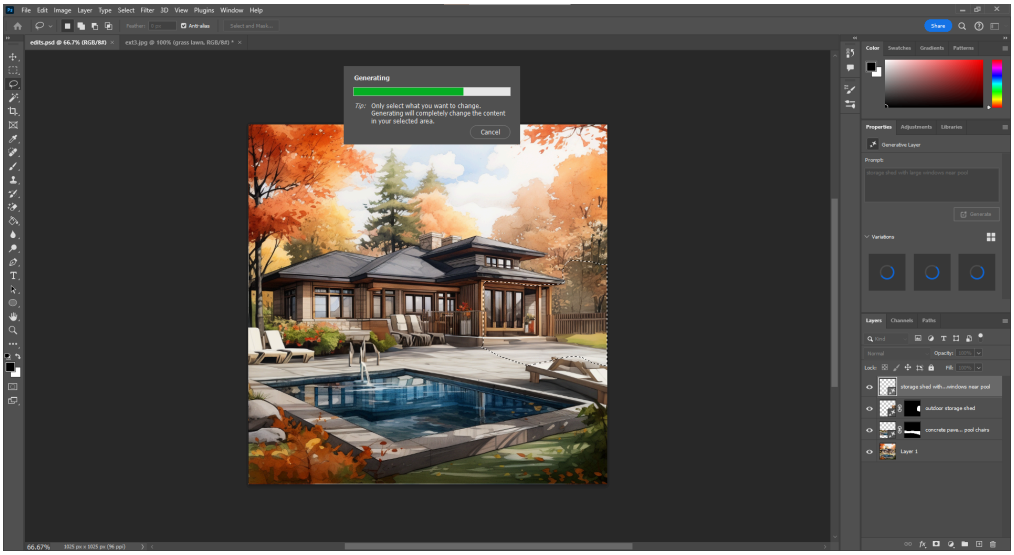


Figure 4.36 Photoshop Interface Credit: Author

The architect can select many different areas of the image and draft different prompts for each, for example in Figure 4.37 selecting the area surrounding the pool to add concrete paving, and selecting the nearby yard to add a fence. Enabling users to add different prompts for specified areas is an extremely advantageous tool for architects. Specifically in this stage of the design, the architect can utilize this tool to make the AI-generated scenes more realistic and catered closer to what the client was envisioning. Unfortunately, the quality of the AI-produced

edits is clearly inferior to the original image. The edits contain the familiar blur of unrealized and ungenerated masses. The blending of the edits and the original is fine, although the differences in subject quality create a clear distinction and an eye-sore.

Figure 4.37 Photoshop Backyard Edit Credit: Author

Another downside of using Photoshop generative fill is the lack of context awareness within the image. For example, by selecting a general area next to the pool in the original backyard image and typing in the prompt '*add outdoor storage shed next to the pool,'* Photoshop will generate edits of a shed next to another pool. The generative fill is not aware of the pool in the image, as the selection the architect is using does not contain the pool in it. If the pool is to be selected and then prompted to add a shed next to the pool, the AI will generate a new pool on top of the original with a shed next to it.

Similarly, scale and location is a noticeable issue in these edits. Selecting a small area near the pool and prompting for a shed will generate a miniature shed, obviously out of place with the surrounding objects. Since the generative fill will only edit the selected area, and seemingly does not generate edits of portions of sheds or any object, a large selection will need to be made to achieve the correct scaled object. This becomes challenging when editing a perspective rendering of a 2D image. Selecting a larger area now includes more depth, and again the AI does not understand context without the entire image being selected. With the inclusion of depth and the inability to specify where the object is to be placed in relation to others, the

generative fill feature becomes incapable of producing desired results. For example, *'Large outdoor shed in front of house and next to pool'* generates edits of blurred fences, doors, and stairs - irrelevant and useless to the architect.

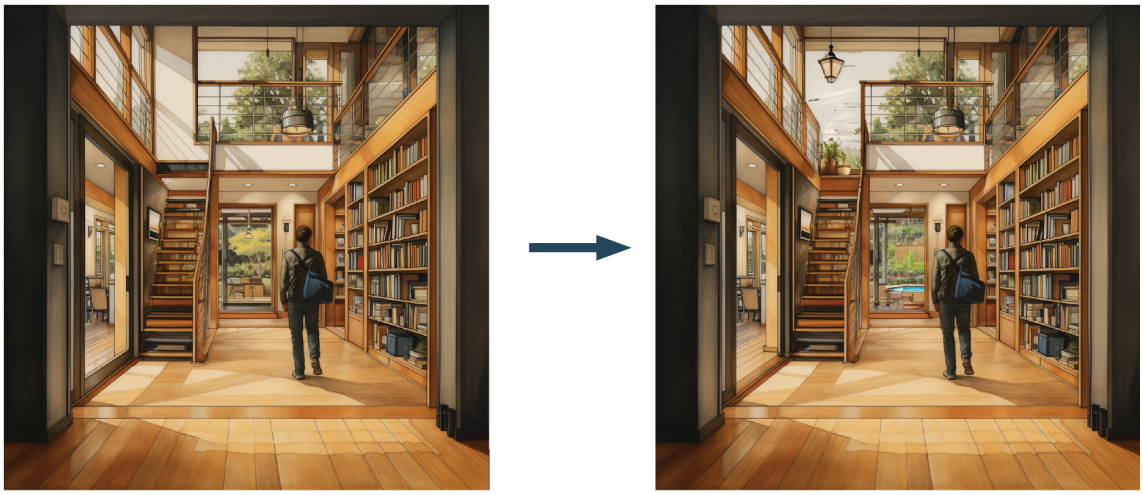


Figure 4.38 Photoshop Library Edit Credit: Author

Despite the severe need for specificity in the prompts and the apparent lack of ability to add specificity, Photoshop's AI can still be productive in adding small details throughout an image. The library rendering generated from Midjourney was great for preliminary design synthesis. However, now in the design refinement stage, this image needs to be edited to introduce more realism and relevance to the house's design. Adding an entryway to the top of the stairs was accomplished relatively effortlessly, as well as fixing the threshold at the left doorway and adding the pool outside. These elements are small details to the image but are required if the design is to move forward and be considered by the client. The process was again iterative with multiple failed attempts before achieving the desired results, but for instances like this, it seems Photoshop's AI is quite capable and useful.

Figure 4.39 Photoshop Frontyard Edit Credit: Author

Even when small selections and relatively modest edits are made, the AI has trouble matching the style of the image. Since it is clear the generative fill does not consider context when generating edits, it should be assumed that the style of edits is irrelevant to the style of the original image. The substandard results behind the AI also mean the comprehension of style articulation is substandard. Using the same prompt language in Photoshop as the architect used in Midjourney, like '*-in a hand-drawn architectural rendering style,'* produces widely variable results. Even after iterating and trialing a number of stylistic cues, the generated edits are almost always an identifiably different style.

When editing the backyard in Figure 4.39 for example, fixing the slope of the backyard to better match the actual site worked well enough; blending the original with new and even continuing the mowed lines of the lawn. Adding the backyard forest - a contextual necessity - and the family silhouette in the front - a typical architecture rendering practice - both look out of place and clearly edited. Specifying different styles made no difference, and it was difficult enough to get the desired content let alone the desired content in the correct style. If the architect is not careful, using this AI tool will lead to an assortment of varying edits, creating a Frankenstein of a rendering. Although it will include the necessary context and realism elements to the image, it could look unprofessional and off-putting to the client.

Figure 4.40 Photoshop Bedroom Edit Credit: Author

While good practice in using Photoshop's generative fill is to make small and simple edits, it should also be noted that the AI can both add and remove objects. The generative fill is not strictly 'fill,' also allowing the architect to utilize AI to remove selected items, like the skylight in the bedroom in Figure 4.40 for example. Here, the edits can remove and replace objects given the prompt, even adding items in addition to removing them, like the hanging light fixture and semi-transparent curtain in front of the window. These elements again make this space more realistic to the overall design. The quality of the edits, however, does detract from the realism of the scheme in general. The AI-generated dog for example is evidently incomplete and slightly off compared to the rest of the image. Using AI for an edit like this may be a time saver but clearly does not produce better results than traditional methods.

For design refinement, given the issues in using this AI and the lack of usable edits, it may be more efficient at this point for the architect to use traditional means. While the edits only take a maximum of 10 seconds, regenerating dozens of times for each selection adds up and is an exhaustive and futile process. The architect is likely better off printing the image and sketching over it, a process the client would not mind and might actually appreciate the level of detail included in the edited sketches. The architect could also use Photoshop without the AI, the way it was intended to be used before the generative AI revolution. Using Photoshop may take longer but would produce more concise and tailored results. The architect could also use the AI tool as an assistant for some edits, generating moderate edits quickly and drafting layers for the architect to use traditionally.

Accessing and using Photoshop's generative fill is an easy process, with intuitive and familiar functionality to traditional Photoshop. There is no upcharge for the generative fill, as it is included in the base 2023 Photoshop or later. The price of Photoshop, $23/month, is more than other AI design assistance but obviously comes with more functionality with other standard Photoshop features. Purchasing Photoshop primarily for the AI feature may not be worth it to the architect, given the challenges and steep price relative to other available tools. Not only does Photoshop's generative fill require advanced prompt engineering, but it now requires acute selection engineering. The architect needs to know exactly what to select and not select to make contextual edits and exactly how to draft a prompt that generates relevant results. The

compounding of specificity makes the tool hard to use and largely unproductive to take over design work, although it has the potential to assist architects with minor design edits.

AI Home Design

AI Home Design is a website that uses AI to redesign spaces inside and outside of the house. The tool launched in 2023 and allows users to upload pictures, either schematic renderings or actual photos of their house to let AI redesign them effortlessly. There are several features of AI Home Design, including an interior design editor, completely changing the style and color palette of the image to the user's satisfaction, and a day-to-dusk filter, adjusting the subject in the photo from a daytime shot to a nighttime shot or vice versa. There is also a virtual stager and furniture remover, either adding staging furniture to an empty room or removing furniture from a room, both useful in the realty and design industry.

For this project, previously used generative AI created multiple photos of the house design. In addition to Photoshop editing, the architect can utilize AI Home Design to enhance the photos and alter them to best fit their client's style. While there may be limitations in previous image generator prompts, this AI tool assists in adding the style and/or furniture that was missing. Using AI Home Design is very intuitive, fast, and the results are effective. All the results include a comparison slider, giving the architect and client real-time changes to the original design. This tool can be very useful not only in editing photos of the house design but also letting the client see the house in a variety of different styles to inspire or even inform future design choices.

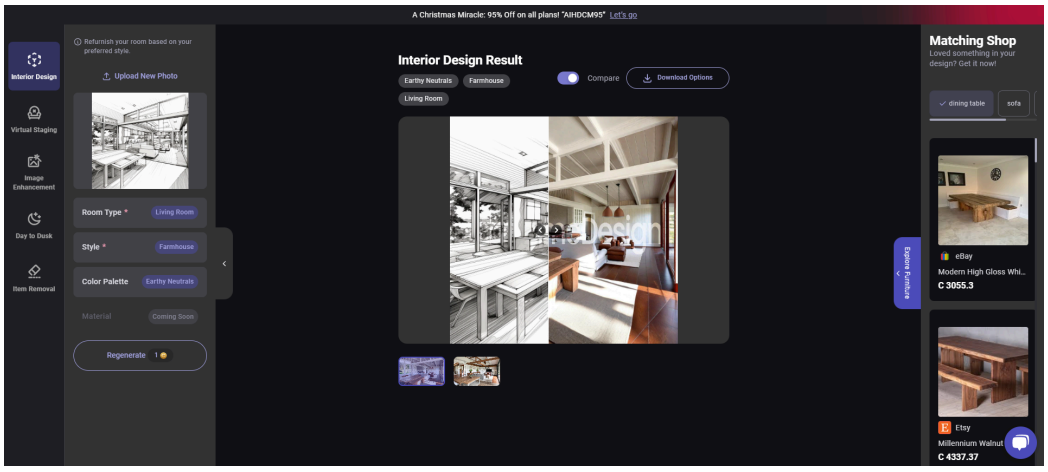


Figure 4.41 AI Home Design Interface Credit: Author

In addition to the AI-assisted options and the comparison sliding tool, AI Home Design also includes furniture identification. This analyzes original photos and identifies items of furniture, categorizing them on the sidebar with where to buy them. This feature also works and is perhaps more useful in the virtual staging and interior design tools, since the AI generates the furniture in these edited images it then also identifies them for the user. Within the interior design editor, there are many styles and color palettes the architect can choose from. Styles, ranging from modern to Scandinavian to industrial and much more, 9 options in total. These styles also include holiday editions, altering the images to add holiday decorations and context. Similarly, there are 17 color palettes to consider, all with varying degrees of neutrals, pale tones, and primary colors.

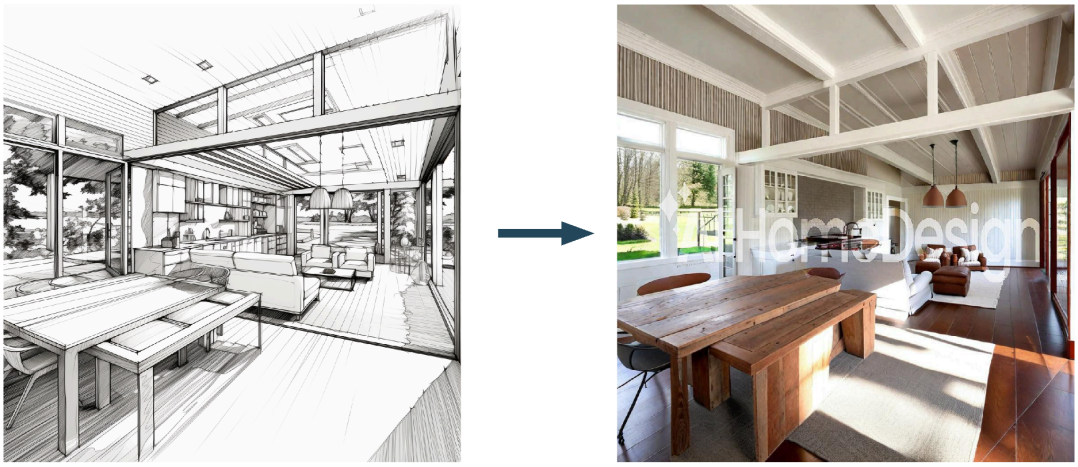


Figure 4.42 AI Home Design Style 1 Credit: Author

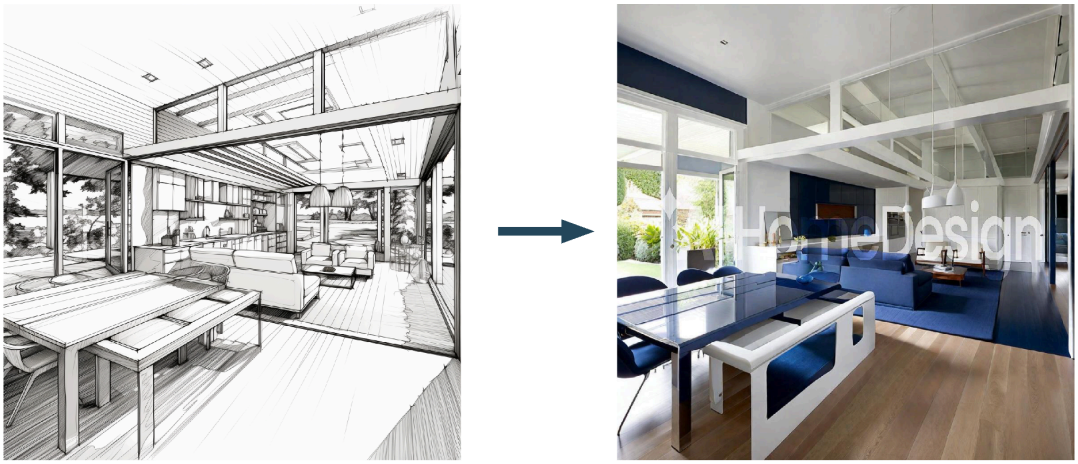


Figure 4.43 AI Home Design Style 2 Credit: Author

The AI style editor works exceptionally well with blank canvases, such as the black and white schematic sketch in Figures 4.42 and 4.43, generated earlier from Midjourney. Here, the architect can select any number of combinations, a contemporary style with a forest color palette or a farmhouse style with earthy neutrals for example. The architect should understand the client's style and run the project renderings through AI Home Design to cater to that style. If the client doesn't have a defining style, this tool again should be used to draft multiple renderings with a variety of styles, giving the client visualized choices. These iterations take less than 10 seconds to rendering and can be reiterated or edited as many times as desired. The results, including the comparison slider, are useful enough to warrant using this tool for any design refinement, both indoor and outdoor.

Figure 4.44 AI Home Design Exterior Credit: Author

On the outside of the house, AI Home Design can alter the design style similar to the interior design spaces, but can also edit the image to appear at night. Night renderings are often useful to architects to display how spaces are used at different times of the day and how the feel of the design changes once artificial lights are required. For this project, using the AI tool to convert the exterior perspective of the house from daytime to nighttime gives the architect another rendering exemplifying the house design in a new way. The results are not spectacular, the image is maybe slightly dimmed and the sky is a few shades darker. What is very impressive with this edit is the interior spaces lit up, as if all the lights were turned on. This was all done by AI Home Design, there were no prompts or selections to identify where there should be lights. This tool not only gives the architect a nighttime rendering in a matter of seconds but also helps inform the architect about interior and exterior lighting demand.

The other useful feature of AI Home Design, in addition to the interior and exterior style editor and day-to-dusk filter, is the use of AI to add and remove furniture. Adding furniture to an empty space will prove revolutionary for the realty industry, saving countless hours in physically staging a house or editing photos to promote the sale of the house. For architects, this tool could also be productive when working with existing buildings or are in the early stages of the design and need inspiration for how the space will be populated. Using AI to remove furniture is equally productive, with the ability to easily remove furniture from an existing image can help users further understand the space they have available to them. This again has implications to assist in the realty industry, removing clutter and unwanted furniture from house sale photos, and also for the architecture industry, reducing unneeded furniture from existing photos or providing more renderings with and without furniture in it.

Figure 4.45 AI Home Design Furniture Edit Credit: Author

To assist in this project, since previous AI programs already provided renderings of interior spaces with furniture, AI Home Design can be used to remove the furniture from these spaces, helping the client to see exactly what to expect when the house is constructed. This can be useful if the original rendering with furniture was not to the client's satisfaction. Instead of changing the space and creating varied renderings, AI can help to remove the furniture and articulate the space plainly. Again the results are not spectacular but the tool is still impressive and can be extremely useful as a preliminary design tool.

Using AI Home Design was easier than most AI tools, with the architect simply needing to upload a photo and select their desired editing choice. There were no specificity issues, no poor quality control, and no iterations required to achieve the desired results. Since there are no collaborative capabilities, using this tool in the firm would be on an individual basis, although that does not detract from the potential success this will have in inspiring interior and exterior design choices. Priced at $10/month for light users and $25/month for everyday business users, it is a comparable and valuable tool that firms can utilize today. The ability to easily adjust a project's design style within 10 seconds for any space in the design should not be taken lightly. This tool can easily be a staple program that firms use daily to assist in design work.

D. Documentation

D.1 Schematic Design Documents

In order for the client to fully understand the spaces, uses, and scale of the project, a preliminary set of schematic design documents are drafted in the documentation phase. While these are certainly not construction documents ready for construction, they are the precursor that will communicate the proposed spaces to the client. These documents will typically include floor plans, site plans, sections, outline specifications if applicable, and a preliminary cost estimate (Emerging Professional's Companion, 2013). As stated, no AI tool was discovered to assist in the creation of the outline specifications, a task typically included in the schematic design documents and could take about 9 hours for this case study project, according to a survey completed by 14 architects (Appendix D). Once the client receives the completed documents, they are able to make informed decisions on the intent of the project moving forward. An architect will likely need to wait for final approvals from the client before continuing to design development, so the proper execution of the schematic documentation phase is paramount.

Maket

Maket is an architectural design program that was started in 2019 and recently integrated the use of AI to generate floor plans. This tool can help make early design work very simple. With AI-generated floor plans, these plans can be drafted and iterated within minutes, saving the architect time and giving them the ability to produce multiple designs. Maket allows users to

specify space requirements, such as room square footage and adjacency, and AI will generate several floor plans off on these parameters. Maket allows users to upload existing floor plans as well in addition to AI-generated plans. These plans can then be rendered right in Maket, and exported as images or vector files for BIM integration later in the design process.

The idea of using AI to generate floor plans is intriguing, considering the creative problem-solving and potential time-saving. In practice, however, the use of AI to generate floor plans is unproductive and at this moment completely useless to architects. For this project, floor plans are ready to be developed after the parti and design have gone through iterations and refinement. Using the square footage provided in the parti from ChatGPT to provide Maket's AI parameters seems seamless and intuitive. The results should be an exact visualization of all of the development of the design to this point. The floor plans generated in Maket, however, are simply too unpredictable and unsuccessful.

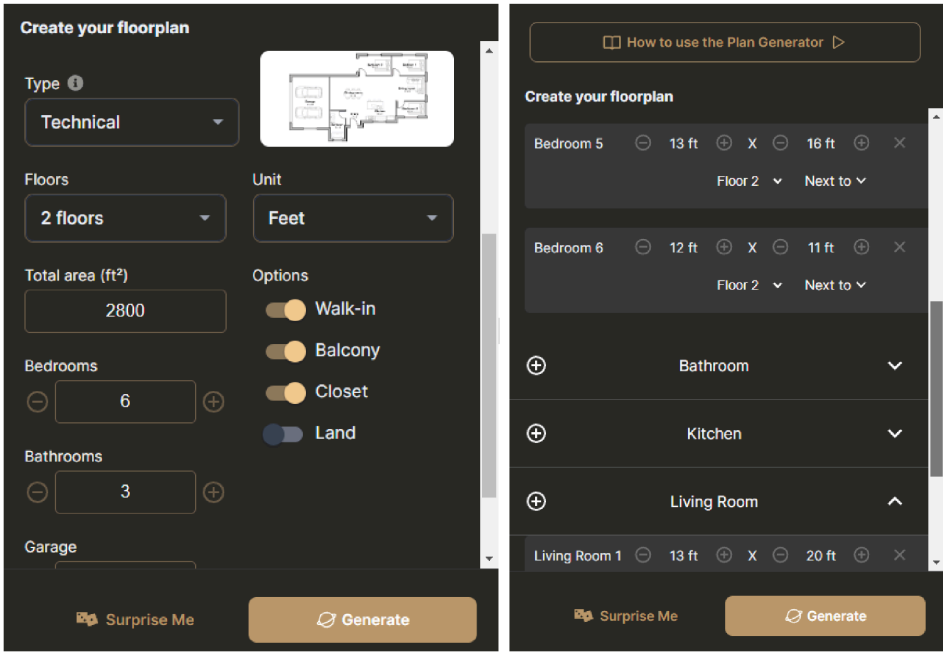


Figure 4.46 Maket Interface Credit: Author

Using the plan generator in Maket is easy enough; there are limited options for input data and after completing each the floor plans can be generated. Under an advanced settings tab, the individual room dimensions can be edited, otherwise, the AI will generate dimensions based on the house's total area. These rooms cannot be renamed, for example, '*Library'* on the first floor

instead of '*Bedroom 3,'* but the ability to alter their dimensions to match exactly what was provided in the parti is helpful. The generative AI will produce a floor plan for each floor, although they do not seem to be integrated in any way, let alone functional.

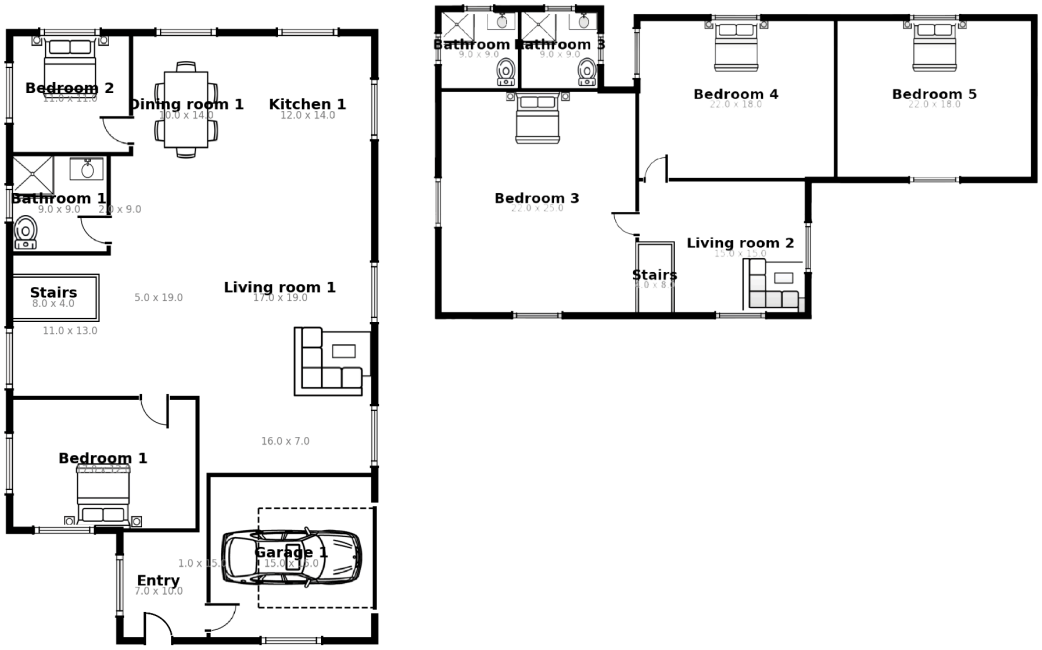


Figure 4.47 Maket First and Second Floor Plan Credit: Author

The floor plans generated from Maket are evidently lacking. Firstly, the spaces created are within the parameters set, but the location and orientations generated from the AI make the floor plans unusable. The entry next to the garage has no access to the rest of the house, and the stairs between Bedroom 1 and Bathroom 1 are out of place in a void of useless space. The upstairs plan seemingly is unrelated to the first floor, with a completely different geometry and room layout. Not to mention the complete failure of the room layout, placing both bathrooms off one bedroom and placing the access to a bedroom through another bedroom. These plans are severely underdeveloped and need serious editing.

Maket includes a floor plan editor in their program, allowing the architect to better control the floor plan produced by the AI. Since the original floor plan was largely a failure and the rooms could not be placed in an L-shape to match the actual design, the editor will need to be used to produce the desired plans. The editor isolates each room as an editable rectangle, giving

the user complete control to move and scale these spaces. Rooms can also be added and removed here, essentially meaning the original floor plan can be removed entirely in favor of one the architect makes from scratch. While the layout in this instance is not AI-generated, since the architect needs to physically place each room, a floor plan vector file and image can be created by AI based on the placed rooms.

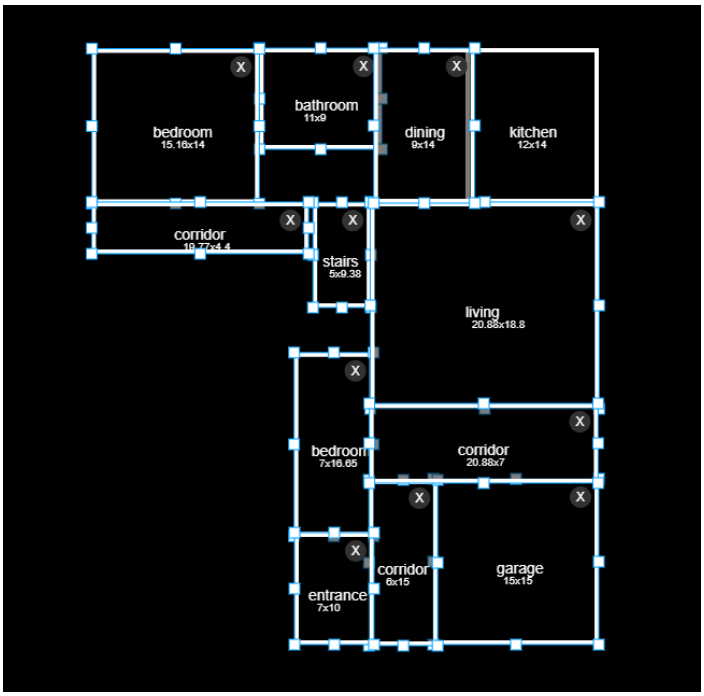


Figure 4.48 Maket Plan Editor Interface Credit: Author

Using the editor interface was as simple as clicking and dragging rectangles to the desired positions. When editing the floor plan, the architect can place rooms in the configuration and scale they desire to make the layout both livable and match the L-shape of the design parti. These rooms again cannot be renamed beyond the subject of the space, like *'bedroom'* or *'living room'*. Once the edit is complete, the architect can use Maket to generate the floor plan, adding walls, doors, and windows where the AI deems relevant. While the edited floorplan is slightly incomplete and minimal, the use of AI should assist in making the spaces more realistic and ready for future design phases.

The quality of results from Maket is once again underwhelming here. Even after countless attempts to generate anywhere close to a reasonable floor plan, the best result is still

incomprehensible and a useless floor plan for an architect. When comparing the editor version of the plan and the AI-generated plan, it is clear that the AI uses the rooms as a reference but largely ignores the actual connections and layout of the spaces. Maket struggled mightily with the L-shaped floor plan, continuously trying to merge the two wings into one large rectangle. It should be noted that the second-floor plan could not be edited, making the whole process futile anyway.

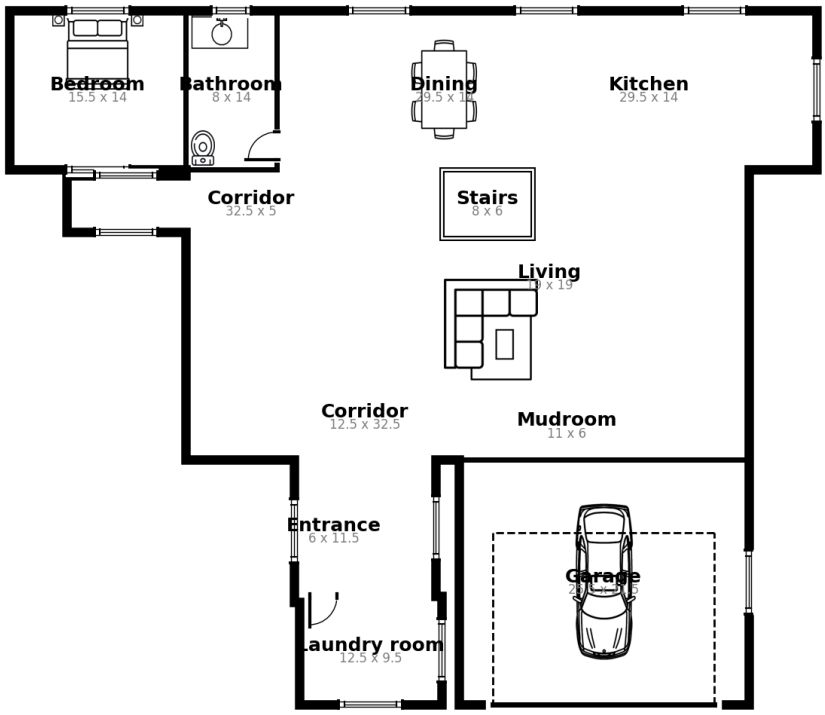


Figure 4.49 Maket Edited Floor Plan Credit: Author

The lack of functionality in Maket makes the tool mostly valueless in a firm. The process of inputting parameters and editing the results multiple times is at that point comparable to the architect generating the plans by traditional methods, either using BIM technology or hand-drawn. The manual editing alone is very similar to floor plan creation using BIM technologies, except there is significantly less functionality in the Maket tool. The AI assistance in generating the floor plans would not be beneficial to the architect or client.

Even if an architect uploads an existing floor plan instead of using the poor AI-generated plans, the floor plans are imported as images and the user is required to use the editor to overlay

the rooms over the image. This will again lead to an AI-generated floor plan with similarly poor results. Maket does have other features, including floor plans and elevation renderings. Using both existing floor plans and generated plans in this rendering feature yields familiar results, useless renderings that the architect would not be using for this design.

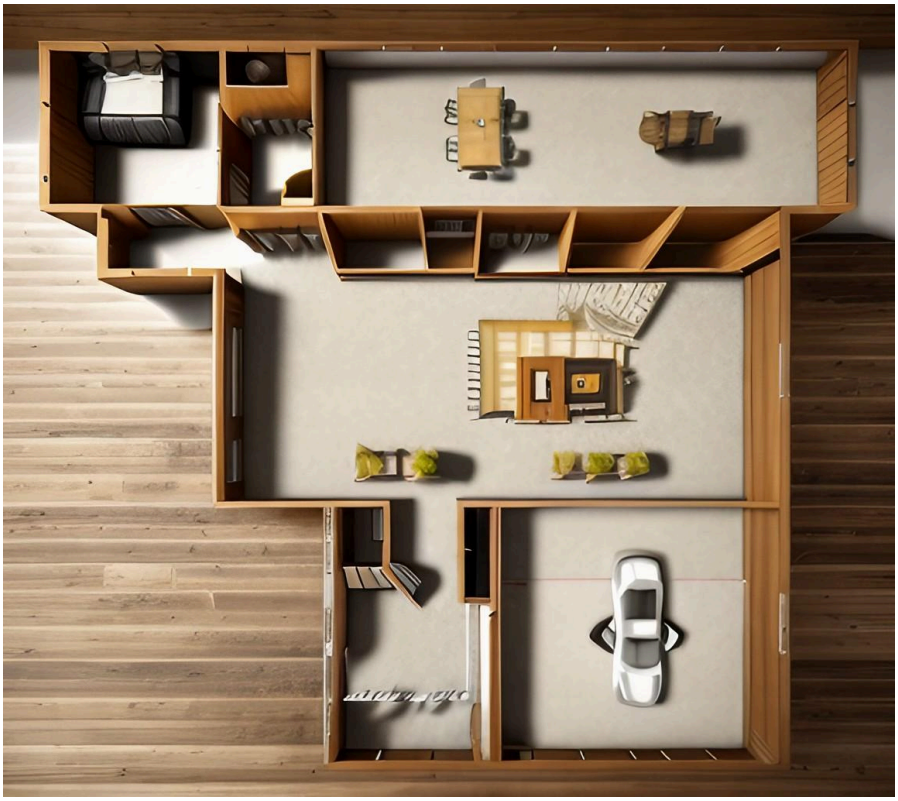


Figure 4.50 Maket Rendered Floor Plan Credit: Author

The rendering quality of Maket's floor plan is incomprehensible and appears to have just added color to the vector plans. Rendered floor plans are usually not needed for architects in this phase of the design, although the client could find them useful when envisioning the spaces inside the house. Maket itself is not collaborative, meaning the design team would have to work independently to generate plans. The price for Maket is $30/month, giving users unlimited generation and full access to their many unique features. However, given the challenges in floor plan generation and the poor results in all areas of this AI tool, it is clear that the architect is better off utilizing other means to generate schematic construction documents.

PlanFinder*

PlanFinder is an AI tool that generates floor plans for apartment layouts. The tool is very productive, easy to use, and extremely well integrated with existing modeling software. Unfortunately for this thesis, PlanFinder is only compatible with apartment layouts at this moment, so the generation of floor plans for a house is not yet available. Regardless of its compatibility, this tool needs to be mentioned because of its superior features and implications in time-saving. PlanFinder integrates as an add-on with Revit, Rhino, and Grasshopper. Once the tool is added it becomes effortless to generate floor plan configurations.

Figure 4.51 PlanFinder Interface Credit: Author

PlanFinder generates floor plans using two features; fit and furnish. To utilize these features the user will need to start with the building's exterior walls and interior circulation. The fit command will generate unit layouts based on the inputted parameters. Here, the user will select the perimeter walls of the unit and specify the unit attributes, including bedroom and bathroom count, as well as walk-in closets and storage spaces. There are no space considerations in this input, as the existing walls provide borders and the AI will fit the layout however possible. This feature will generate up to five variations of unit layouts, each of which can be individually selected per unit. Although individual items, like door placement or furniture layout, are not editable in the PlanFinder interface, these can be adjusted within the modeling software once the plan is generated and published.

The furnish command will furnish the plans in real-time, providing preliminary beds, tables, and cabinetry in appropriate spaces. This helps give the room's scale and will provide more information on circulation and uses. PlanFinder uses advanced machine learning that was trained with thousands of plans, generating original yet functional floor plans in every iteration. With a successful model like PlanFinder's, the generated results are fast and effective. After a floor plan is generated, the perimeter walls remain linked meaning moving the walls after the plan is generated will instantaneously create a new plan that fits the edited layout.

Figure 4.52 PlanFinder Customization Credit: Author

This tool has proven to be intuitive and has significant implications of being an efficient AI tool in the firm. Preliminary floor plans are generated in the schematic design phase for the architect to understand space requirements and ensure the proper building footprint is being considered. Utilizing an AI tool like PlanFinder can completely revolutionize this process, essentially creating every possible configuration for a space in a matter of minutes. This tool currently costs $13/month, a reasonable price for the performance. The time and cost savings in using this tool could lead to a quicker and cheaper schematic design process, alleviating time and budget constraints significantly.

Hypar*

Hypar is an AI design automation platform that generates comprehensive designs for architects and developers. Hypar has recently been released for public use to assist in the completion of early design work for commercial spaces. There are multiple features of this advanced tool, including design generating, space planning, and test fit. Hypar utilizes AI to generate layout design, envelope and facade design, and even early structural design with little input required. Since this AI tool is only compatible with commercial spaces at the moment, it cannot strictly be tested for this thesis; however, the use case implication Hypar has in the architecture industry warrants it being mentioned.

Figure 4.53 Hypar Space Planning Parameters Credit: Author

The primary feature of Hypar is the space planning tool, here creating a 2D-floor plan and 3D model from space parameters inputted by the architect. These parameters are specific enough to accomplish any space the architect might want, and the AI tool is advanced enough, again using sophisticated machine learning, to create a comprehensive and usable floor plan. The general layout can be controlled, by drafting overall dimensions and interior circulation routes. This feature is fully customizable with all of the project levels and is accomplished within minutes thanks to the efficiency in AI assistance.

Figure 4.54 Hypar Space Planning Model Credit: Author

Once the proper attributes are drafted and generated in Hypar, it can be run through a number of tests to assess compatibility with the site, structure, and other building systems. Since this tool is used for preliminary design synthesis, these tests can be extremely useful to inform the architect of variation requirements. The efficiency in this generative AI means multiple iterations of a design can be generated to best fit the project criteria. Hypar also has integrations with Revit, Rhino, and Grasshopper as an add-in tool, meaning these designs can be easily updated for existing projects or be used to initiate a new BIM project.

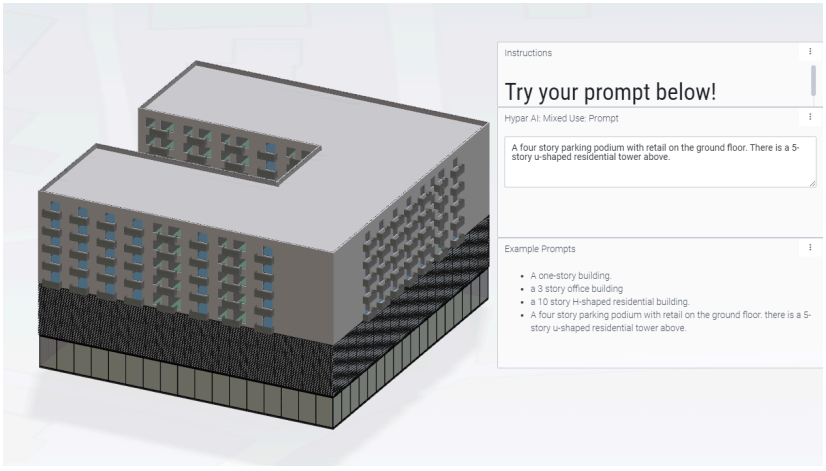


Figure 4.55 Hypar AI Design Credit: Author

Another advantageous feature of Hypar is its Hypar AI design. Instead of manually drafting a project with defined space parameters, Hypar AI design can be used to create a new project from a prompt. Similar to image generators, a user can input a desired prompt, this time generating an entire project model. This model is comprehensive, again with facade, structure, interior layout, and core configurations. The impressive ability to generate this type of model from a few words proves how advanced and sophisticated Hypar's AI has developed. While architects likely won't use this feature for schematic construction documentation, it is an enticing tool that can incept design ideas during early concept phases.

After the design in Hypar is developed to the architect's content, documents for architect and client use can be outputted. These schematic construction documents like floor plans, elevations, sections, and even room and door schedules, are all automatically generated when the design is created. These documents are exactly what the client needs at this phase, and will be used for discussions with the client before progressing the design. Since the design from Hypar is easily integrated into BIM technologies, the design can seamlessly move into the next phase of design; design development.

Utilizing an advanced and evidently powerful AI tool like Hypar can accelerate the design process exponentially. Within minutes a project can transition from a design idea to schematic documentation with very few issues. This will alleviate a lot of time architects previously had to spend on document drafting, saving firms time and money in this early design stage. The results are functional enough to serve as the basis of design, almost irradicating the design synthesis process for commercial buildings entirely. While input and intervention from architects will still be required, tools like Hypar are a huge appeal of AI integration within design firms.

D.2 Schematic Renderings

At the conclusion of the schematic design phase, the client will want to discuss and approve the proposed project. One of the typical submittals given to the client for this discussion will be schematic renderings. These renderings are not expected to be final drawings or design decisions, they are meant to be representative of the architect's vision for this project. Digital renderings may not be common in this particular phase, as most architects would be able to

produce drawings, diagrams, and sketches to adequately convey the project design. Schematic renderings will typically include exterior perspectives, elevations, and any strong design elements the architect wants to discuss with the client. These schematic renderings are the summation of all analysis, synthesis, and refinement (Borson, 2019).

Vondy[D]

With multiple AI tools available in its database, Vondy can be used for a variety of solutions in architectural design. Now that a design choice has been finalized and refined, final schematic renderings can be drafted to send to the client for review. Utilizing Vondy in this stage can help the creation of these renderings through one of their many AI solutions. The benefit of using Vondy in this stage or any stage of design is that it hosts hundreds of specialized AI tools, meaning each tool is specifically trained in its designated role. Compared to other image generators or chatbots that need to be trained across multiple applications, Vondy isolates its tools for specific applications.

For the purposes of this project, finding the most useful AI tools to render final schematic drawings is foremost. Although the architect can parse Vondy's database manually, they could also utilize Vondy's AI-powered search engine to find the optimal tool. For example, searching for tools to generate '*architectural schematic renderings'* will yield results for *Realistic Renderer*, a tool generating photorealistic art, *Sketchify* and *Ballpoint*, both tools generating high-quality sketches using pencil and pen weight respectively, as well as *Aerial Photo Creator*, a tool generating aerial photographs. All of these tools can prove useful for this stage of design and should be utilized to produce high-quality and effective renderings.

Given that the design has already been defined and iterated, this stage of generating AI images needs to be highly specific. For example, the architect can no longer draft a prompt for an L-shaped house with a pool. The prompts need to specify every detail of the design exactly, working to match the work previously generated in Midjourney and refined in Photoshop and AI Home Design. Generating differing designs at this point would be counterproductive and confuse the client. For this reason, the engineering of the prompts will need to be exact and deliberate. Because the specificity may never yield the exact house design once again, and considering the

design team already generated multiple renderings of the house, it may be more productive to focus on smaller-scale details.

Figure 4.56 Vondy House Rendering Credit: Author

Using Vondy to prompt for another house rendering will generate a house reasonably similar to the previously designed house, but after countless drafts, there will never be an exact match, regardless of specificity or iterations. Instead, AI image generators at this stage of the design can focus on previously un-rendered parts of the design. This can include interior shots with more context to the surrounding rooms, close-up views of the outdoor landscape, or just schematic views indicating the connection of masses. These are not only relevant to the client to see more of the house design but can help the architect to assemble a collection of images best representing the design.

The quality of results is not quite to the standard that was previously established. While the images are complete without blurs or inexplicable objects, they still lack a level of realism that is expected at this point. The style of the image does not have to be photo-realistic, rather the content within the image needs to be based in reality, something that a majority of the images did not contain. While the subject matter of the images generated is a result of the prompt engineering, Vondy's tools are much less reactive to the prompt than other AI image generators, at times ignoring details or not understanding the items specified.

Figure 4.57 Vondy Pool Perspective Credit: Author

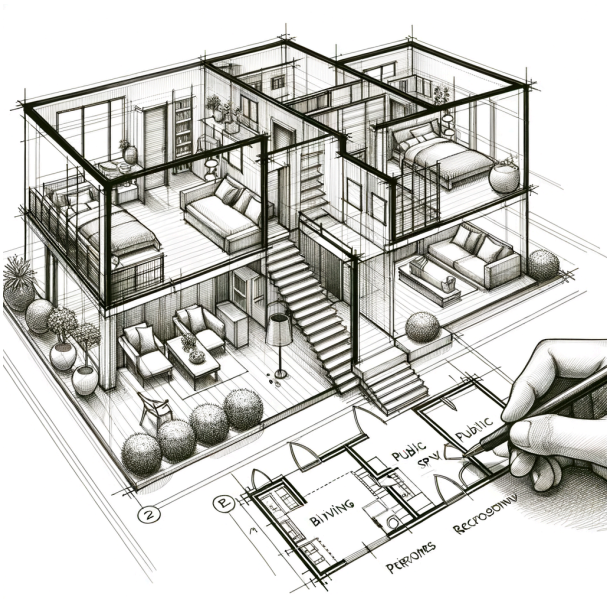


Figure 4.58 Vondy Abstract Section Credit: Author

Figure 4.59 Vondy Entrance Sketch Credit: Author

Although some of the generated images can be used for final schematic renderings, most are either not coordinated with the actual house design or detract from other generated images that convey the design in a more impactful manner. Despite the access to its specialized AI tools, none of the tools appear to be overly successful in their own discipline. Evidently, the major difference between Vondy's AI image generator tools is the style of the image produced. While this seems useful as there doesn't need to be the inclusion of style in the prompt, the quality of results is hardly worth the time to sift through each tool for everyday design work.

While Vondy is an intuitive and reasonably priced ($19/month for base tier and $49/month for premium tier) tool, utilizing it may not be the best use of an architect's time. Similar to the results in the design synthesis subphase of schematic design, Vondy is once again not a strong recommendation for productive renderings. Utilizing Vondy at this stage of the design process should be advantageous with the multitude of tools at the architect's disposal. However, the variability in the results and the lack of sensitivity to prompt details make this an exhaustive and ineffective process. Controlling the images to produce an exact rendition of the design to this point is nearly impossible, and even after focusing on small design elements or abstract concepts, Vondy fails to produce useful schematic renderings.

LookX

LookX is an AI assistance tool for architects that was released in May 2023. LookX is specifically designed for architects, creating an advanced machine-learning model trained by architectural work from around the world. This powerful tool can completely take over the schematic design process, utilizing AI to generate images, 3D massing, and even plan drawings. Similar to other AI tools, architects can produce these results by typing in a prompt. LookX also includes the ability for architects to upload base images for the AI to render and a reference style image to provide even more detail the AI can use.

In addition to the rendering features of this tool, architects can also natively edit their renderings right in the LookX interface. The editing feature enables architects to select anything in the image, type a prompt, and let the AI generate a new edited image. LookX is comprehensive and can be extremely useful to architects looking to begin design synthesis or

draft final design renderings. Because of its many high-quality outputs, this tool should be utilized throughout the design.

Within the many output options, architects can further select exactly what they are looking for without ever having to specify in the prompt. Rendered images for example can be set to realistic, detailed sketches, or conceptual sketches. The 3D massing can be either conceptual or detailed, and the plan drawings can be either site or architectural floor plans. The rendered images and 3D models can also be filtered to the interior or exterior. The customization of results before ever using the prompt dialogue ensures results are catered exactly to the architect. This also cleans up the prompt to only include the subject matter of the content, meaning the AI understands more clearly what is expected.

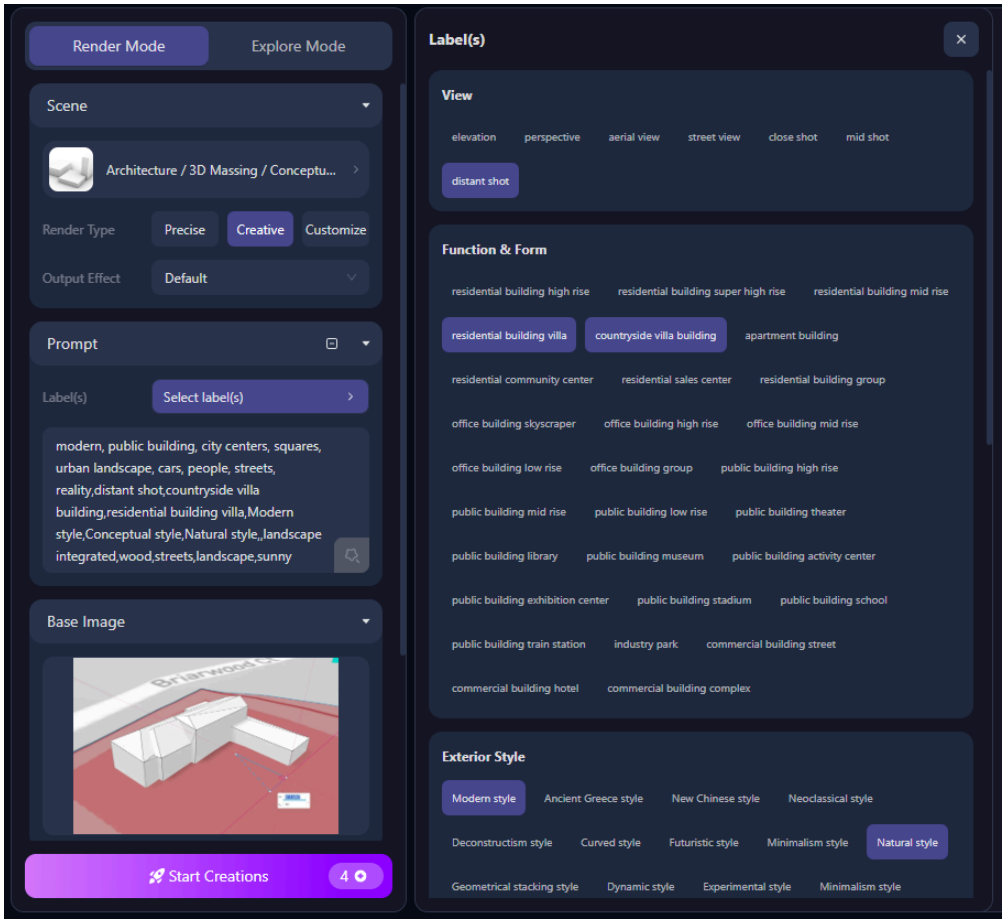


Figure 4.60 LookX Interface Credit: Author

Even once the architects get to the prompt, LookX has impressive features to help facilitate more productive results. Firstly, the prompts are separated into positive prompts and negative prompts. Isolating information that should be included or ignored from the intended results. The prompts also include dedicated labels for a variety of aspects of the design, including the form, style, environment, spatial composition, and even architect precedent, allowing architects to choose between *Gaudi, Le Corbusier, Mies van der Rohe,* and *Louis Kahn*. Selecting label items within each discipline adds more context and useful detail information to the prompt. The labels are physically typed into the prompt, and more can be added, depicting the exact content the architect is looking for. Even more impressive, LookX includes an AI elaborate feature. This takes a simple prompt that does not include any of the labels and enhances it to a more descriptive prompt the AI can use.

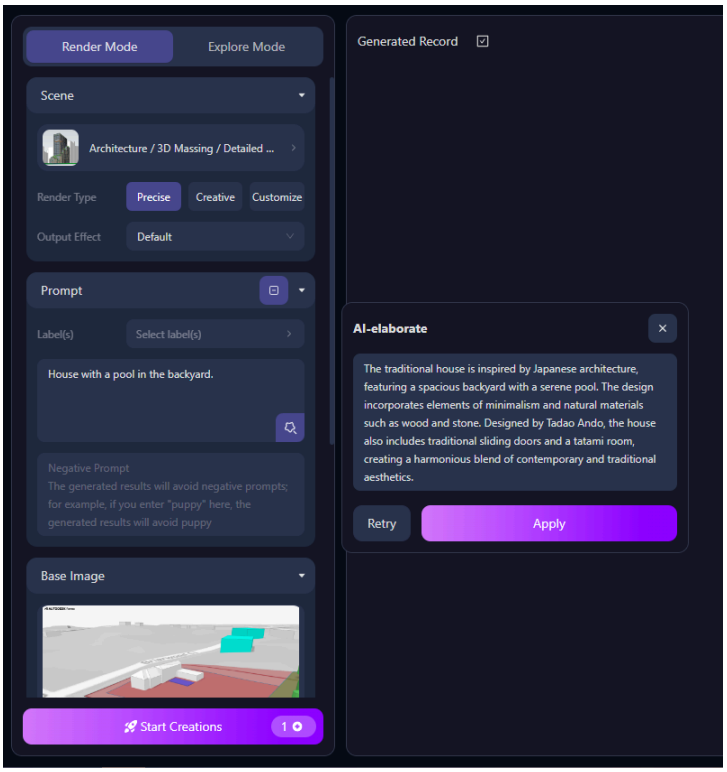


Figure 4.61 LookX AI Elaborate Credit: Author

This unique feature not only adds more detail that the AI can understand and utilize in the expected results but also informs the architect what keywords and descriptors should be used in a prompt to achieve more productive renderings. This completely resolves any issues of prompt

engineering, taking the human error out of the prompt drafting. Although it seems like the architect is intervening less and less with this tool, it is quite the opposite. All of these AI features are optional and completely customizable, enabling the architect to choose when to manually or automatically control project details. All of this serves to help the architect achieve better results, faster.

For this project, the base image and style image can be used to generate final schematic design images based exactly off previously rendered design images. With a base image of the house design from previous renderings and the massing created in Forma, and a reference style image either received from previous renderings or the LookX database of architectural projects, the prompt dialogue can almost be ignored. The prompt adds contextual information to the rendering, specifying the scale by typing '*residential home'* and the level of completion desired. The renderings can always be regenerated by running the same parameters again under a randomized seed. This ensures the AI model creates a similar rendering but with enough variations to warrant a regeneration. Unfortunately, since no usable floor plan could be generated from previous AI sources, the plan generator in LookX cannot be utilized. Although the architect could utilize this feature using a traditionally generated floor plan, none were generated for this case study scope and thus none could be used to assess this LookX feature.

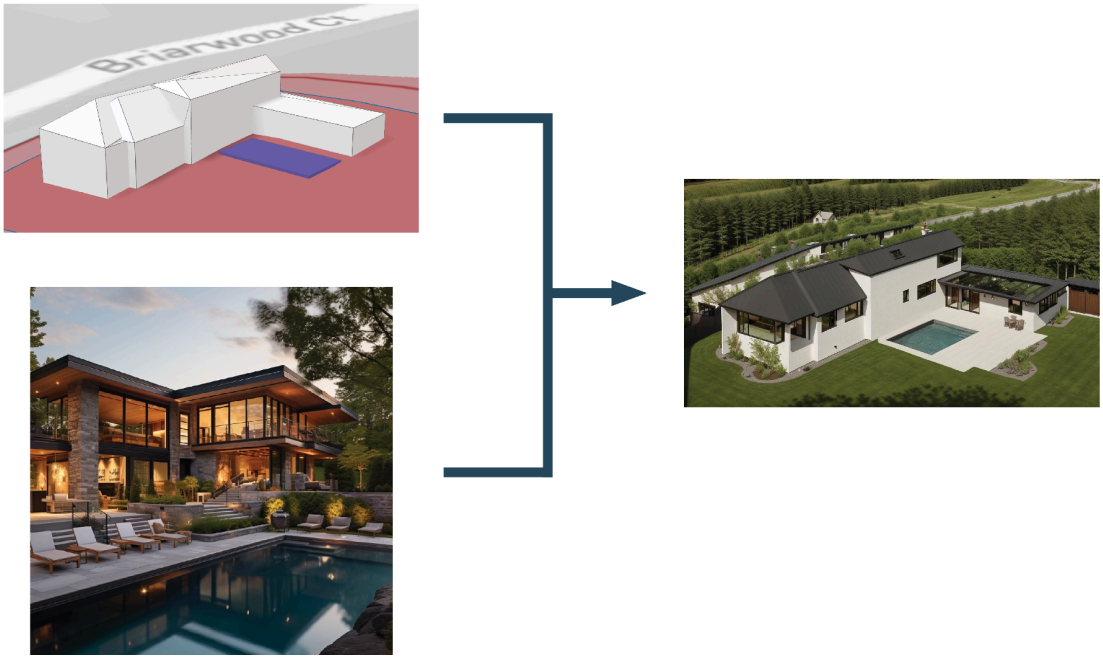


Figure 4.62 LookX Backyard Rendering Credit: Author

Utilizing LookX at this stage of the design will be most impactful to re-render previously generated perspectives of the house that were poor quality, generate new renderings of the house form in a new style, and generate plans if possible. The building form generated and refined in Forma will become extremely relevant, serving as the base image that LookX will stylize and render as both 3D massing and architectural renderings. Images of the front yard of the form and backyard of the form will be used, and a variety of rendering styles will be generated from this both to assess LookX and to provide the client with multiple images to enjoy and compare.

The base image is always the geometric boundaries of the produced generations and the referenced style image is used only for the artistic and architectural design style, the content itself is not actually considered. This means any image can be used for the reference style image, it does not have to have a similar form to the base, or even be related to the project at all. For this reason, the referenced style images are selected from both previous renderings, like ones received from Midjourney and DallE and refined in Photoshop and AI Home Design seen in Figures 4.62 and 4.65, and LookX provided images seen in Figures 4.62 and 4.64.

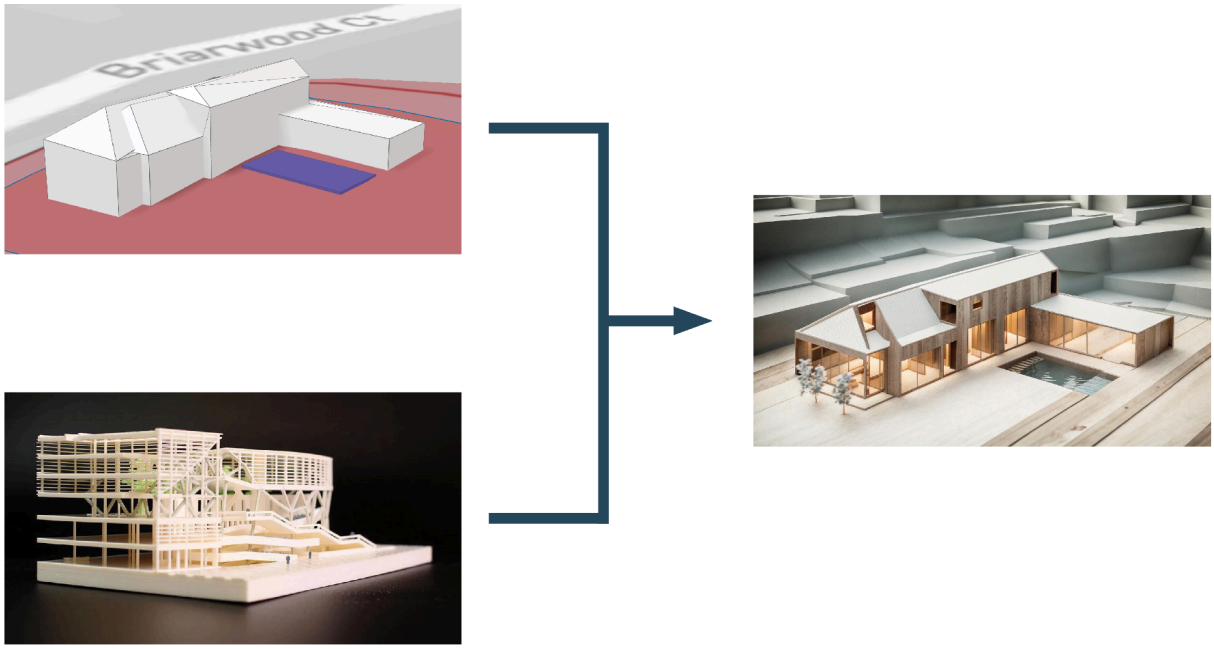


Figure 4.63 LookX 3D Model Credit: Author

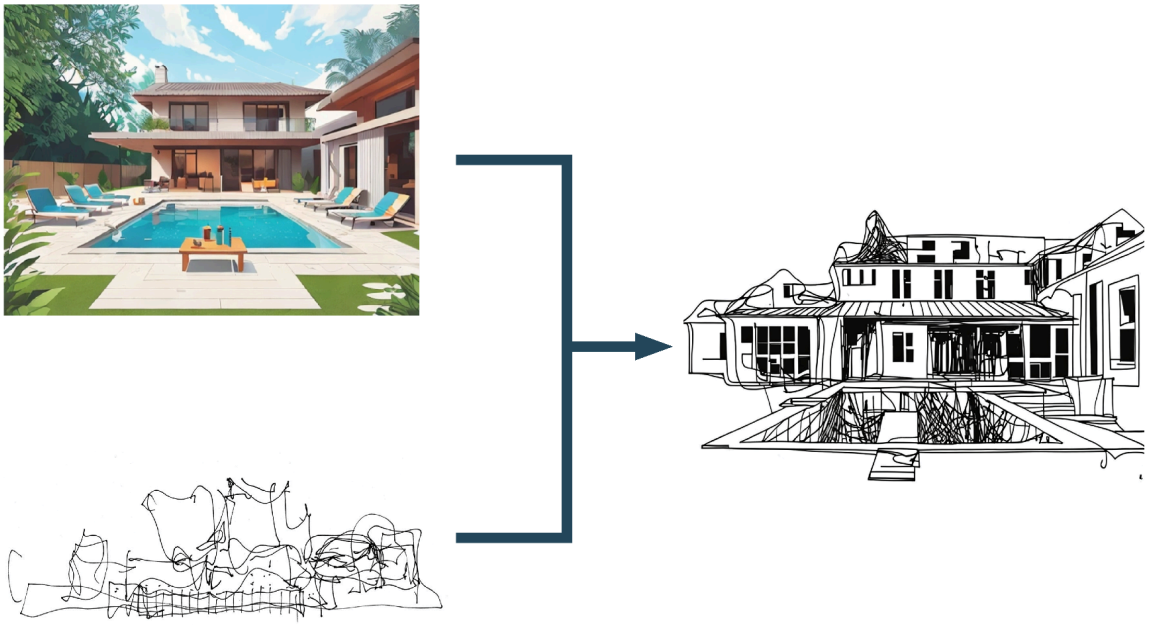


Figure 4.64 LookX Conceptual Sketch Credit: Author

Figure 4.65 LookX Interior Rendering Credit: Author

Similar to the Midjourney interface, LookX has an extensive ‘explore’ tab that serves as a database for other user-generated work. This provides samples of work architects can use for their projects and examples of successful prompts that they can learn from. These examples can easily be duplicated to be used in the architect's current project, all creating more relevant and impactful work. The quality of results exhibited by architects with experience using LookX proves the success of the AI model and the profound implications this tool can have on the architectural design process.

With the multitude of successful output options, LookX is distinctly a valuable tool firms should consider for schematic design. This tool is most useful in early design, working to explore massing and design options and providing schematic renderings and plan drawings. This is a comprehensive, high-quality, and functional design assistance tool. Using LookX has a slight learning curve with the advanced input decisions, but for the most part is intuitive and responsive to the architect's needs. It is clear this AI tool was made specifically for architects, and the results speak to the attention and training the model went through.

LookX prices its service at $20/month or $200/year. This is an understandable and extremely reasonable price for the many features architects can utilize. It is compatible with Rhino and Sketchup at the moment, providing functionality with other design tools so architects can seamlessly progress the design to the next phases. The collaboration within the tool, both with capabilities to share work amongst the design team and with the ‘explore’ tab to learn from and work with other architects’ designs, makes the tool even more applicable in design firms.

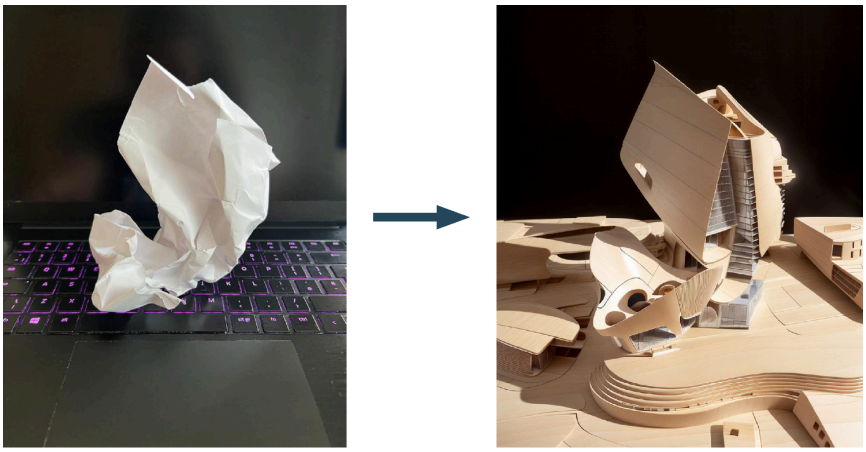


Figure 4.66 LookX Tim Fu Design Credit: Dezeen

LookX is readily available and developed enough that firms can trust and utilize this AI tool for early design work today. Designer Tim Fu from Studio Tim Fu has been using LookX since it was released. As an experiment to how advanced the generative AI is, he used the trained model to produce renderings from a crumpled piece of paper (Carlson, 2023). The results prove the sophistication of the model, understanding complexities in the paper, and the constructing of a high-quality 3D model that could realistically be used in a design project. The implications of this are revolutionary, with the potential for LookX to inform future designs from any uploaded object, crumpled paper, preliminary design model, or items relevant to the designs parti.

5. ASSESSMENT

5.1 Savings, Productivity, and Utility

The utilization of the 13 available AI tools has culminated in a completed and comprehensive design through the schematic design phase. This design was accomplished entirely through the use of AI. This AI-generated project, including AI ideas, AI modeling, and AI rendering worked to produce actionable results. The quality of the results is subjective to the client, who now can view and discuss the design with the architect. Through using AI, the architect was able to produce a variety of design solutions, with a diversity of concepts, styles, and output mediums. Although there were multiple instances of AI tools lacking production, the culmination of the remaining productive tools has enabled the architect to produce these results with significant time and cost savings.

When assessing the available AI tools, the decision flowchart was followed to ensure each tool was uniformly tested and understood. This flowchart provided valuable information about the tool's cost of service, quality of results, specificity requirements, and potential for multiple use cases. These qualities were all noted and can now be used to properly assess and compare these tools. Figure 5.1 showcases a heatmap of this flowchart, indicating the qualities that are most frequent. Since 5 of the 18 AI tools identified were not available at the time of testing, only the 13 available tools were employed for these final assessments.

The heatmap illustrates the concentration of tools that have similar attributes. For example, almost all of the tools, with the exception of 3, require payment to use. Almost half of the tools were initially successful in executing their functions, with the remaining tools splitting the flowchart in benefitting from specificity and failing to produce positive results at all. While this visualization is helpful in assessing the overall quality of these AI tools, it lacks a detailed comparison model that can accurately evaluate the tools. Each tool was subject to evaluation in its designated subphase, Analysis [Red], Synthesis [Orange], Refinement [Green], and Documentation [Blue]. After utilizing the tools for the given functions, a quantitative analysis can be constructed to assist in this final evaluation. Quantifying the attributes both from the decision flowchart and observations made using the AI tool will yield values that can compare and rank these tools.

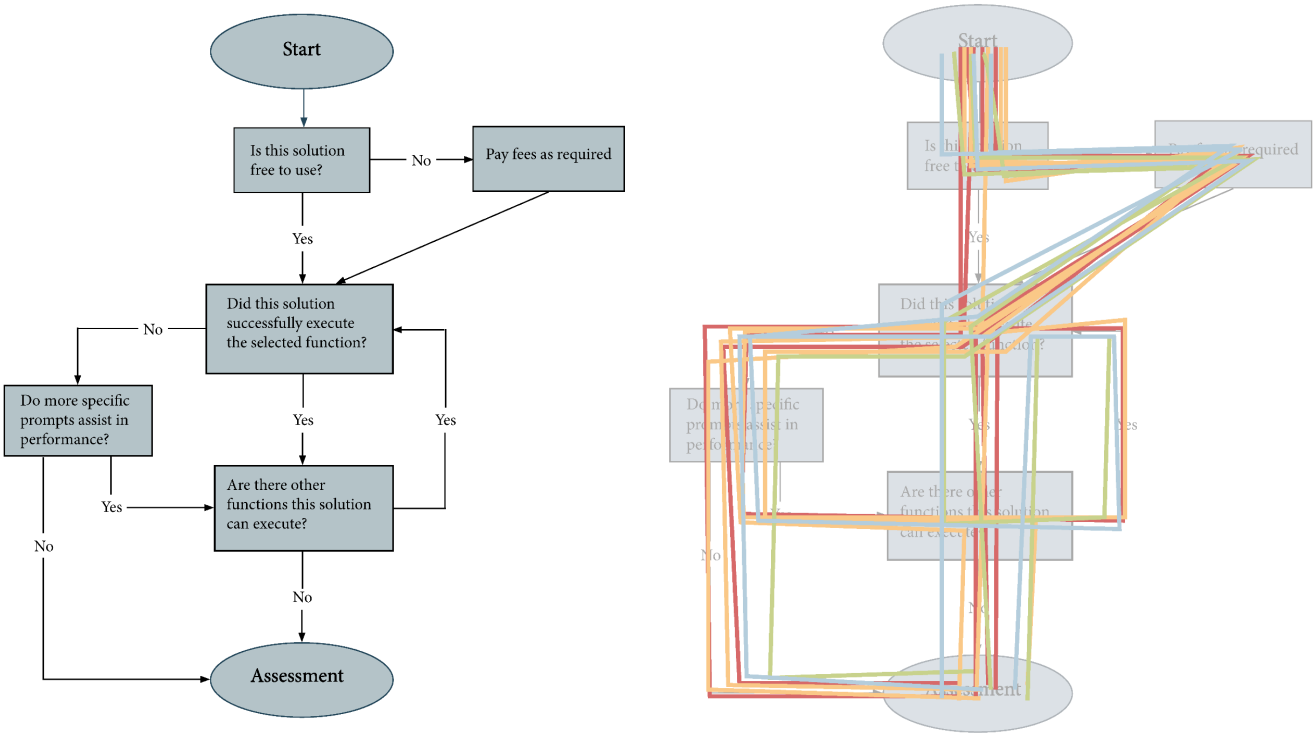


Figure 5.1 Decision Flowchart Heatmap Credit: Author

While each tool was being used to produce results to progress the design, metrics were recorded to be used in this final analysis. Observations including time spent on tasks using the AI tool, the cost to access and use the tool, and the practicality of using the tool, both from an individual and collaborative perspective were all recorded and given number values. The final quality of results was also recorded and quantified as a final assessment metric. These values can be used to compare the tools amongst other tools in their subphase as well as across all tools used in the project. Not only does this inform architects what tools are most productive and valuable to a firm, but also what tools should be avoided for architectural design work.

The time savings realized from using these AI tools is one of the primary motives for using AI. Without considerable, or at the very least noticeable, time savings, it would not be worth it for the architect to employ AI to assist in design work. While the quality of results the AI produces may be worth losing the time savings, those attributes will be revealed in following assessments. The equation for Time Saving is simply the difference between the time spent on a task without the use of AI and the time spent on the same task with the use of AI, all in hours.

The time on task without the use of AI, t_0, was collected from a survey of 14 architects in February 2024 on their assumed time spent on specific tasks in each subphase. The full collection of results from this survey can be found in Appendix D, as this survey was used multiple times throughout this thesis. The time on task with the use of the AI tool, t_1, was collected during the actual use of the AI tool.

AI Scorecard			
	Time Savings		
	t_0	t_1	Δt
Analysis			
Fireflies	5	0	**5**
SGE	6	1	**5**
ChatGPT[A]	6	2	**4**
UpCodes	10	6	**4**
Forma[A]	10	4	**6**
Synthesis			
ChatGPT[B]	8	1	**7**
ChatUML	8	4	**4**
Vondy[B]	8	3	**5**
DallE	19	4	**15**
Midjourney	19	3	**16**
Refinement			
Forma[C]	12	4	**8**
Photoshop	10	4	**6**
AI Home Design	10	1	**9**
Documentation			
Maket	27	12	**15**
Vondy[D]	29	9	**20**
LookX	29	6	**23**
		Mean (μ):	**9.50**
		Standard Deviation (s):	**6.02**

$$\text{Time Saving}$$
$$t_0 - t_1$$

t_0 = time on task without AI tool
t_1 = time on task with AI tool

Table 5.1 Time Savings Assessment Credit: Author

These metrics tell an important story in the practicality of using some of these tools. For starters, some of the tools resulted in significant time savings, as much as 23 hours, while others took more time to produce results, including time savings of 4 and 5 hours. These lower time savings could mean either the time on task without AI was low to begin with (as seen in Fireflies) or the time on task with AI was so high that it resulted in minimal savings (as seen in Chat UML). This range of results highlights the volatility of available generative AI tools. The results do conclude that there are considerable time savings when using AI to assist in architectural design work, and by catering to the few AI tools that had the most time savings, a firm can tremendously improve productivity. The mean and standard deviation of this data were

collected for a fully-encompassing Utilization Score tabulated after completion of all assessments.

In addition to calculating the time savings realized from using AI, the main driver in using AI is the potential money savings. Without reasonable savings, a firm is less likely to consider using generative AI tools. Similar to the slow integration of sustainable design elements like solar panels, AI would not be integrated into a firm unless it involved an economic benefit (Arezki, 2021). In light of this, it is important that firms understand that there are cost savings in utilizing AI, and these savings can be realized today through the multiple identified AI tools available.

AI Scorecard					
	Cost Savings				
	r	t_0	t_1	c	Δc
Analysis					
Fireflies	$ 100.00	5	0	$ 58.00	**$ 442.00**
SGE	$ 100.00	6	1	$ -	**$ 500.00**
ChatGPT[A]	$ 100.00	6	2	$ -	**$ 400.00**
UpCodes	$ 100.00	10	6	$ 136.00	**$ 264.00**
Forma[A]	$ 100.00	10	4	$ 370.00	**$ 230.00**
Synthesis					
ChatGPT[B]	$ 100.00	8	1	$ -	**$ 700.00**
ChatUML	$ 100.00	8	4	$ 6.00	**$ 394.00**
Vondy[B]	$ 100.00	8	3	$ 38.00	**$ 462.00**
DallE	$ 100.00	19	4	$ 15.00	**$ 1,485.00**
Midjourney	$ 100.00	19	3	$ 60.00	**$ 1,540.00**
Refinement					
Forma[C]	$ 100.00	12	4	$ 370.00	**$ 430.00**
Photoshop	$ 100.00	10	4	$ 46.00	**$ 554.00**
AI Home Design	$ 100.00	10	1	$ 50.00	**$ 850.00**
Documentation					
Maket	$ 100.00	27	12	$ 60.00	**$ 1,440.00**
Vondy[D]	$ 100.00	29	9	$ 38.00	**$ 1,962.00**
LookX	$ 100.00	29	6	$ 40.00	**$ 2,260.00**
				Mean (μ):	**$ 869.56**
				Standard Deviation (s):	**$ 628.00**

Cost Saving

$r(t_0) - (r(t_1) + c)$

r = billable rate of architect
t_0 = time on task without AI tool
t_1 = time on task with AI tool
c = associated cost of AI tool

Table 5.2 Cost Savings Assessment Credit: Author

The equation for cost savings uses the time savings measured previously. The cost savings in using AI is understandably the cost of completing the task without the use of AI minus the cost of completing the task with the use of AI. Since both costs include a billable fee for the

architect's time, it is necessary to convert the time metrics into dollar amounts. This is accomplished by using a standard fee rate of $100, converting the time spent on task from hours to a cost the firm will experience. While this rate may be higher or lower than an architect's actual billable rate, it is kept consistent for every tool to ensure a standard in the cost savings assessment.

The other element introduced in this cost saving is the cost to access and use the AI tools. This can dramatically change the practicality of integrating the AI tool into the firm. Even with significant time savings, which directly results in significant cost savings, the added fee of purchasing the AI tool may cancel out the savings entirely. While some tools were free to use, others had considerable fees associated with them, as much as $185/month. Again, to remain consistent in this assessment, all tools were assumed to require 2 months of their service. This means any tool with a monthly fee encountered a two-month fee associated with the tool, while the associated cost for other pay-per-credit tools included a two-month supply of credits.

The cost savings realized from these AI tools do once again conclude that there are savings to be had from using generative AI in an architecture firm. With savings as high as $2,260 for one task, this can significantly reduce costs to the firm and the client. By specifically choosing identified tools that had both high time savings and low associated costs, like LookX with 23 hours of savings for only $40 associated costs, firms can dramatically save money. The implications of this cost-saving, extrapolating to every project's schematic design (and potentially beyond,) can mean cheaper projects, more projects a firm can take on at once, and more time and resources devoted to powerful and impactful designs.

Despite all of the potential benefits of utilizing an AI tool in time and cost saving, the tool would be useless to a firm if it is not productive in its designated task. A productivity assessment is required to fully understand a tool's practicality in use and potential for immediate integration into a firm. This Productivity Score is a calculation of the success of the tool, including whether it is collaborative, intuitive, and yields high-quality results. All of these metrics are necessary to understand when assessing a tool's viability, and the final Productivity Score provides a consensus value that can be used to compare and rank these tools against others in their subphase and the collection as a whole.

AI Scorecard				
	Productivity Score			
	1x	1.5x	2x	P
	p_1	p_2	p_3	
Analysis				
Fireflies	2	2	2	**9.0**
SGE	0	2	1	**5.0**
ChatGPT[A]	0	2	2	**7.0**
UpCodes	1	1	0	**2.5**
Forma[A]	2	1	1	**5.5**
Synthesis				
ChatGPT[B]	0	2	2	**7.0**
ChatUML	1	0	0	**1.0**
Vondy[B]	0	1	0	**1.5**
DallE	0	2	0	**3.0**
Midjourney	1	1	2	**6.5**
Refinement				
Forma[C]	2	0	2	**6.0**
Photoshop	0	1	1	**3.5**
AI Home Design	0	2	2	**7.0**
Documentation				
Maket	0	1	0	**1.5**
Vondy[D]	0	1	1	**3.5**
LookX	2	0	2	**6.0**
			Mean (μ):	**4.7**
			Standard Deviation (s):	**2.3**

Productivity Score

$((1.0)p_1+(1.5)p_2+(2.0)p_3)$

p_1 = collaboration availability [scored 0-2]

p_2 = ease of use [scored 0-2]

p_3 = quality of results [scored 0-2]

Table 5.3 Productivity Assessment Credit: Author

There are three metrics identified that contribute to the Productivity Score. These metrics include the tool's collaborative capabilities, ease of use, and the quality of the tool's results. These metrics are multiplied by a weighted multiplier, and then summed, providing each tool a final value on their productivity. The weighted multiplier for each metric was determined by the survey of 14 architects, who chose which of the three qualities were most important to an AI tool's productivity (Appendix D). The resultant productivity score ranges from 0 to 9, providing a wide range of results and an easy-to-compare scale to understand a tool's general level of productivity.

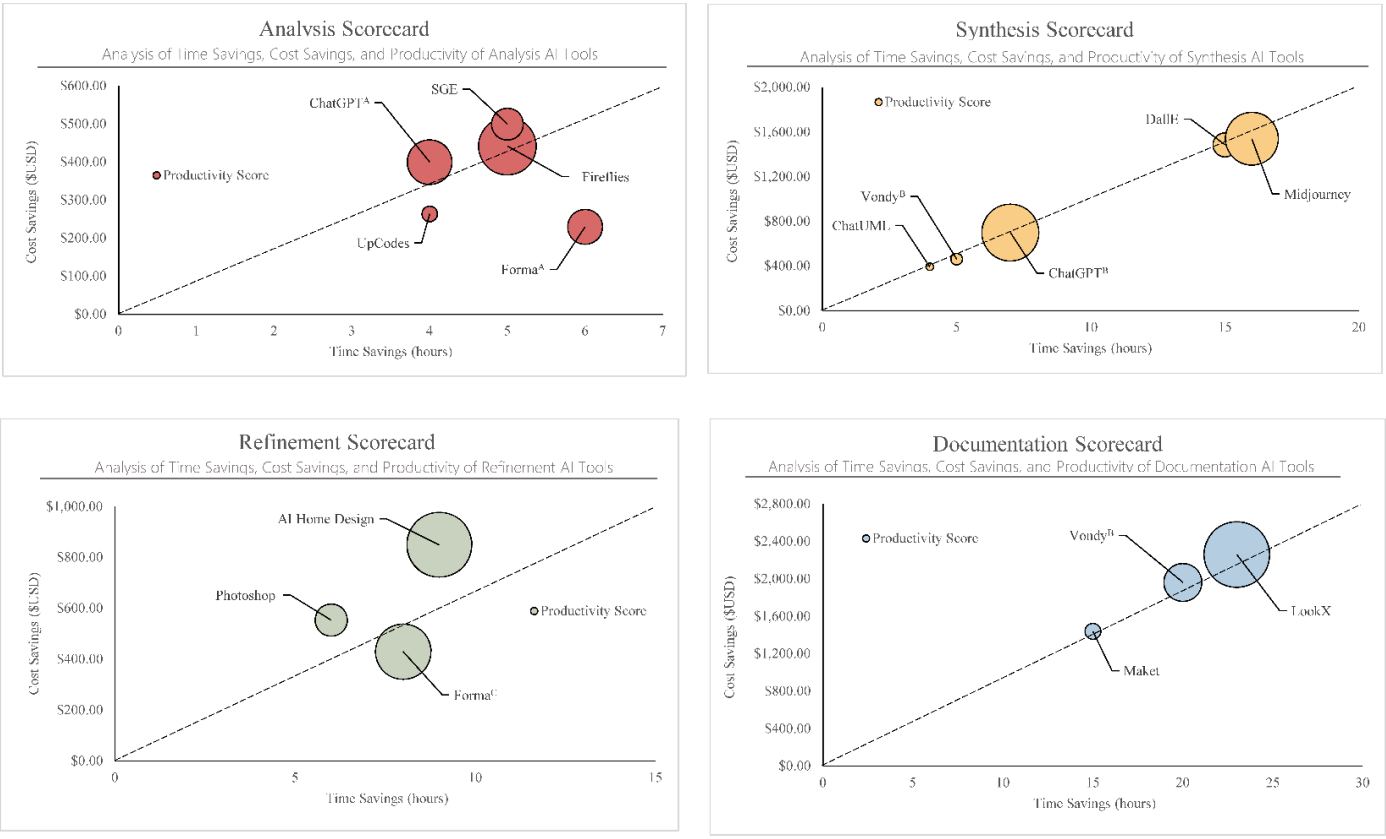
The collaboration metric, p_1, is scored from 0 to 2. A tool is given a 0 if it does not enable the user to collaboratively work with other users, while a 2 is given to tools that are completely collaborative. A 1 is given to tools with partial collaboration capabilities, for example, tools like Midjourney that allow for one-way collaboration, allowing users to view and build off of other's

work. The collaboration of a tool is not strictly a requirement, but it is an extremely advantageous attribute. Collaboration enables architects to create integrated designs more easily and with fewer design-based changes (Shen et. al., 2010).

The ease of use metric, p_2, is also scored from 0 to 2. For this metric, a value of 0 is given to tools that are complex and difficult to use, a 1 is given to moderately easy-to-use tools, and a 2 is awarded to tools that are highly intuitive and easy to use. This attribute benefits tools that do not require an extensive learning process when using the tool for the first time, something architects are likely to favor when considering AI tools in their design work. Finally, the quality of results metric, p_3, is scored from 0-2 on the overall quality of the AI tool's results. A 0 would mean the tool produced poor and mostly useless results to an architecture firm, a 1 is given to tools that produced average or maybe serviceable results, and the maximum 2 is given to tools that produced favorable and advantageous results for the architect.

While the length of time an AI tool has been in development can impact a tool's productivity, it won't play a significant role in this assessment. Given the recent improvements in artificial intelligence, AI tools have only started to be developed within the last 18 months or so. Because of this, including a metric to study the effects of an AI tool's years in development would prove futile since most of them would have been developed in either 2022 or 2023. Any differences in the length of time they've had to develop would be evidenced by the quality of their results, ease of use, and collaborative capabilities, metrics that are already studied and measured for this assessment.

For example, AI solutions that were released extremely recently, including those that were still in beta when tested, are likely to have more significant challenges and be less productive of a design assistant, earning a worse productivity score. Generative AI tools that were released much earlier had time to improve and evolve their models, and most importantly had the resources to collect more data to feed their models, something that directly influences the productivity of the model (McKinsey, 2023). The resulting productivity score not only identifies the most successful AI tools used but also indicates the level of separation some tools have in quality and production over other tools.

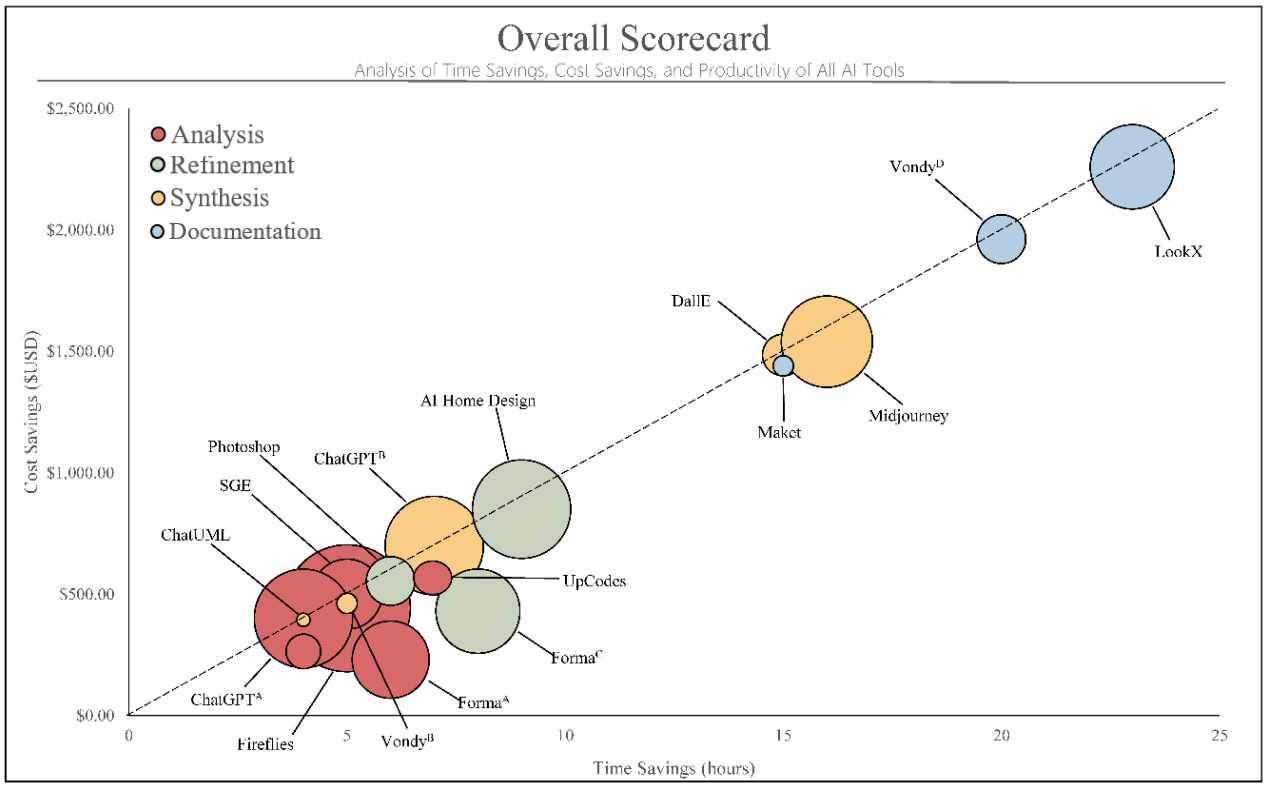


Figures 5.2-5 AI Tool Scorecards Credit: Author

The visualization of these three metrics, Time Savings, Cost Savings, and Productivity will further assist firms in understanding the full picture of an AI tool's viability. Figures 5.2-5.5 graph the metrics of each tool in their respective subphases. The further along the x-axis the more time savings a tool employs, and the further up the y-axis the more cost savings. The size of the tool's bubble corresponds to the productivity of the tool, the larger the bubble the higher the score. The diagonal trendline separates the tools into more cost-efficient or more time-efficient. With savings in time and cost being directly proportional, it should be more likely that a tool lands on this line, being as efficient in cost-saving as it is in time-saving. This is the case for a majority of the AI tools assessed, however, there are some tools that do not follow this trend.

The deviation from the trendline can mean the tool's associated cost is negatively impacting this relationship, as is the case in Forma^{A}, with only a net of 6 hours in time savings

but an additional $370 in cost, pushing it well below the trend line. Alternatively, a tool like SGE may be placed above the trendline, indicating it has a higher cost savings relative to the time savings. This is possible in particular scenarios where the time savings were limited but significant cost savings were still experienced, likely due to low, or in the case of SGE no associated cost.



Figures 5.6 Overall AI Tool Scorecard Credit: Author

An overall scorecard with every tool assessed on the same graph will help compare these tools against each other and better showcase the differences in cost and time efficiencies as well as productivity scores. The most influential tools include Midjourney and DallE, with the most time and cost savings, and Fireflies, with noticeably the largest productivity score. The graph also visualizes the less impactful tools, like Forma - which in both subphases it was used had more time savings relative to cost savings meaning it cost proportionally more to use this tool compared to other AI tools - and Vondy^{B} and ChatUML - which both had negative time and cost savings and trivial productivity scores. This scorecard is highly effective at mapping the

successes and faults of each individual AI tool but does not strictly compare the tools easily. A comprehensive measure can be used to accurately and holistically grade these tools.

AI Scorecard																	
	Time Savings			Cost Savings					Productivity Score				Utilization Score			
	t_0	t_1	Δt	r	t_0	t_1	c	Δc	1x p_1	1.5x p_2	2x p_3	P	z_t	z_c	z_p	Σz
Analysis																
Fireflies	5	0	**5**	$ 100.00	5	0	$ 58.00	**$ 442.00**	2	2	2	**9.0**	-0.75	-0.68	1.84	**0.4**
SGE	6	1	**5**	$ 100.00	6	1	$ -	**$ 500.00**	0	2	1	**5.0**	-0.75	-0.59	0.12	**-1.2**
ChatGPT[A]	6	2	**4**	$ 100.00	6	2	$ -	**$ 400.00**	0	2	2	**7.0**	-0.91	-0.75	0.98	**-0.7**
UpCodes	10	6	**4**	$ 100.00	10	6	$ 136.00	**$ 264.00**	1	1	0	**2.5**	-0.91	-0.96	-0.95	**-2.8**
Forma[A]	10	4	**6**	$ 100.00	10	4	$ 370.00	**$ 230.00**	2	1	1	**5.5**	-0.58	-1.02	0.34	**-1.3**
Synthesis																
ChatGPT[B]	8	1	**7**	$ 100.00	8	1	$ -	**$ 700.00**	0	2	2	**7.0**	-0.42	-0.27	0.98	**0.3**
ChatUML	8	4	**4**	$ 100.00	8	4	$ 6.00	**$ 394.00**	1	0	0	**1.0**	-0.91	-0.76	-1.60	**-3.3**
Vondy[B]	8	3	**5**	$ 100.00	8	3	$ 38.00	**$ 462.00**	0	1	0	**1.5**	-0.75	-0.65	-1.38	**-2.8**
DallE	19	4	**15**	$ 100.00	19	4	$ 15.00	**$ 1,485.00**	0	2	0	**3.0**	0.91	0.98	-0.74	**1.2**
Midjourney	19	3	**16**	$ 100.00	19	3	$ 60.00	**$ 1,540.00**	1	1	2	**6.5**	1.08	1.07	0.77	**2.9**
Refinement																
Forma[C]	12	4	**8**	$ 100.00	12	4	$ 370.00	**$ 430.00**	2	0	2	**6.0**	-0.25	-0.70	0.55	**-0.4**
Photoshop	10	4	**6**	$ 100.00	10	4	$ 46.00	**$ 554.00**	0	1	1	**3.5**	-0.58	-0.50	-0.52	**-1.6**
AI Home Design	10	1	**9**	$ 100.00	10	1	$ 50.00	**$ 850.00**	0	2	2	**7.0**	-0.08	-0.03	0.98	**0.9**
Documentation																
Maket	27	12	**15**	$ 100.00	27	12	$ 60.00	**$ 1,440.00**	0	1	0	**1.5**	0.91	0.91	-1.38	**0.4**
Vondy[D]	29	9	**20**	$ 100.00	29	9	$ 38.00	**$ 1,962.00**	0	1	1	**3.5**	1.74	1.74	-0.52	**3.0**
LookX	29	6	**23**	$ 100.00	29	6	$ 40.00	**$ 2,260.00**	2	0	2	**6.0**	2.24	2.21	0.55	**5.0**
	Mean (μ):		**9.50**		**Mean (μ):**			**$ 869.56**	**Mean (μ):**			**4.7**				
	Standard Deviation (s):		**6.02**		**Standard Deviation (s):**			**$ 628.00**	**Standard Deviation (s):**			**2.3**				

Utilization Score

$$\Sigma\left(\frac{x-\mu}{s}\right)$$

Σ = Sum of values
x = individual data point
μ = mean of sample
s = standard deviation of sample

Table 5.4 Utilization Score Assessment Credit: Author

Assessing the whole AI Scorecard at once can help illustrate the positive and negative qualities of each AI tool evaluated. The (3) metrics calculated can be combined into one final Utilization Score. This value is calculated using the mean and standard deviation of each of the (3) metrics to understand each tool's value relative to this mean. The z-score is essentially the number of standard deviations a data point is away from the dataset's mean, either in the positive or negative direction (KhanAcademy, 2024). Plainly, this means a positive z-score value means that the AI tool is better than the rest of the AI tools in that assessment. There are (3) z-scores

calculated from the (3) assessments. Summing these scores will result in one number, a final score that grades the AI tool in its utilization across time savings, cost savings, and productivity.

The Utilization Score converts all of the AI tool's attributes into one common integer. These attributes that were measured from the decision flowchart and observations of using the AI tools can now be quantified, compared, and ranked. Converting hours, dollars, and productivity scoring to one comparable integer, a z-score, will facilitate this analysis and provide easy-to-understand results. An AI tool's individual z-score tells a story, for example, Vondy^{D} with both positive and negative z-scores, articulating how it performed better than the other tools in time and cost savings but was below average in productivity. These values are important when assessing what tools a firm should seriously consider. Summing these values provides one fully encompassing score, a comparative metric a firm can use to rank these tools.

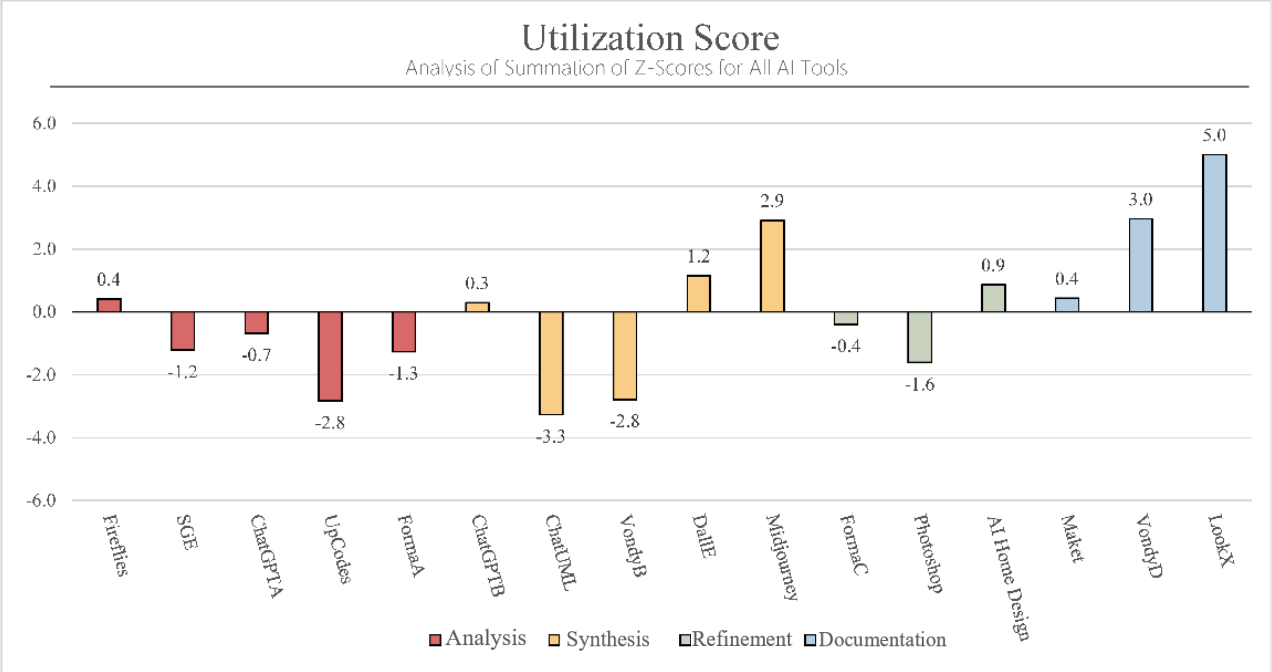


Figure 5.7 Utilization Score by Subphase Credit: Author

Graphing the Utilization Score in Figures 5.7 and 5.8 visualizes the utilization of these generative AI tools in architectural schematic design. Sorting them by subphase easily identifies the most productive tool a firm can use in each subphase, Fireflies for Analysis, Midjourney for Synthesis, AI Home Design for Refinement, and LookX for Documentation. Sorting these tools

by value will easily rank these tools from best, with the highest utilization score, to worst, with the lowest utilization score. Here, LookX outperformed all other AI tools, and without very much competition. Upcodes in the Analysis subphase and ChatUML in the Synthesis subphase performed the worst, with negative impacts in all assessment categories.

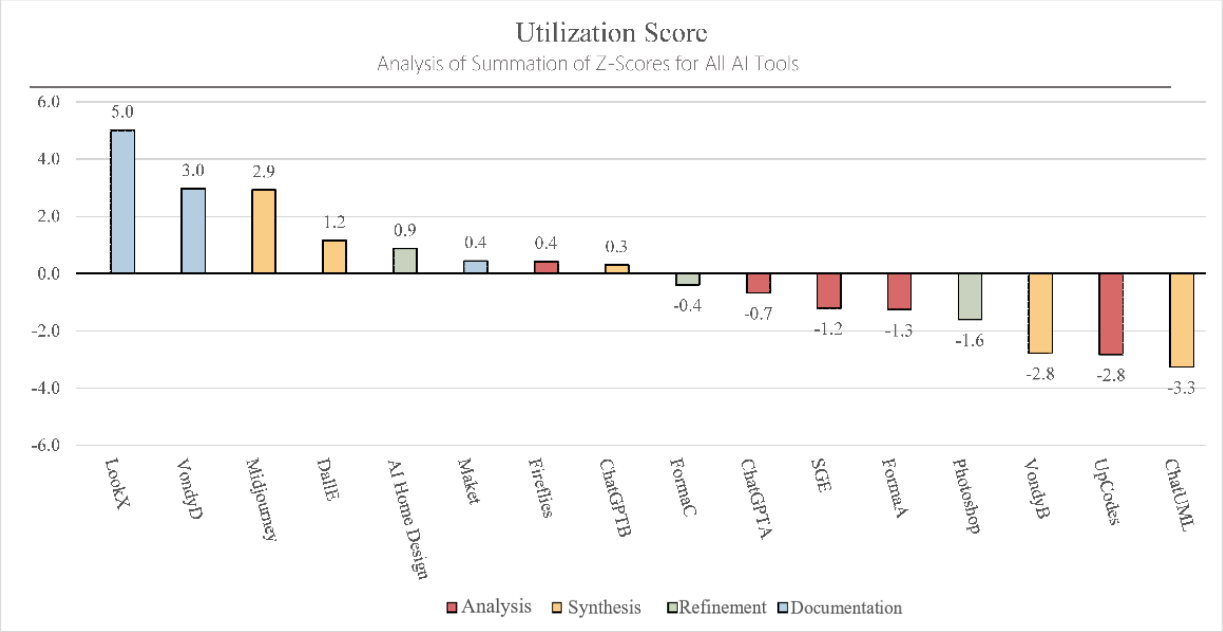


Figure 5.8 Utilization Score by Rank Credit: Author

It should be noted that since these values are the tool's number of standard deviations away from the mean, there are an equal number of tools with positive and negative values. This means that even though some tools may have a negative utilization score, they still could have been productive and valuable tools to the architect. A negative score does not strictly mean it was a negative experience and should not be considered, only that it performed relatively worse compared to other tools. The Utilization Score is not a means to rule out half of the tools evaluated, it simply ranks the tools in order from most impactful to least, giving architects and firms a sequential order of AI tools to follow when considering integrating AI into design work.

6. JUSTIFICATION

6.1 Evolution of Artificial Intelligence

The advancement and evolution of AI have garnered mainstream attention within the last 18 months. Regardless of its intended discipline, AI is a newfound and widespread phenomenon that piques interest and concern. The concern with integrating AI and justifying its existence in a firm, company, or business practice is the unknown. What happens when AI is everywhere; when it is the assumed means of receiving and generating information? This existential question does not have an answer, and there is no sure way of understanding if it will have a positive or negative outcome, at least not yet.

The concern that AI may overtake disciplines and control the job market is a credible concern given the recency of these impressive innovations. The current state of AI does not pose any significant threat, at least the AI tools that are available to the public. It's certainly true that some AI tools are capable of completing notable tasks; however, the collective state of AI is still less than capable of task completion compared to humans. Many AI users and developers are worried about how the world will change when these tools do eventually evolve to the human level, what happens when they can understand and produce as well as humans can, and what happens if it advances beyond that?

As evidenced by this thesis and many other studies, like Forbes' conclusion that AI lacks significant developments in common sense, cause and effect relationships, and ethical standards, AI has a long way to go before it can match human's production level (Toews, 2021). However, it is still unclear at this point if AI is and will always remain inferior to human work due to these mentioned shortcomings, or if it simply is just not there yet. Understanding this evolution and the developer's progress in overcoming current ailments is necessary to justify AI's integration within businesses.

AI is not to a human level, but it is certainly creeping up to it. According to a whimsical study by Adam Scherlis, Chat GPT-4 has the capacity of a squirrel's brain. By relating the learnable parameters (AI's functional capacity) to animals' brain synapses, AI can be directly compared to different animal's intelligence. This establishes a new unit of measure; converting

artificial intelligence to something humans can better understand, animal intelligence. When ChatGPT-2 was released in February 2019, it was capable of about one billion parameters, similar to the synapses in a bee's brain. However, 37 months later, in March 2023, ChatGPT-4 was released with over one trillion learnable parameters, akin to the intelligence of a squirrel (Scherlis et al, 2023).

This is rapid improvement in just one company's [Open AI] AI tool. It should be assumed that this evolution will continue, exponentially increasing until… no one knows how far this will go, that's the existential threat. If it took 37 months to increase artificial intelligence a hundredfold, is it reasonable to project similar growth for the next 37 months? How long until ChatGPT reaches the capacity of a toddler's brain, over 100 trillion synapses, or at a human's peak brain capacity of about 1 quadrillion (Wanner, 2018)? It might not take 37 months, or even a fraction of that time.

There is no perfect way to predict the trajectory of AI's intelligence. Moore's Law is a common observation in technological advancement, articulating the exponential capacity in computing power due to the number of transistors in an integrated circuit doubling about every two years. This is observed while simultaneously observing exponentially cheaper costs for computer memory and storage (Our World in Data, 2024). This may be the best standard to understand AI's exponential growth, mapping a daunting future with uncertain outcomes.

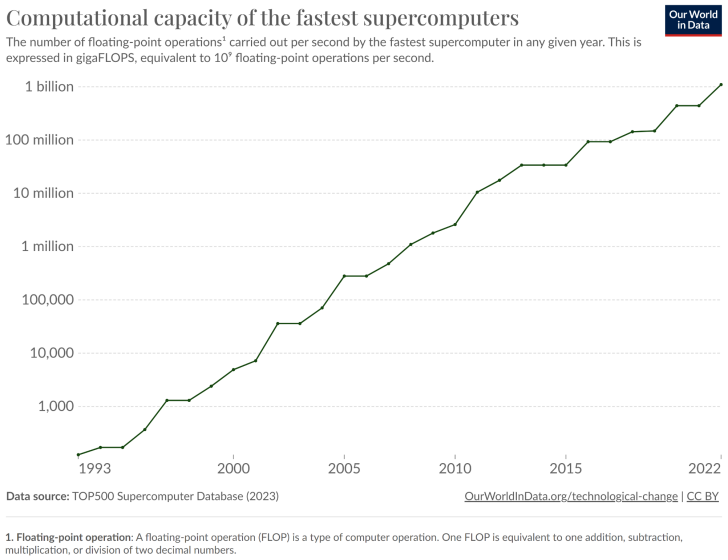


Figure 6.1 Moore's Law Computational Capacity Credit: Our World in Data

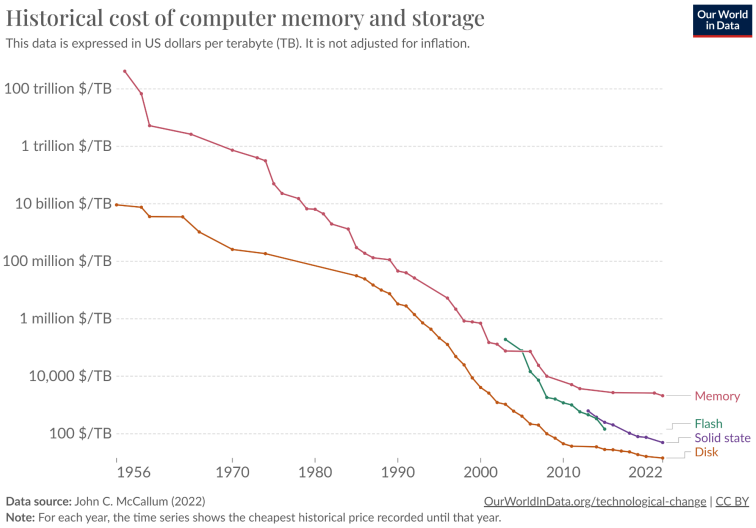


Figure 6.2 Moore's Law Computing Costs Credit: Our World in Data

Even with a trajectory potentially mapped for AI's future, it hardly justifies integrating AI into our firms and practices. Knowing it may reach human-level productivity soon does not directly mean AI should be allowed to continue evolving and revolutionizing the market and our work as we know it. The reason this needs to be discussed now while it still lacks fundamental human-level capabilities, is that once AI becomes more advanced, it will become more involved and prevalent. The marketplace, in the United States a system that favors cheaper labor and reduced overhead costs, will welcome AI and integrate it within industries to the point where it no longer can be reversed.

Andrew Yang, a businessman and lobbyist for AI regulation, understands the concern with AI's continual evolution. "Uber is going to get rid of its drivers as soon as it can. Its job isn't to hire lots of people - its job is to move customers around as efficiently as possible. The market will continue to throw millions of people out of the labor force as automation and technology improve" (Yang, 2018). It's easy to understand now that once AI has a grasp on assisting firms and companies, it will save costs by reducing labor and improving productivity. While this sounds like an improvement, it is for the company's profit, not the workers who just got laid off. This should be evidence enough that AI has no right to enter the workforce, however, this of course is not the whole story.

Similar to what Yang is projecting in his 2018 book, switch operators in the 1920s United States were outsourced when the automatic switchboard was developed and integrated within the workforce. This eliminated the position overnight, forcing hundreds of thousands of employees out of work. These workers, many of whom were young women who were needed during war efforts, may have lost their jobs but they were never removed from the labor force. Although automation was the reason for their job loss, this automation led to different opportunities, like secretarial work and service jobs. While demand for operators declined, it was inversely counteracted by an increased need in other positions, in the long run helping this generation of workers and future generations (Feigenbaum et al, 2020).

Comparatively, AI outsourcing workers, like Uber drivers or architects, does not necessarily mean these workers will be out of work, only that they will need to find alternative occupations in the new market. The lump of labor fallacy assists in justifying the evolution of AI despite its potential path of destruction. This fallacy is a common misconception that there are a set number of jobs available in the market and once someone (or some machine) takes the job it is gone. This is not true and similar to switchboard operators transitioning to different work, workers outsourced due to AI will need to adapt and find a place in this new way of life. Jobs are dynamic and indicative of a healthy society, changing work creates new work and new opportunities for everyone (Davidson 555., 2023).

AI will not reduce the availability of jobs or push out entry-level workers, quite the opposite. With AI thunderously entering the workforce, it is the entry-level workers, the ones with the most adaptability and willingness to learn who will prosper in the newfound job opportunities. AI has the ability to lower barriers for entry-level professionals by providing step-by-step instructions to begin tasks, giving advice, and directly assisting in the work. This could lead to a larger shift in workers entering industries they previously thought were inaccessible. With a dynamic job market, entry-level positions do not need to be restrictive to professionals or higher-educated students. AI can facilitate this transition, opening doors for countless workers to enter the workforce or jump to a more favorable position.

Even when speaking in generalities, it should be noted that this transition will never be advantageous for everyone. While switchboard operators found new work and entry-level workers are more likely to land on their feet, AI will be extremely widespread and impact almost

every discipline. There will be hundreds of thousands, if not millions, who will be removed from the labor force and unable to find new positions. The revolutionary projections for AI will lead to negative impacts on countless jobs and disciplines. However, the advancements and cost savings could increase opportunities and wealth for future generations, similar to the automation of the switchboard in the 1920s and factory work in the 1960s (Holzer, 2022). There is no reason to believe that the evolution of AI should be any different from these instances…unless there is.

In their yearly analysis of AI's advancement, McKinsey & Company identified 2023 as Generative AI's breakout year. The report uses advanced statistics to understand AI's integration with the workforce and the hesitations companies and individuals have with AI. It is clear that AI will be disruptive in as many disciplines as it touches (and it may very well affect every discipline regardless). This disruption can only be justified if it can be accurately predicted that it will lead to the betterment of products, services, and above all else people. McKinsey is not so sure it will. Even though AI is still a number of iterations away from human-level intelligence and full integration into the workforce, organizations studying AI, as well as the AI developers themselves, have identified multiple areas of risk. The most notable from this study, in Figure 6.3, are the current inaccuracy of AI-generated results, the lack of cybersecurity, and intellectual property infringement.

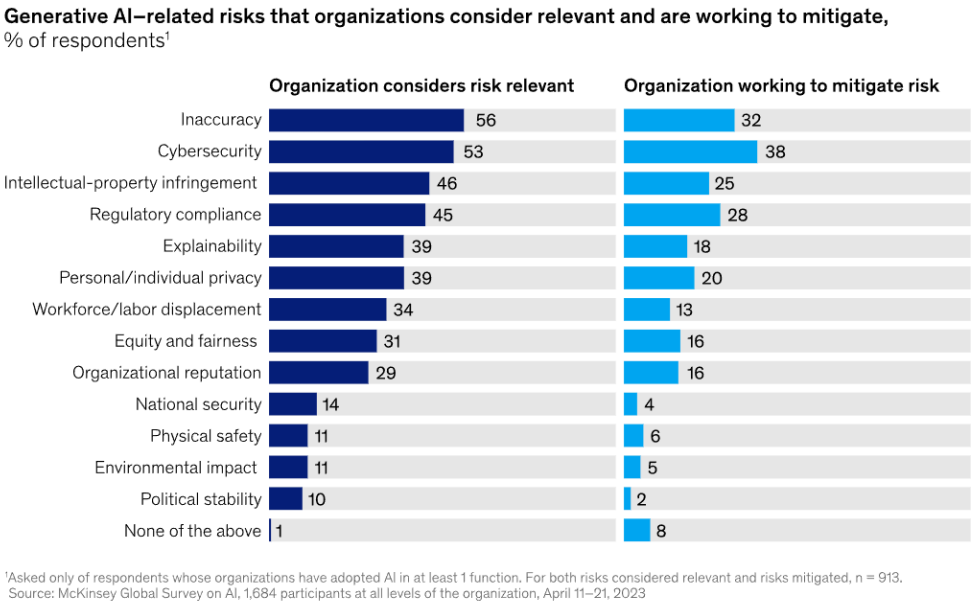


Figure 6.3 McKinsey Risks of Generative AI Credit: McKinsey & Company

To better understand these hesitations with AI, a survey was conducted with 14 architects in February 2024. This survey asked working-class architects their opinion on AI and the potential risks they believe to be the most prevalent (Appendix D). The results, in Figure 6.4, tell a similar story to the McKinsey report, with the exception of cybersecurity. Here, a majority of architects worry most about their job security, designs that are code compliant and aesthetically pleasing, and the ownership of the AI generated designs. Experts from the OECD's AI division agree that AI use could lead to copyright and ownership disputes, but the conclusion is still unknown and each case is treated differently (Charlesworth, 2023). The consensus is AI use is fair to use until more apparent precedents are established. The remaining hesitations that architects have when considering using generative AI are not unfounded, especially after witnessing the many failed designs from this thesis that were neither aesthetically pleasing nor code compliant.

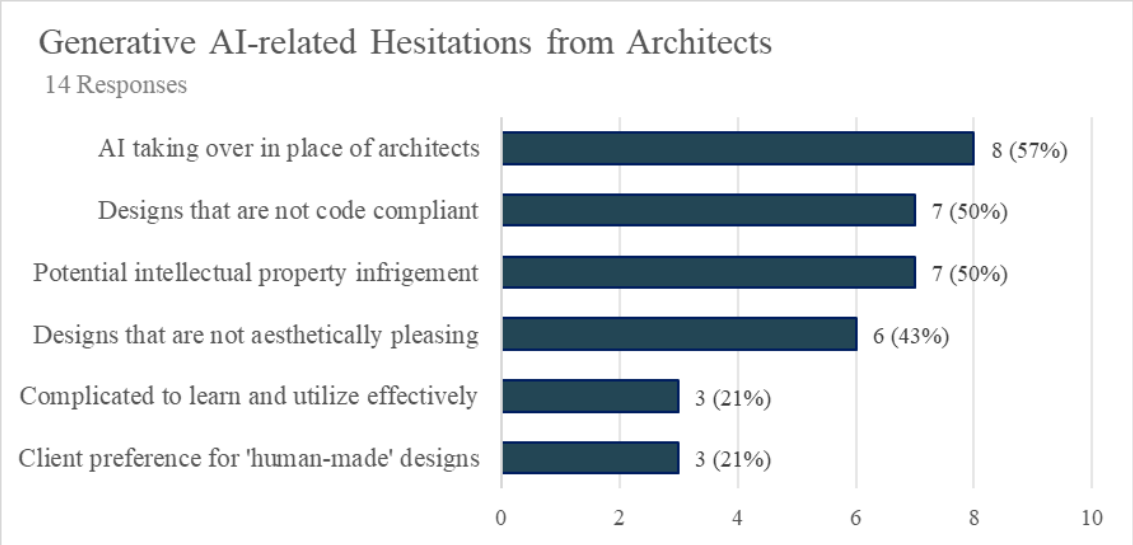


Figure 6.4 Architect Survey Generative AI Hesitations Credit: Author

If architects, and more generally, humans can account for these risks and develop AI without any of the concerns identified, then surely it would be justified to encourage AI to integrate within our businesses. The only caveat to that then is if developers can create the generative AI tools without inaccuracies or potential for cybersecurity breaches. While that is to be determined in the coming months, it is ultimately in the hands of humans how to evolve AI. At this time, generative AI is not an uncontrollable entity, it is made by humans for humans. If

humans develop AI to displace workers, then that's what it will do but if their goal is to produce powerful and efficient work safely then that's what it will do. It is not the AI that humans need to control and be concerned about, it is the humans themselves that are developing the AI.

Fei-Fei Li, a pioneer in AI development, said that AI is not promising us anything, it is a piece of software, and it is the users and developers who are promising (Corbyn, 2023). This rhetoric of AI misuse and disruption is only due to those using the AI, not because of the AI tool itself. In order to willingly justify AI's involvement in our businesses and our homes, this relationship needs to be understood. The consensus recommendation for reducing the evolution of dangerous AI and the potential misuse of existing AI is to bridge the gap in technological literacy (Mello-Klein, 2022). Education is the strongest tool to assist in understanding and using AI properly, that is if it isn't too late already.

Developers of AI are very intrigued with pursuing generative AI, oftentimes caught up in discovering whether it can accomplish a task they rarely pause and ask whether it should. As mentioned, it may not be as disruptive to the market or workers if generative AI takes over or heavily assists in design work, for example. Caution, however, should be practiced in the development of AI as it could reasonably lead to more harm than good, including the development of purposefully harmful AI (manipulating election results, spreading false information, or facilitating the mental or physical harm of others). Users also must practice caution, it is extremely likely that AI already exists that users can manipulate and utilize for illicit purposes. While the AI tools may not have been developed for these purposes, there is always the possibility of bad actors working to misuse AI, something the developers need to account for and regulate.

Since the AI itself cannot be held responsible, nor can the developer or user be solely held accountable for the AI's action, something needs to be established to regulate and hold authority over the evolution of AI. Some AI companies are aware of this need, taking it upon themselves to safely develop their product. Anthropic, an AI company competing with Open AI, is aware of the multitude of companies looking to establish their product as the dominant and mainstream AI tool of the future and is aware of the danger this raises without proper technological literacy established. Anthropic is working to develop its AI product with built-in safety features, known as a 'constitution.' This acts as a regulatory blocker and a filter that the

machine learning must abide by at all times, it is written by humans to assure functionality and safe integration with clients (Kundu et al, 2023).

It should not be expected that every company developing AI establishes a constitution similar to Anthropic's. A regulatory party will need to be introduced in the coming months, one that intervenes to establish safety standards and precautions. Government intervention, and maybe even international counsels like the United Nations, are warranted to step in and assist in this process. Since no departments of this nature exist at this point, AI development is left in the hands of the companies and personnel writing the lines of code. Many AI companies, including Anthropic, Google, Microsoft, and OpenAI formed a division of their own, called Frontier Model Forum. This is an oversight group to self-police their evolution of AI and are themselves calling for government regulations. Their mission is to advance AI safety research and help AI progress to meet society's greatest challenges while also establishing best practices and self-established guidelines (Frontier Model Forum, 2023).

Ideally, regulations would be established and upheld by an unbiased third-party but until that exists Frontier Model Forum will serve as the safe haven for AI development. This hardly justifies the continual evolution and eventual assimilation of AI into the workforce, but it is a start. The idea of differential technology development is at play here. A term recently introduced to identify the tension between progressing AI to become more powerful while not creating a product that could seriously affect the lives of millions. AI companies need to stall the "development of dangerous and harmful technologies, especially ones that raise the level of existential risk; and accelerate the development of beneficial technologies, especially those that reduce the existential risks posed by nature or by other technologies (Bostrom, 2019).

The survey of architects conducted for this thesis asked the opinion of architects on the evolution of AI (Appendix D). The survey participants were more in favor of caution than assimilation. When given the choice between 1) assimilating AI into the architectural practice, 2) exercising caution with AI integration, or 3) working together to resist the integration of AI, 43% of architects thought architects should assimilate AI while 57% argued architects should be cautious. The reasons to exercise caution are plentiful, namely the unknown outcomes and threatened dangers with full integration. The respondents who favored assimilation noted it would be for the betterment of the industry, aware of the possible time and cost savings, and any

negative outcomes would be resolved over time. Clearly, there is no right or wrong answer here, no one yet knows the effects AI will have on the architecture industry or beyond.

For architects and professionals across all disciplines to want to use AI, they need to know it is safe and harmless for their practice. The AIA Code of Ethics does not yet discuss AI and the potential revolution it can have on the industry. Instead, AIA's vision is centered on embracing change and promoting the inclusion of diverse and impactful work. AIA stands for "federal policies that help firms thrive, not hold them back" and "policies that provide better access and financing for young people to enter and remain in the profession of architecture" (AIA, 2023).

This language does not explicitly relate to artificial intelligence, but it does articulate the need for progressive and idealistic changes to their process. As this message reads, AIA should have no issues with the integration of AI within architecture. Assuming the AI tools are safe (and productive to the practice), AIA may soon be an early adopter of AI. To assist in the introduction of entry-level professionals and facilitate designs that are passionate and innovative to help firms thrive, introducing AI should be a no-brainer. Similar to the welcoming of CAD technologies in the 1980s and beyond, generative AI may see a similar inclusion in architectural firms. So long as regulations are constituted and met, AIA could establish a precedent for AI integration, not only for the architecture industry but for the global market as well.

6.2 Justifying AI Use in an Architecture Firm

This thesis proves that generative AI has a place in architectural design. The AI tools certainly have to be safely regulated and resistant to risks like inaccuracies and copyright issues if it's implementation is to be justified. As argued, the disruption to the job market should be equalized by the creation of new jobs and the availability of entry-level workers to step in. Architects themselves should not overtly fear the integration of AI, however, it is always a possibility some or many may lose their jobs as they currently exist. While this thesis proved AI is capable of completing a small set of tasks within schematic architectural design (which itself is a subset of the overall architectural design process), it has proved that generative AI is not yet capable of fully taking over design work.

The AI tools used in this thesis assessment showcased that AI is best used for broad, more general tasks, as seen in the productivity of ChatGPT and Midjourney. Generative AI has yet to prove useful in specialized instances with tasks that professionals typically do with ease, as seen in the poor performances of Maket and CodeComply. This gap in broad and specialized uses may change, but it highlights the current state of architecturally relevant AI tools - it will not be completing a comprehensive design anytime soon. By compartmentalizing the processes of schematic architectural design, the AI tools in most cases were able to complete the singular given tasks. Utilizing multiple AI tools is the only way to complete the schematic design process at this time, but for generative AI to properly be introduced in the architectural practice it will need to be multidisciplinary and productive for many of the tasks identified.

When surveyed, architects were prompted on their trust and confidence in using AI, as well as their current willingness to offload their work to AI (Appendix D). If a multidisciplinary generative AI were to be developed and successfully integrated into the architectural practice, it is important to gauge the involvement and eagerness architects would exhibit. The results from these survey questions, seen in Figures 6.5-7 show that architects have limited trust in the AI they would be using. Similarly, there is little eagerness to offload their current workload to this artificial assistant. This is not due to their ability to understand and use the tools, as many responded they would be very confident in their ability to use AI.

How would you rate the following categories related to the potential of using AI for design and/or office work? [Scale 1-5]

Trust in using AI Tools.
[1 - no trust, 5 - complete trust]

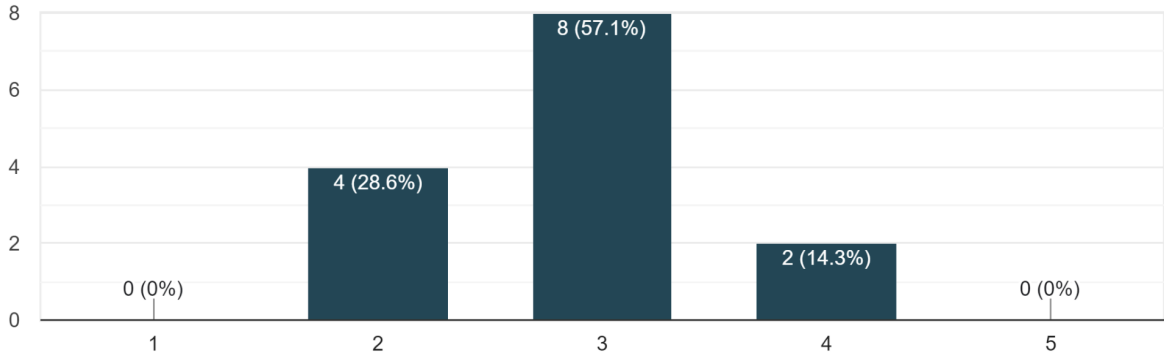


Figure 6.5 Architect Survey Trust in AI Credit: Author

Confidence in ability to learn and use AI Tools daily.
[1 - no confidence, 5 - complete confidence]

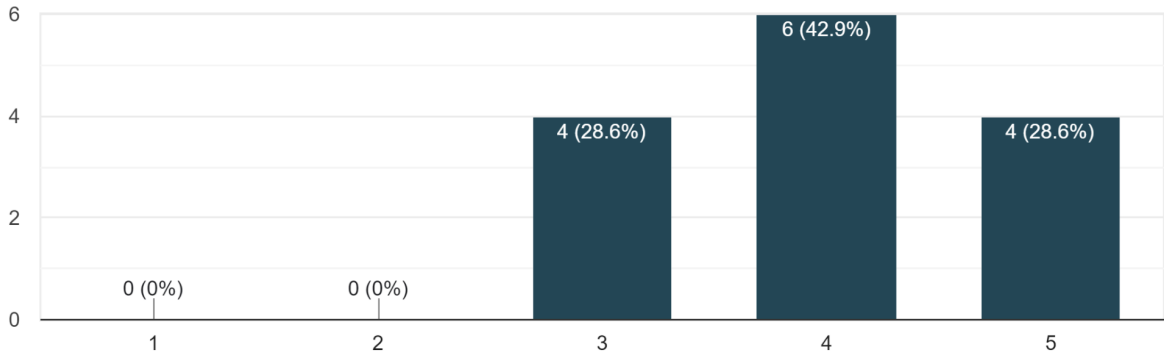


Figure 6.6 Architect Survey Confidence in Ability with AI Credit: Author

Willingness to offload current work to AI assistance.
[1 - no work, 5 - all current work]

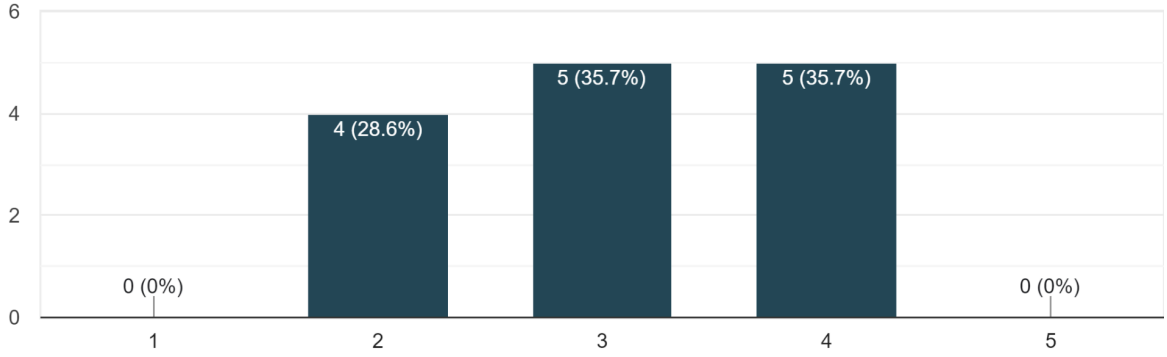


Figure 6.7 Architect Survey Willingness to Utilize AI Credit: Author

The problems experienced in this thesis, including troubles in prompt engineering and context articulation, are not unique experiences. Anna Bernstein, whose job title is Prompt Engineer for the AI company, Copy.ai, helps users like architects write prompts with precise language and specific details. The compounding issues where the specificity was not specific enough and the context was difficult to articulate were never faults of the AI tool, but rather a lack of experience in the user. Anna describes that it is possible to craft the perfect prompt to generate exactly what the user is seeking - to hit the nail on the head regardless of the AI tool being used (Bernstein, 2023). The ability to craft useful prompts, or engineer prompts, is a learned skill. If architects are to be expected to utilize AI to assist in design and office work, the ability to construct these prompts will need to be taught.

Some tools had more opportunities to engineer the prompt to the user's favor. While a good prompt should be productive in any tool, these opportunistic tools provided more assistance in prompt engineering - tools like LookX that provide both positive and negative prompts, and other ways to prompt the AI. These tools are called multimodal AI, tools that accept multiple media inputs as prompts, including text, images, voice, and video (Meta, 2024). Generative multimodal AI tools may end up making the user experience so much better and yield better results that they will be the successful and dominant choice for an AI tool in the future. If architects are looking for tools that will be productive and last in their firm, multimodal AI tools would be the safest option.

For an architectural design that utilizes generative AI, the conventional process of generating designs will shift toward prompt writing and editing. This may not be what architects have trained for or prepared for, but they are the most capable workers to produce designs, even if it is through prompts. This potential shift in the industry will dramatically increase the number of individuals who can complete design tasks. The ability to access AI design tools will allow anyone to complete design tasks that were previously only possible by professionals. Even though a licensed architect will be more competent in completing an overall design, it is now available for any entry-level worker or otherwise to try their hand at architectural design. Is this a potential threat to the architectural industry, now that clients can do potentially complete designs on their own? Or is this an opportunity to open the door to clients and architects to work more collaboratively in design? Perhaps this is why only 50% of the architects surveyed had a positive opinion about AI (Appendix D). The other architects were neutral towards it, likely wary and conscious of the uncertainty and possible division its inclusion may cause.

It is impossible to say the exact impact generative AI will have on the architecture industry. Not only will architects lose their jobs or be forced to transition to prompt engineers, but the architectural practice itself could dissolve as the architect is no longer the only one capable of generating and iterating designs. Carl Christensen, the Vice President of Product at Autodesk, agrees that the future is uncertain, but maintains that the inclusion of AI will only be an industry shift, not a dissolution (Franco, 2023). The integration of AI will produce more unique results, with new materials and construction practices, and the ability to address more pressing issues, like extreme weather conditions and changes in urban living. The question of

course is “Are we as architects better prepared now than in the past to adapt to these transformations? Maybe it's AI itself that will assist us in navigating these transitions” (Franco, 2023).

The use of AI would be completely justified for an architecture firm if architects can absorb this transition and benefit from the many advantageous AI promises. Some architects are not as fond of AI promises. Mark Alan Hewitt, an architectural historian, is fully against the integration of generative AI . Hewitt understands that artificial intelligence models are trained on existing data, then once AI-generated designs become commonplace the model will in turn be trained on previously generated, possibly poorly generated AI designs (Hewitt, 2023). If AI establishes its place in architectural practice, will the results one day be so incomprehensible and useless that we can no longer use AI? Is it possible that generative AI will cement its tools in architecture design that architects now require its assistance, and what happens when it no longer produces favorable designs?

Mark Alan Hewitt doesn’t want to wait that long to find out. He believes AI-generated designs today are already unfavorable and should warrant their expulsion from the practice entirely. “AI will never produce works of craftsmanship or art comparable to that of these human wonders… Any style can be copied, but no masterpiece can be replicated” (Hewitt, 2023). Hewitt is correct that AI will only ever replicate designs. The creativity and unique craftsmanship an architect provides can never be matched by a machine. As AI exists today, it only ever regurgitates data to generate work it expects its user to prefer, work it knows architects have produced in the past. Maybe after enough data feeding, these models may eventually stumble into novel, genuinely creative designs. But that is not the case in today’s generative AI, a model built to reproduce and assume designs based on previous examples.

This introduces an interesting discussion; even if generative AI can be safely and productively introduced to assist in architectural design, will architects even like the results? Will the clients? It's not yet understood whether clients would prefer hand-drawn, or at least human-made, designs over a computer model’s design. It is likely they would be content so long as the design meets their expectations (including design articulation and budget and time constraints). It will be an interesting relationship in the near future how clients will react when

given AI-generated designs, that is if the architects tell them they were AI-generated. Only 78% of the architects surveyed responded that they would be completely honest with their client about their [the architects] AI use (Appendix D). This means that almost a quarter of the architects assessed would consider being dishonest or at the very least quiet to their client about AI's involvement in their project. This should be troubling to clients everywhere, especially considering the many risks they would be exposed to without their knowledge or consent.

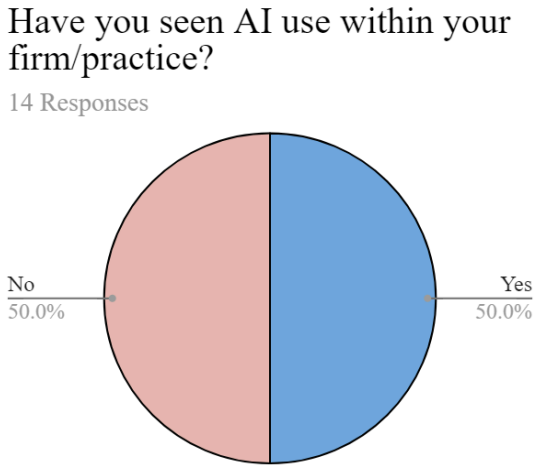
From an industry-wide perspective, it should be justified and advantageous to at least try integrating AI assistance, if only for internal exploration. Generative AI allows architects to workshop new design ideas and relatively effortlessly develop designs they otherwise wouldn't pursue. Recent design contests have been developed that encourage the use of AI. These contests, like the ones sponsored by SPACE10, are part competition and part open-source research, helping researchers and AI developers to better understand the potential of AI integration (Arellano, 2023).

Contests like this are beneficial to the justification of AI use in architecture. New ways to approach design should always at least be attempted and studied. Contests like this are essential to publicly assess the viability of AI. Generative AI introduces a much-needed element in architectural design; competition. Competition is essential to any discipline, as too little competition leads to little variation and likely mundane and subpar products (Boushey et al, 2021). Utilizing AI will incentivize creativity by adding an endless supply of competition and assisting in rudimentary tasks to alleviate workload and allow architects to develop more creative designs.

While competition is sought after in business, the loss of repetition is not always strictly a benefit. AI will have the ability to overhaul architectural design practices, minimizing the necessity for repetitive tasks. While on the surface this appears to be another advantage in a firm, repetition does overtime lead to expertise. It has been proven that repeating specific skills or tasks will make a person more proficient over time, i.e. practice makes perfect (Chandrasekara, 2023). While reducing the repetitive tasks required of a trained architect may free up their time, does it not also limit the necessary and valuable experience for an architect-in-training? The founder of LookX, Wanyu He focuses only on the positive outlook of it, arguing that AI will

“liberate us from repetition and allow us to concentrate on things with added value to society" (Barker, 2023). With increased competition, increased access to creativity, and the potential for groundbreaking innovations within the industry, AI can justly be integrated into architecture at least on a trial or temporary basis.

Many of the architects surveyed agree, and some have already begun seeing it used within their firms, or used it themselves. Figures 6.8-10 showcase the current involvement of AI within architecture firms. These questions were posed to better understand how relevant AI is in firms today, and how architects believe AI will be used in their firms in the near future. Interestingly, all of the architects surveyed believe they will start seeing AI use in the architecture industry within the next 5 years. Even more compelling, 50% of the architects have already witnessed AI use in their firm or practice. As the percentage of firms using AI increases over time, the impact and justification of generative AI use becomes more necessary to resolve. However, of the architects surveyed, only 50% of them believed AI will have a bigger impact on the utilization [time savings, cost savings, and productivity] of the practice than BIM (Appendix D). The inclusion of BIM software allowed for 3D modeling in lieu of hand drawing, revolutionizing how projects are workshopped, detailed, and rendered. With 50% of architects believing AI will not bring a similar or more impactful revolution, there is a significant disconnect between AI companies and the architects that have yet to indulge them (Appendix D).



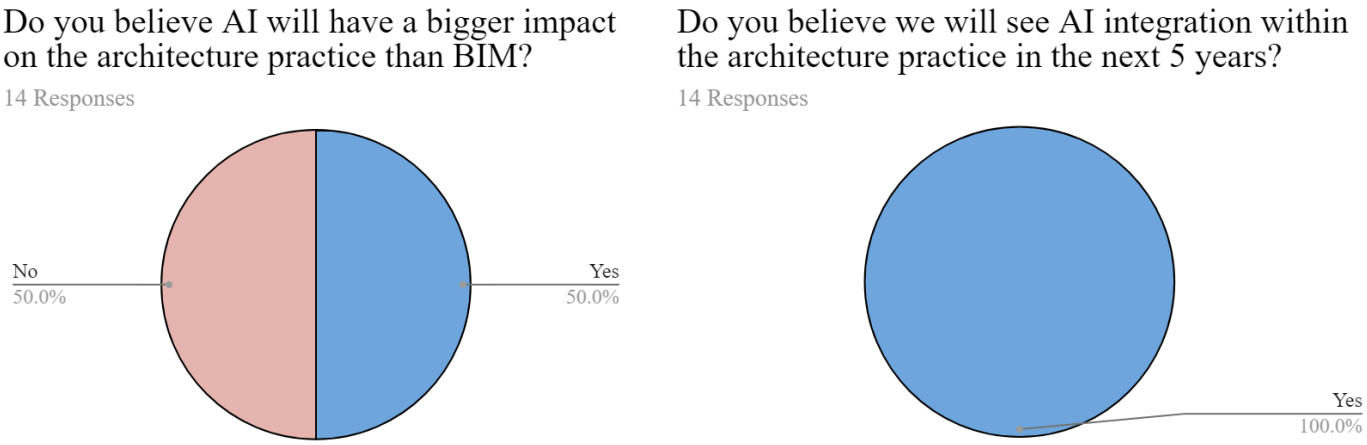


Figure 6.8-10 Architect Survey Exposure to AI Credit: Author

At this point, many professionals have heard about AI in passing, but are mostly adverse to its implications, either consciously or ignorantly. Conscious ignorers of AI, the Luddites of the 2020s, are actively not using it to dissuade its advancement and revolution in professional spaces. These are professionals similar to Mark Alan Hewitt, who likely have experience with AI and are acutely aware of the many dangers it currently poses (Davidson 554., 2023). Perhaps more likely are the professionals who have yet to experience AI, it is after all a novel technological advancement within the last few years, something many people avoid. These professionals are content in their current way of business and do not need to make adjustments - after all, if it's not broke why fix it?

It's the architect's decision on their involvement with generative AI. It is ultimately their choice and preference if they decide to integrate AI into their design practice or not. Despite its intriguing promises and glaring dangers, generative AI will eventually be introduced into architectural practice regardless. Already there are plenty of firms utilizing AI tools, most notably Zaha Hadid's Studio committing to developing most of their projects using AI-generated images (Nayeri, 2023). Now that AI has already penetrated the discipline, is it too late for architects to make a choice? Is the AI revolution here and unpreventable?

While as discussed there likely will not be massive shifts in the industry all at once, or at least not immense job loss, it is still likely that generative AI may become commonplace in

architecture firms across the world within the coming months and years. This ‘AI takeover’ will not be as dramatic as the movies and newspapers warn, as this thesis has proven the results are subpar. AI use in architecture firms across the world will likely produce similarly average and repetitive results; what the models think the architects want. For now, humans have an incredible advantage; diversity and unique experiences. Humans can break the mundane and cloudiness of AI-generated work by adding their individual flairs of creativity and style. Generative AI models lack contextual awareness, something architects can utilize to separate their AI-generated work from others, creating unique and never-before-seen creativity and thoughts.

The creation of art cannot always be left to the machine, it is the humans interacting with and iterating designs that understand how to make art. Art is subjective, while also having a direct relationship with the world around it. Art, as is seen in architecture, can serve both as a mirror and a catalyst for cultural change (Currents, 2023). Even the most sophisticated AI models (at this time still with the capacity of a squirrel) will never understand the impact art has on society. As styles and meanings change, so too will the design in architecture. The human advantage is this understanding, and more importantly, desire, to influence change through their medium. Architects will never entirely give up design control to an AI model, the meaning is too important. That, however, does not mean AI should be entirely ignored.

While architects bring diversity and unique experiences to the proverbial drafting table, AI has its own advantages. AI production is extremely cheap and fast. The iterations capable of any of the AI tools assessed were incomparable to that of a human. The continuous and progressive improvements in the results over a very short period of time will prove advantageous to any user. This advantage does not automatically qualify its justification in an architecture firm, but it does inspire productive use cases. By combining the attributes of humans and machines, a product can be generated faster, cheaper, and with more creativity and inspiration. Where humans are cognitive and exploratory, machines are rational and interpolative. When combined they can offer new creative opportunities (Bolojan, 2021).

The choice to utilize AI for design assistance does not have to be an all-or-nothing approach. This thesis proves that completely entrusting AI to accomplish even a subset of architectural design will yield choppy and incomprehensive results. Generative AI assistance

would be justifiably used for design when done in a collaborative approach. AI exceeds in many criteria (fast and low-cost iterations, advanced data comprehension) but lacks in others (understanding context, creativity, and subjectivity of art). Architects similarly are limited in their capacity to design. An inclusive and collaborative approach to AI utilization will prove to be the most effective strategy for the architectural industry.

The Chinese proverb from Lao Tzu, a philosopher and founder of Daoism, is becoming exceedingly relevant, “Knowledge is knowing a lot of facts, and wisdom is knowing which ones matter” (Chan, 2018). AI tools are amazing, yet daunting innovations. They have all the data in the world at their disposal, yet are completely useless until humans interact with them. Generative AI has countless knowledge, but no wisdom. Humans can step in to fill this gap, creating an evolved collaboration of humans and machines. This collaboration now is wiser than ever before, and thus capable of any imaginable task the human requires.

The cooperative design approach - that is the newfound way architects will use AI in design - can begin as early as today. The many productive AI tools that were identified in this thesis can and should be used collaboratively for any task within architectural design, not singularly schematic design. These tools are available now for firms to take advantage of, and can be used as needed throughout the design process. This approach will ensure the slow integration of AI within architectural design while assessing its viability and function within each firm. To reinforce this approach, 100% of the architects surveyed are willing to work alongside an AI assistant to help in design and office work (Appendix D).

In seeking the least destructive, most virtuous way to use AI, architects can establish a powerful precedent for other industries to follow. The industry as a whole will of course need to consider the immense possibilities in design efficiencies and innovations, as well as the need for standardized regulations and technical literacy education. The unrealized cost and time savings, as well as the improved productivity and overall utility experienced by this collaborative approach will surely revolutionize the industry. It is important to remember that despite how fast or disruptive this process may be in the near future, it is the humans - the developers, the users the conscious ignorers, the regulators, and everyone in between - who have the control to limit AI exposure and justify its place in our industries, at least for now before it reaches human-level intelligence, then it is anyone’s guess.

7. CONCLUSION

7.1 Key Findings

The assessment and discussion of generative AI tools in this thesis provided valuable insights into the potential integration of Artificial Intelligence within architectural design. The objective of this study was to complete the schematic design process and above all else perform a uniform comprehensive design, to then assess the tools used, ranking them on their potential savings and productivity, and discuss whether the tools can be justified for use within architecture firms at this time.

The AIA subphases of schematic design - Analysis, Synthesis, Refinement, and Documentation - were specified to compartmentalize the design process and identify tasks for AI tool utilization. These subphases, and the schematic design phase as a whole, were chosen for use in this thesis because of the general broadness of necessary design elements and availability of mass-market AI solutions to these tasks, more so than proprietary or specialized algorithmic tools dedicated to one task or firm. The Integrated Design Process (IDP) also informs architects that design-based changes are more costly later in the design process, meaning any assistance in creating a functional design early could have significant cost savings implications.

Utilizing AI tools for common schematic design phase tasks - like parti drafting, concept design synthesis, and image editing - could result in a more efficient schematic design phase, leading to time savings, cost savings, and a superior design. The time savings achieved by utilizing these AI technologies will empower architects to focus on other tasks, leading to more productive employees and more meaningful and creative designs. The cost savings that firms will soon realize will result in cheaper projects, shifting the industry to a more cost-friendly model, and more disposable income for employees' salaries, benefits, and productivity in the firm. The superior design has compelling implications for the architecture industry, with creative problem-solving, advanced building system integration, and innovations in sustainable design. Significant advances in any task or process could result in the eradication of traditional design processes altogether.

In the actual use and assessment of AI tools to discover these potential benefits, it was proven that at this time, AI is still a long way off from fully and comprehensively taking over design work. These tools still require extensive data (in the ballpark of billions of learnable parameters) to be productive, more than any AI has currently. Data feeding will help make these tools more serviceable and is achieved when architects and researchers use tools today like the ones identified in this thesis. Any issues and flaws witnessed in the AI tools utilized for this thesis were not unique experiences. Issues like prompt engineering (in some cases, selection engineering), context awareness, and unintuitive interfaces have all been experienced and addressed as common problems all AI tools have at this moment.

Perhaps the most important takeaway from this thesis is the need for prompt engineering. Before any integration and utilization of AI tools can be established, proper prompt engineering training will be required. Understanding the syntax of a sentence, like the location of specific details, periods, commas, and adjectives will need to be taught to users prior to using the AI tools. It is nearly certain that prompt engineering classes, or at least lessons, will be made available to architects in the near future as they prepare for the integration of AI into their firms. It was made apparent in this thesis that the most successful tools were the ones that actively worked to mitigate issues due to the construction of the prompt. These tools (like Midjourney and LookX) were mostly multimodal AI, with capabilities in prompt assistance and textual and visual prompt cues.

The common sentiment is that these issues witnessed in this thesis and identified by other users will not hinder AI's involvement in our industries. Bill Gates understands that there are limitations in AI today, but they will be gone before we know it. He believes AI will eventually result in a 'personal agent,' an AI-trained technological companion to both "improve your work on tasks you want to do and free you from the ones you don't want to do" (Gates, 2023). It has been increasingly apparent that AI is not ready to take over design work today but will get to that level eventually. The use of personal agents may exist in recreational life, but will certainly first be utilized within businesses and firms to increase productivity. The existential implications of the AI takeover should not warrant the dismissal of these algorithmic productivity boosters, but architects should still exercise caution when introducing them into the firm.

The cooperative design approach, a term coined in this thesis to identify the cooperative relationship architects will soon have with their AI assistants, will become commonplace in the discipline. Architects have creative and diverse experiences but cannot compete with AI's level of production. The cheap and fast iterations created by any of the AI tools assessed were incomparable to that of an architect. Cooperatively using generative AI to produce work the architect envisions will revolutionize the architecture industry, so long as regulations are instituted and followed to ensure safe and fair designs. The implications of AI use are profound, with the actual impact on the architecture industry and beyond still unknown.

7.2 Further Research

The research completed in this thesis is a broad understanding of generative AI and its uses and merit in an architecture firm. Further research into AI's use in the architecture discipline would be most impactful using the same assessment under a different scope. Altering the case study scope that was used for all the AI tools will create new tasks and uses to assess the AI. Changing the building typology and project location will also increase the availability of other AI tools, tools that couldn't strictly be used for the residential house in Albany, NY of this thesis. Continuing to assess the tools identified in this thesis as they develop and additional AI tools that architects could utilize will continue the conversation and add to the data-feeding that AI requires.

With the development of new technologies, the continual advancement in computing power, and the evolution of AI, new tools will always become available for use and testing. Generative AI in the near future will continue to have intriguing and innovative applications. So long as architects and researchers continue to discover and use these tools, AI will continue to evolve and progress to meet the expectations set for it. With this brings more research published on the implications of AI use, and more discussion on the need for regulations on AI development and use.

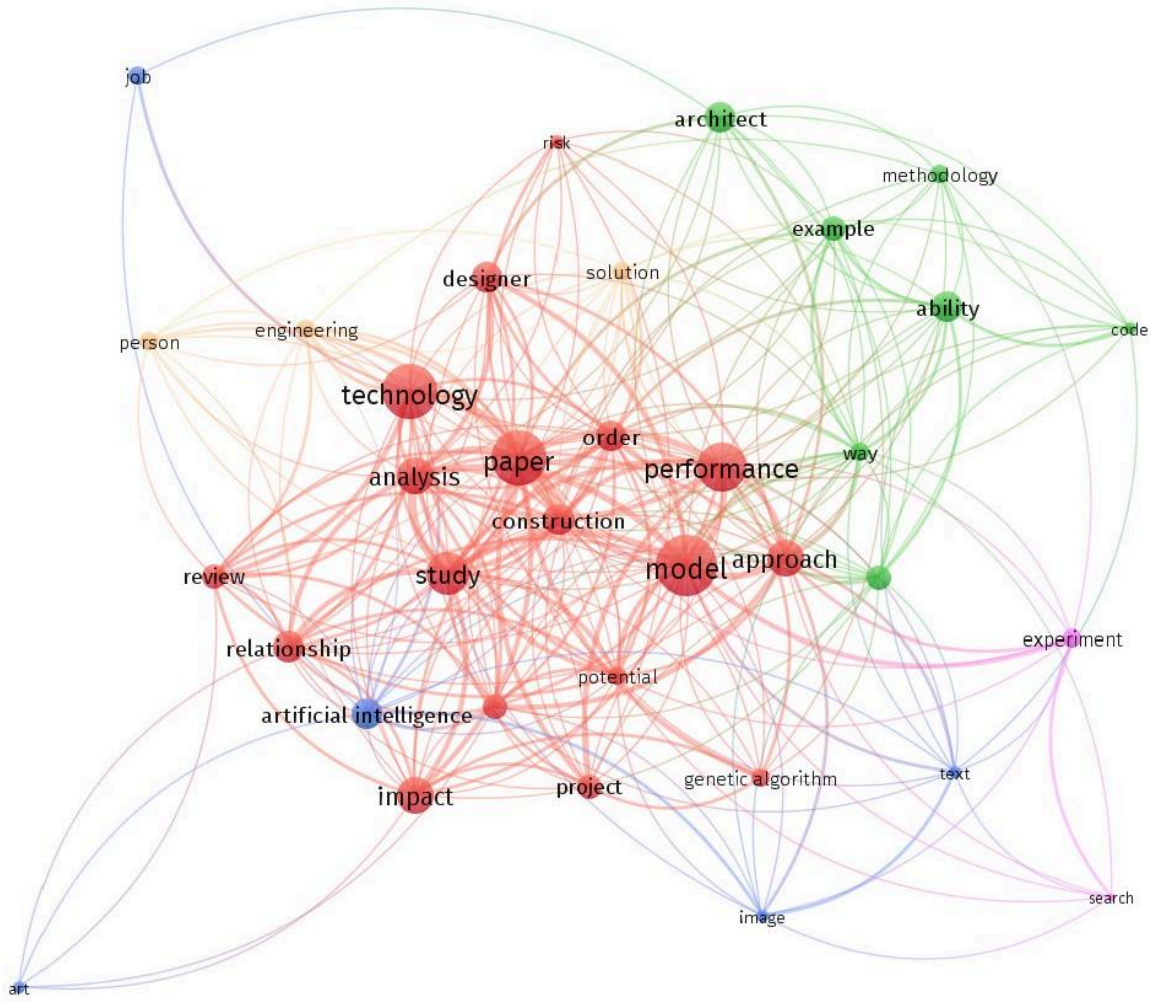


Figure 7.1 Bibliometric Analysis Credit: Author

From VosViewer, this bibliometric analysis of the sources used in both the utilization and justification of generative AI technologies shows the interconnectivity of the topics of AI and Architecture. Keywords were identified that had at least 5 connections within all the sources used for research in this thesis, creating a database of 113 keywords and their correlation. Further research should use the terms identified in the bibliometric analysis for an investigative understanding of the research conducted in this thesis. It is almost certain that continued architecture-centered AI research will contain similar clusters of keywords but with more nuanced and specified terms near the perimeter. From this thesis, there is no doubt that the Artificial Intelligence revolution is coming, and it is in the architect's hands to decide if its involvement in the industry will lead to a revolutionary transformation or its dissolution.

8 . BIBLIOGRAPHY

"Adding Function to Form." *John Hearn Architect*, 2023, https://jharchitect.ca/services/programming/.

Ahramovich, Aleksandr. "The Role of AI in Architecture." *Itransition*, https://www.itransition.com/ai/architecture#:~:text=AI%20allows%20them%20to%20brainstorm,workflows%20to%20the%20next%20level.

Architechtures - AI-Powered Building Design. https://architechtures.com/en. Accessed 16 Dec. 2023.

Arellano, Monica. "SPACE10 Announces Winners of Global AI Design Competition." *Arch Daily*, June 2023, https://www.archdaily.com/1002023/space10-announces-winners-of-global-ai-design-competition.

Arezki, Rabah. "The Economics of Sustainability: Causes and Consequences of Energy Market Transformation." *Economics of Energy & Environmental Policy*, vol. 9, no. 2, Apr. 2021. *DOI.org (Crossref)*, https://doi.org/10.5547/2160-5890.9.2.rare.

Armstrong, Helen, and Keetra Dean Dixon, editors. *Big Data, Big Design: Why Designers Should Care about AI*. First edition, Princeton Architectural Press, 2021.

Art & Architecture Source. https://web-s-ebscohost-com.ezproxy.rit.edu/ehost/search/advanced?vid=0&sid=15790309-7aa7-4703-9d3a-d10a455dfb8a%40redis. Accessed 27 Apr. 2023.

As, Imdat, et al. "Artificial Intelligence in Architecture: Generating Conceptual Design via Deep Learning." *International Journal of Architectural Computing*, vol. 16, no. 4, Dec. 2018, pp. 306–27. *SAGE Journals*, https://doi.org/10.1177/1478077118800982.

Autodesk Forma Software (Formerly Spacemaker) | Login & Buy Forma. https://www.autodesk.com/products/forma/overview. Accessed 14 Dec. 2023.

Barker, Nat. "Will Architects Really Lose Their Jobs to AI?" *Deezen*, July 2023, https://www.dezeen.com/2023/07/27/architects-lose-jobs-ai-aitopia/.

Becker, Kory, and Justin Gottschlich. *AI Programmer: Autonomously Creating Software Programs Using Genetic Algorithms*. arXiv:1709.05703, arXiv, 17 Sept. 2017. *arXiv.org*, http://arxiv.org/abs/1709.05703.

Bernstein, Anna, and David Shapiro. *Professional Prompt Engineer - "We Don't Have to Forfeit the Realm of Creativity."* 7 Jan. 2023, https://www.youtube.com/watch?v=ekn5Tcqgs7o.

Betker, James, et al. *Improving Image Generation with Better Captions*. 2023.

Bidding. AIA.

Bolojan, Daniel. "Creative AI: Augmenting Design Potency." *Architectural Design*, vol. 92, no. 3, May 2022, pp. 22–27. *DOI.org (Crossref)*, https://doi.org/10.1002/ad.2809.

Borson, Bob. "Architectural Sketh Series: Schematic Design." *Life of an Architect*, 13 Aug. 2019, https://www.lifeofanarchitect.com/architectural-sketch-series-schematic-design/.

Bostrom, Nick. "The Vulnerable World Hypothesis." *Global Policy*, vol. 10, no. 4, Nov. 2019, pp. 455–76. *DOI.org (Crossref)*, https://doi.org/10.1111/1758-5899.12718.

Boushey, Heather, and Helen Knudsen. "The Importance of Competition for the American Economy | CEA." *The White House*, 9 July 2021, https://www.whitehouse.gov/cea/written-materials/2021/07/09/the-importance-of-competition-for-the-american-economy/.

Brown, Nathan C., and Caitlin T. Mueller. "Design Variable Analysis and Generation for Performance-Based Parametric Modeling in Architecture." *International Journal of Architectural Computing*, vol. 17, no. 1, Mar. 2019, pp. 36–52. *DOI.org (Crossref)*, https://doi.org/10.1177/1478077118799491.

Campo, Matias, and Neil Leach. "Can Machines Hallucinate Architecture? AI as Design Method." *Architectural Design*, vol. 92, no. 3, May 2022, pp. 6–13. *DOI.org (Crossref)*, https://doi.org/10.1002/ad.2807.

Cao, Bin, et al. "Development of a Multivariate Regression Model for Overall Satisfaction in Public Buildings Based on Field Studies in Beijing and Shanghai." *Building and Environment*, vol. 47, Jan. 2012, pp. 394–99. *DOI.org (Crossref)*, https://doi.org/10.1016/j.buildenv.2011.06.022.

Cao, Shi-Jie, and Chen Ren. "Ventilation Control Strategy Using Low-Dimensional Linear Ventilation Models and Artificial Neural Network." *Building and Environment*, vol. 144, Oct. 2018, pp. 316–33. *DOI.org (Crossref)*, https://doi.org/10.1016/j.buildenv.2018.08.032.

Carlson, Cajsa. "Tim Fu Uses 'Midjourney for Architecture' to Transform Crumpled Paper into Starchitect Buildings." *Deezen*, https://www.dezeen.com/2023/06/29/tim-fuai-crumpled-paper-starchitect-building-designs/.

Castelo-Branco, Renata, et al. "Sketching Algorithmic Design." *Journal of Architectural Engineering*, vol. 28, no. 2, June 2022, p. 04022010. *DOI.org (Crossref)*, https://doi.org/10.1061/(ASCE)AE.1943-5568.0000539.

Chan, Alan. "Laozi." *The Stanford Encyclopedia of Philosophy*, edited by Edward N. Zalta, Winter 2018, Metaphysics Research Lab, Stanford University, 2018. *Stanford Encyclopedia of Philosophy*, https://plato.stanford.edu/archives/win2018/entries/laozi/.

Chandrasekara, Ashan. “The Power of Repetition: Mastering Skills Through Consistency.” *Medium*, 11 Sept. 2023, https://ashanchandrasekara.medium.com/the-power-of-repetition-mastering-skills-through-consistency-6ac2b417ead3.

Charlesworth, Keystone Law-Will. *“Does Copyright Protect Original Work from AI-Generated Content?” Lexology, 11 Aug. 2023, https://www.lexology.com/library/detail.aspx?g=775bd0c9-30c7-4d91-8116-c210aadcb0b*

ChatGPT. https://chat.openai.com. Accessed 15 Dec. 2023.

ChatUML | AI Assisted Diagram Generator. https://chatuml.com/edit/new. Accessed 15 Dec. 2023.

Chiavaroli, Julius J. *Comprehensive and Integrative Architectural Design*. Routledge, 2022.

“CodeComply.Ai.” *Codecomply*, https://www.codecomply.ai. Accessed 19 Dec. 2023.

Colton, Simon, et al. *Generative Search Engines: Initial Experiments*.

Construction Administration. AIA, 201AD.

Construction Documents. AIA, 2013.

Corbyn, Zoe. “AI Pioneer Fei-Fei Li: ‘I’m More Concerned about the Risks That Are Here and Now.’” *The Guardian*, https://www.theguardian.com/technology/2023/nov/05/ai-pioneer-fei-fei-li-im-more-concerned-about-the-risks-that-are-here-and-now.

“Crunchbase: Discover Innovative Companies and the People behind Them.” *Crunchbase*, https://www.crunchbase.com. Accessed 14 Dec. 2023.

Currents, Cerebral. “Art as a Reflection of Society: Understanding the Cultural Impact.” *Medium*, 2 Aug. 2023, https://cerebralcurrents.medium.com/art-as-a-reflection-of-society-understanding-the-cultural-impact-270c8d641fc2.

Davidson, Adam. *554. Can AI Take a Joke?* Aug 23, 2023, https://freakonomics.com/podcast/can-a-i-take-a-joke/.

Davidson, Adam. *555. New Technologies Always Scare Us. Is A.I. Any Different?* Aug 30, 2023, https://freakonomics.com/podcast/new-technologies-always-scare-us-is-a-i-any-different/.

Davidson, Adam. *556. A.I. Is Changing Everything. Does That Include You?* Sep 6, 2023, https://freakonomics.com/podcast/a-i-is-changing-everything-does-that-include-you/.

Design Development. AIA.

"Design Process." *DSA Architects*, 2023, https://www.dsaarch.com/design-process.

Edwards, Stephen, et al. "Problem Solving and Algorithms." *Objects First*, 2012, http://sofia.cs.vt.edu/cs1114-ebooklet/chapter4.html.

El Asmar, Mounir, et al. "Quantifying Performance for the Integrated Project Delivery System as Compared to Established Delivery Systems." *Journal of Construction Engineering and Management*, vol. 139, no. 11, Nov. 2013, p. 04013012. *DOI.org (Crossref)*, https://doi.org/10.1061/(ASCE)CO.1943-7862.0000744.

Feigenbaum, James, and Daniel P. Gross. "Automation and the Fate of Young Workers: Evidence from Telephone Operation in the Early 20th Century." *SSRN Electronic Journal*, 2020. *DOI.org (Crossref)*, https://doi.org/10.2139/ssrn.3722562.

Fireflies.Ai - Free Meeting Recorder. https://fireflies.ai/. Accessed 14 Dec. 2023.

Fisher, Al. "Engineering Integration: Real-Time Approaches to Performative Computational Design." *Architectural Design*, vol. 82, no. 2, Mar. 2012, pp. 112–17. *DOI.org (Crossref)*, https://doi.org/10.1002/ad.1387.

Franco, Jose Tomas. "Navigating Complexity and Change in Architecture with Data-Driven Technologies." *Arch Daily*, https://www.archdaily.com/1001585/navigating-complexity-and-change-in-architecture-with-data-driven-technologies.

Frew, Samantha. "15 Top AI Tools for Architects and Designers." *Architizer*, 2023, https://architizer.com/blog/practice/tools/top-ai-tools-for-architects-and-designers/.

"Frontier Model Forum." *Frontier Model Forum*, https://www.frontiermodelforum.org/. Accessed 9 Jan. 2024.

Fuhrmann, Oded, and Craig Gotsman. "On the Algorithmic Design of Architectural Configurations." *Environment and Planning B: Planning and Design*, vol. 33, no. 1, Feb. 2006, pp. 131–40. *DOI.org (Crossref)*, https://doi.org/10.1068/b32050.

Garfinkel, Simson. "A Peek at Proprietary Algorithms." *American Scientist*, vol. 105, no. 6, 2017, p. 326. *DOI.org (Crossref)*, https://doi.org/10.1511/2017.105.6.326.

Gates, Bill. "The Age of AI Has Begun." *Gatesnotes.Com*, https://www.gatesnotes.com/The-Age-of-AI-Has-Begun. Accessed 3 Jan. 2024.

"Generative AI In Construction Market." *Precedence Research*.

Generative Design | Architecture Design Software | Maket. https://www.maket.ai/. Accessed 21 Dec. 2023.

George, A. Shaji, et al. *A Review of ChatGPT AI's Impact on Several Business Sectors*. Partners Universal International Innovation Journal, Jan. 2023.

"Grammer and Spelling Checker." *Grammarly*, https://www.grammarly.com/grammar#sectionGrammarCheck_2qOECeWHX7BdDR610BJIb4.

Hayes, R. L. *The Architect's Handbook of Professional Practice*.

Heaven, Will Douglas. "This Avocado Armchair Could Be the Future of AI." *MIT Technology Review*, 5 Jan. 2021, https://www.technologyreview.com/2021/01/05/1015754/avocado-armchair-future-ai-openai-deep-learning-nlp-gpt3-computer-vision-common-sense/.

Hewitt, Mark Alan. "Architects Must Resist the AI 'Revolution.'" *Arch Daily*, June 2023, https://www.archdaily.com/1003243/architects-must-resist-the-ai-revolution.

Holzer. "Understanding the Impact of Automation on Workers, Jobs, and Wages." *Brookings*, https://www.brookings.edu/articles/understanding-the-impact-of-automation-on-workers-jobs-and-wages/. Accessed 11 Mar. 2024.

"How to Calculate Z-Scores (Formula Review) (Article)." *Khan Academy*, https://www.khanacademy.org/math/statistics-probability/modeling-distributions-of-data/z-scores/a/z-scores-review. Accessed 5 Jan. 2024.

Hygh, Janelle S., et al. "Multivariate Regression as an Energy Assessment Tool in Early Building Design." *Building and Environment*, vol. 57, Nov. 2012, pp. 165–75. *DOI.org (Crossref)*, https://doi.org/10.1016/j.buildenv.2012.04.021.

Ilozor, Benedict D., et al. "Building Information Modeling and Integrated Project Delivery in the Commercial Construction Industry: A Conceptual Study." *Journal of Engineering, Project, and Production Management*, vol. 2, no. 1, Jan. 2012, pp. 23–36. *DOI.org (Crossref)*, https://doi.org/10.32738/JEPPM.201201.0004.

"Juhani Pallasmaa: Transcript." *Archtalks*, June 2010, http://archtalks.com/archtalks-home/2010/6/9/juhani-pallasmaa-transcript.html.

Kochhar, Rakesh. "Which U.S. Workers Are More Exposed to AI on Their Jobs?" *Pew Research Center's Social & Demographic Trends Project*, 26 July 2023, https://www.pewresearch.org/social-trends/2023/07/26/which-u-s-workers-are-more-exposed-to-ai-on-their-jobs/.

Kundu, Sandipan, et al. *Specific versus General Principles for Constitutional AI*. arXiv:2310.13798, arXiv, 20 Oct. 2023. *arXiv.org*, http://arxiv.org/abs/2310.13798.

Kwok, Alison G., and Walter T. Grondzik. *The Green Studio Handbook: Environmental Strategies for Schematic Design*. Architectural, 2007.

Liang, Lou Y. "An Improved Cost Optimisation Algorithm for Site Building Layout Planning." *Architectural Science Review*, vol. 51, no. 3, Sept. 2008, pp. 269–76. *Taylor and Francis+NEJM*, https://doi.org/10.3763/asre.2008.5132.

Lin, Haosheng, et al. "A New Optimization Model of CCHP System Based on Genetic Algorithm." *Sustainable Cities and Society*, vol. 52, Jan. 2020, p. 101811. *ScienceDirect*, https://doi.org/10.1016/j.scs.2019.101811.

LookX AI Cloud. https://www.lookx.ai/. Accessed 22 Dec. 2023.

Luo, Xi, et al. "Bi-Level Optimization of Design, Operation, and Subsidies for Standalone Solar/Diesel Multi-Generation Energy Systems." *Sustainable Cities and Society*, vol. 48, July 2019, p. 101592. *ScienceDirect*, https://doi.org/10.1016/j.scs.2019.101592.

Marozas-Aliaga, Lourdes. *Data Driven Energy Efficiency Strategies for Commercial Buildings Using Occupancy Information*.

Mello-Klein, Cody. "Artificial Intelligence Is Here in Our Entertainment. What Does That Mean for the Future of the Arts?" *Northeastern Global News*, 9 Sept. 2022, https://news.northeastern.edu/2022/09/09/art-and-ai/.

"Model Comparison Tool." *Alteryx*, 2022, https://help.alteryx.com/20223/designer/model-comparison-tool.

Multimodal Generative AI Systems. https://ai.meta.com/tools/system-cards/multimodal-generative-ai-systems. Accessed 11 Jan. 2024.

Nayeri, Farah. "How A.I. Is Helping Architects Change Workplace Design." *The New York Times*, 15 June 2023. *NYTimes.com*, https://www.nytimes.com/2023/06/15/business/workplace-design-zhai-ai.html.

Nellis, Stephen. "Adobe Adds Generative AI Features to Photoshop Software." *Reuters*, 23 May 2023. *www.reuters.com*, https://www.reuters.com/technology/adobe-adds-generative-ai-features-photoshop-software-2023-05-23/.

Open-Source Architecture Community - Wiki.OSArch. https://wiki.osarch.org/index.php?title=Open-Source_Architecture_Community. Accessed 27 Apr. 2023.

Özerol, Gizem, and Semra Arslan Selçuk. "Machine Learning in the Discipline of Architecture: A Review on the Research Trends between 2014 and 2020." *International Journal of*

Architectural Computing, vol. 21, no. 1, Mar. 2023, pp. 23–41. *SAGE Journals*, https://doi.org/10.1177/14780771221100102.

"Parti Diagrams." *Bibo Studios*, 2023, https://bibostudio.com/parti-diagrams/.

"PlanFinder." *PlanFinder*, https://www.planfinder.xyz. Accessed 21 Dec. 2023.

Potter, Richard. "Peak Decision Intelligence Maturity 2022." *Peak.Ai*, 2022.

Programming. AIA, 2013.

Radhakrishnan, Ar Mohesh. *CREATIVITY? : AN ATYPICAL ERA OF AI-BASED REPRESENTATION & ITS EFFECT ON CREATIVITY IN THE ARCHITECTURAL DESIGN PROCESS*. no. 1, 2023.

Roggio, Bob. "Pseudocode Examples." *University of North Florida*, 2012, https://www.unf.edu/~broggio/cop2221/2221pseu.htm.

Rotman, David. "How Technology Is Destroying Jobs." *MIT Technology Review*, June 2013, https://www.technologyreview.com/2013/06/12/178008/how-technology-is-destroying-jobs

Schematic Design. AIA.

Schematic Design: Quality Management Phase Checklist.

Scherlis, Adam, and Lawrence C. *GPT-175bee*. *www.lesswrong.com*, https://www.lesswrong.com/posts/YKfNZAmiLdepDngwi/gpt-175bee. Accessed 9 Jan. 2024.

Shen, Weiming, et al. "Systems Integration and Collaboration in Architecture, Engineering, Construction, and Facilities Management: A Review." *Advanced Engineering Informatics*, vol. 24, no. 2, Apr. 2010, pp. 196–207. *DOI.org (Crossref)*, https://doi.org/10.1016/j.aei.2009.09.001.

Sultan, Sahar. *Limitations Of Artificial Intelligence*.

Sun, Hongwei, and Inhan Kim. *Applying AI Technology to Recognize BIM Objects and Visible Proprties for Achieving Automated Code Compliance Checking*. Journal of Civil Engineering and Management, 14 Apr. 2022.

"Supercharging Search with Generative AI." *Google*, 10 May 2023, https://blog.google/products/search/generative-ai-search/.

Tang, Ming, et al. "Performative Computation-Aided Design Optimization." *Enquiry The ARCC Journal for Architectural Research*, vol. 9, no. 1, Dec. 2012. *DOI.org (Crossref)*, https://doi.org/10.17831/enq:arcc.v9i1.68.

The State of AI in 2023: Generative AI's Breakout Year | McKinsey. https://www.mckinsey.com/capabilities/quantumblack/our-insights/the-state-of-ai-in-2023-generative-ais-breakout-year. Accessed 3 Jan. 2024.

Toews, Rob. "What Artificial Intelligence Still Can't Do." *Forbes*, https://www.forbes.com/sites/robtoews/2021/06/01/what-artificial-intelligence-still-cant-do/ . Accessed 11 Jan. 2024.

"Top AI Tools for Architects in 2023." *ARCH GYAN*, 2023, https://archgyan.com/blog/top-ai-tools-for-architects-in-2023/.

"UpCodes Blog." *UpCodes*, https://up.codes/a/introducing-upcodes-copilot. Accessed 14 Dec. 2023.

Velásquez-Henao, Juan David, et al. "Prompt Engineering: A Methodology for Optimizing i Nteractions with AI-Language Models in the Field of Engineering." *National University of Columbia*, Nov. 2023.

Vondy: Next Generation AI Apps. https://www.vondy.com/. Accessed 15 Dec. 2023.

Wang, Yugang. *New Algorithms for Solving Large-Scale Optimization Problems with Application to Engineering Design - ProQuest*. https://www.proquest.com/docview/303890060. Accessed 29 Mar. 2023.

Wanner, Mark. "600 Trillion Synapses and Alzheimers Disease." *The Jackson Laboratory*, 11 Dec. 2018, https://www.jax.org/news-and-insights/jax-blog/2018/december/600-trillion-synapses-and-alzheimers-disease.

What Is Hypar? https://hypar.io/what-is-hypar. Accessed 21 Dec. 2023.

"What Is Moore's Law?" *Our World in Data*, https://ourworldindata.org/moores-law. Accessed 9 Jan. 2024.

"Where Architects Stand: A Statement of Our Values." *AIA*, Sept. 2023, https://www.aia.org/resources/50766-where-architects-stand-a-statement-of-our-va.

Yang, Andrew. *The War on Normal People*. Hachette Books, 2018.

9. APPENDICES

APPENDIX A - Fireflies AI Summary

AI meeting summary:

- *Aaric Celeste confirms that the meeting is being recorded and asks if everything is good on Ms Smith's end. They discuss Ms Smith's new plot of land in Albany, which she wants to build a house on. Aaric asks about the location and size of the land, as well as street access and utilities. Ms Smith provides the address and mentions that there is a paved street but she's unsure about utilities. They talk about the desired specifications for the house, including four bedrooms, three bathrooms, a connected two-car garage, a pool with a shed, space for books and wine collection, and a large kitchen/living room area. Budget-wise, Ms Smith wants it to be comparable to other houses in the area. The style of the house is undecided so Aaric will come up with some design ideas later. They agree to reconvene in a few weeks to review progress on schematic design plans that Aaric will provide along with floor plans and renders for consideration by Ms Smith.*

Notes:

-Aaric Celeste and Ms. Smith discuss a potential project to build a new home on a new plot
-The address of the plot is 222 Briarwood Court, Albany, New York, 12203.
-The plot has paved street access, but it is uncertain whether utilities are available.
-The desired house is a four-bedroom, three-bathroom, approximately 3000 sqft home.
-Specific features requested include a connected two-car garage, a pool with a shed, and space for a large book collection and wine.
-Ms. Smith is open to design suggestions and does not have a specific style or budget in mind.
-Aaric and his team will provide design ideas, floor plans, and renders for the house.
-Aaric assures that the design will consider site requirements and coding/zoning regulations.
-A follow-up meeting is scheduled in a few weeks to review the progress of the design.
-Aaric will ensure the design remains within a reasonable price range
-The conversation ends with both parties thanking each other and saying goodbye.

Chapter Outline:

1. Introduction and Project Overview (01:01- 02:11)
- Introducing the participants (Aaric Celeste and Ms. Smith)
- Confirmation of recording and readiness for discussion
- Ms. Smith's intention to build a new home on a plot of land in Albany, New York
- Aaric's assurance of assistance and request for project details

2. Project Location and Land Details (02:11 - 03:19)
- Ms. Smith provides the address (222 Briarwood Court, Albany, New York, 12203)
- Description of the vacant 1.2-acre land with 60% tree coverage

- Mention of the land being part of a development with other houses nearby

3. House Specifications and Size (03:19 - 04:01)

- Discussion on the desired house size: four bedrooms, three bathrooms

- Agreement on an approximate area of 3000 sqft

- Flexibility for adjustments in the future

4. Desired Features and Spaces (04:01 - 05:04)

- Ms. Smith's requirements for a connected two-car garage, pool with a shed, and ample space for books and wine

- Aaric's suggestions of a wine cellar, library, or a combination of both

- Emphasis on a large kitchen and living room

5. Budget and Style (05:04 - 06:09)

- Confirmation that the budget is not yet determined

- Aaric's commitment to designing a reasonably priced house

- Discussion on the architectural style, with Ms. Smith's openness to suggestions

6. Next Steps and Timeline (06:09 - 07:03)

- Aaric's plan to start the schematic design process

- Agreement to reconvene in a few weeks to review progress

- Aaric's assurance of providing design ideas, floor plans, and renders

- Mention of adherence to coding, zoning requirements, and site compatibility

7. Conclusion and Farewell (07:03 - 07:11)

- Expression of gratitude and appreciation

- Confirmation of future communication

- Wishes for a pleasant day and goodbye

Action items:

1. *Aaric will start working on the schematic design for the house.*

2. *Aaric will come up with design ideas and goals for the house and share them with Ms. Smith.*

3. *Aaric will provide floor plans and renders of the house design to Ms. Smith.*

4. *Aaric will ensure that the house design complies with coding and zoning requirements.*

5. *Aaric will consider incorporating a wine cellar, library, and a large kitchen in the living room, as requested by Ms. Smith.*

6. *Aaric will make sure that the house design takes into account the site's characteristics, such as the existing trees and the paved street access.*

7. *Aaric will strive to design the house within a reasonable budget, keeping it comparable to other houses in the area.*

8. *Aaric and Ms. Smith will schedule a follow-up meeting in a few weeks to discuss the progress of the design.*

9. *Ms. Smith will review the design ideas, floor plans, and renders provided by Aaric and provide feedback.*

APPENDIX B - Chat GPT[A] Architectural Program

Architectural Program Document: Residential House at 222 Briarwood Court, Albany, NY 12203

Client Requirements:

Location: 222 Briarwood Court, Albany, NY 12203.
Type: Residential house.
Size: Approximately 3,000 square feet.
Bedrooms: 4 bedrooms.
Bathrooms: 3 bathrooms.
Stories: Ideally 2 stories.
Garage: Connected 2-car garage.
Outdoor Amenities:

- *A pool in the backyard.*
- *A shed for storage purposes.*

Interior Spaces:

- *Spacious living room and kitchen.*
- *Dedicated room/library for books and wine collection.*

Aesthetic and Atmosphere:

- *Create a beautiful, welcoming home ambiance.*
- *Ensure the design emphasizes comfort and warmth.*

Specific Requirements:

Exterior:

- *Size and Structure:*
- *A two-story house with an approximate area of 3,000 square feet.*
- *Connected 2-car garage integrated into the house design.*
- *Aesthetic appeal: Incorporate architectural elements that offer a welcoming facade.*
- *Outdoor Features:*
- *Design and integrate a pool in the backyard.*
- *Allocate space for a shed to accommodate storage needs.*

Interior:

- *Bedrooms and Bathrooms:*
- *Design 4 bedrooms and 3 bathrooms according to modern standards.*

- *Ensure comfortable sizes and adequate privacy for each bedroom.*
- *Living Spaces:*
- *Create a spacious living room that fosters a cozy and inviting atmosphere.*
- *Kitchen should be well-equipped, spacious, and functional for family use.*
- *Special Room:*
- *Design a dedicated room/library for the client's books and wine collection.*
- *Ensure this space allows for proper storage and display.*

Design Considerations:

- *Aesthetics and Ambiance:*
- *Focus on aesthetics that promote a welcoming and comfortable environment.*
- *Use warm colors, natural lighting, and comfortable furnishings.*
- *Functional Design:*
- *Ensure the layout promotes easy navigation and functionality.*
- *Emphasize energy efficiency and sustainable design practices where possible.*

Budget and Cost Constraints:

- *Cost Expectations: The client is seeking a reasonable price for the area without compromising quality or functionality.*
- *Efficiency: Optimize design choices to balance cost-effectiveness with desired features.*

Timeline:

- *Deadline: The project is expected to be completed within a reasonable timeframe, accounting for design, approval, and construction phases.*

Conclusion:

The architectural design should focus on creating a spacious, functional, and aesthetically pleasing residence that meets the client's desire for a welcoming home. The design should incorporate all specified features while being mindful of cost considerations.

APPENDIX C - Chat GPT[B] Design Goals

Conceptual Idea: "Harmonious Retreat"

Form and Function:

The L-shaped design maximizes both indoor and outdoor space, embracing the natural surroundings while providing privacy. The house is divided into public and private zones, with the public spaces oriented toward the pool area, creating a seamless indoor-outdoor connection.

Level One:

- *Entryway (150 sf): A welcoming foyer acts as the transition point from the exterior to the interior.*
- *Living Areas (900 sf): Open-plan living, dining, and kitchen spaces connect to the pool terrace through expansive sliding glass doors, fostering an indoor-outdoor lifestyle.*
- *Library (150 sf): Adjacent to the living area, a cozy library offers a retreat for reading and relaxation, featuring ample bookshelves and a fireplace.*
- *Wine Cellar (80 sf): Nestled discreetly near the dining area, a climate-controlled wine cellar showcases a collection and offers a space for wine tasting and enjoyment.*
- *Garage (400 sf): Positioned to the side for easy access, the garage accommodates multiple vehicles and includes storage space.*

Level Two:

- *Master Suite (600 sf): Encompassing a bedroom, luxurious bathroom, and a private balcony overlooking the pool area, the master suite offers a serene escape.*
- *Secondary Bedrooms (300 sf ea): Additional bedrooms, each with en-suite bathrooms, provide comfort and privacy for family or guests.*
- *Additional Lounge/Entertainment Space (200 sf): There can be a secondary lounge or entertainment area on the second floor, offering a more private retreat for family members or guests. This space could double as a media room or a relaxation area with comfortable seating.*

Outdoor Amenities:

- *Pool Area (500 sf): A spacious pool deck with lounging areas, outdoor dining, and a covered pergola offers a perfect setting for relaxation and entertainment.*

- *Shed (100 sf): Tucked away in the corner of the property, a well-designed shed provides storage for outdoor equipment and pool maintenance tools.*

Architectural Features:

- *Modern Aesthetics: Clean lines, large windows, and a mix of materials like wood, stone, and glass complement the tree's aesthetic, enhancing the connection between built and natural environments.*
- *Integration with Nature: The design focuses on seamlessly integrating the house with the forest landscape. Large windows and sliding glass doors throughout the house offer panoramic views of the lush greenery.*
- *Backyard Oasis: The backyard features a pool strategically placed to blend with the natural environment, perhaps using natural stone or wood decking. It's surrounded by native plants, creating a serene and private oasis.*

This parti focuses on creating a harmonious retreat that balances luxurious living spaces, functionality, and a seamless integration with the natural landscape of Albany, NY.

APPENDIX D - Architect Survey Results

Generative AI Use in Schematic Design

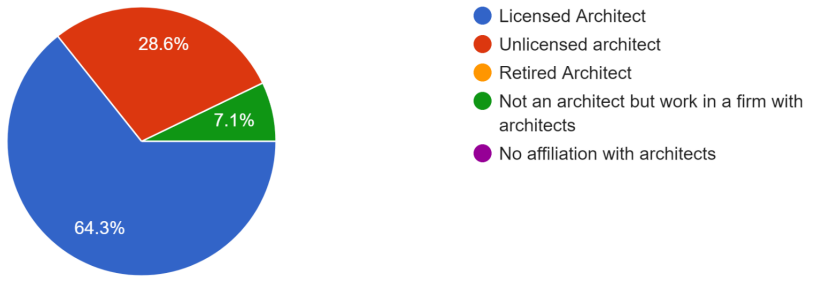
Thank you for agreeing to complete this survey, this will provide necessary and extremely interesting information for my thesis.

Please answer the questions below to the best of your ability. Feel free to leave any question blank if unsure.

Sign in to Google to save your progress. Learn more

What is your current position as an architect?

14 responses



Traditional Schematic Design

I am using a case study project to utilize and test various AI programs within schematic design. I used this case study (see below) as a standard for all of the AI programs I tested and now need a traditional schematic design control to compare.

Case Study Scope

A client has a vacant lot located at 222 Briarwood Court Albany, NY 12203. They want a 4-bed 3-bath house, ideally 2 stories and around 3,000 sf. They want a connected 2-car garage, a pool and a shed in the backyard, a spacious living room and kitchen, and a dedicated room for their books and wine collection. They want the house to be beautiful and feel like a welcoming home. They are not set on cost, although are looking for a reasonable price for the area.

If you were to complete a **schematic design only** for this case study scope, how many hours would you spend on the following tasks using traditional design practices?

Please write a number only, to the nearest 0.5 hours if possible. Leave blank if unsure.

													Average:
Program Analysis (Understanding scope of services and client expectations)	1	1.5	5	1	16	2	8	20	3	6	4	6	6.13

													Average:
Context Analysis (Studying site conditions, demographic information, local precedents, code requirements, etc.)	10	3	5	4	10	8	8	20	8	13	8	20	9.75

													Average:
Establish Design Goals/Parti (Integrate previously learned analysis to create a project parti and design goals, including a dedicated program, parti diagramming, and preliminary spatial organization)	3	1.5	8	5	16	3	8	20	7	10	8	6	7.96

													Average:
Initial Design Creation (Sketch or draft preliminary design ideas based on written program, design goals, and parti. Multiple iterations of physical geometry, location on site, layout of spaces inside the house, and articulations of the design inside and outside of the house should be generated for the clients consideration)	18	17	8	10	24	8	20	40	20	24	16	25	19.17

													Average:
Functional Refinement (Revisit the initial designs and refine to ensure code compliance, structural/mechanical considerations, and site conditions optimization)	8	11	8	10	16	2	10	40	10	16	6	10	12.25

													Average:
Aesthetic Refinement (Revisit the inital designs and refine to better articulate clients scope and the project's design goals. This is where the client can view design options and discuss with architect their expectations moving forward)	3	8	8	5	24	3	10	20	10	15	8	10	10.33

													Average:
Schematic Design 2D Documents (This is not the creation of a full construction document set. This task includes the creation of preliminary floor plans, site plans and elevations to better discuss with the client)	7	5	11	10	16	48	20	100	18	35	24	30	27.00

													Average:
Schematic Design 3D Documents (The renderings should be representative of the house's design and can include sketches, digital renderings, or precedent image collages)	9		5	10	40	48	20	100	16	25	16	25	28.55

													Average:
Schematic Design Outline Specifications	2	8	5	4	32	8	6		12	8	12		9.70

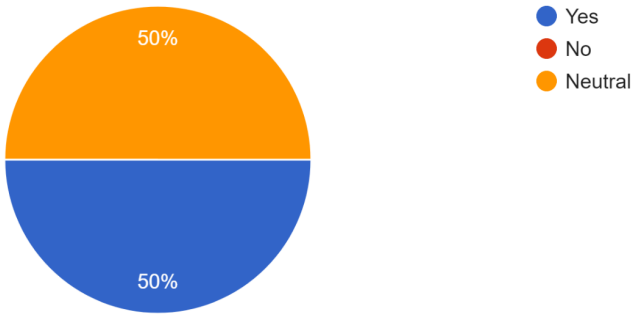
													Average:
Recording/Distributing Meeting Minutes	1	1.5	2	2	16	2	4	10	3	4	4	6	4.63

Merit of AI Use

This section will study the merit of using AI in the firm in lieu of traditional architecture practices. Please answer each question below to the best of your ability.

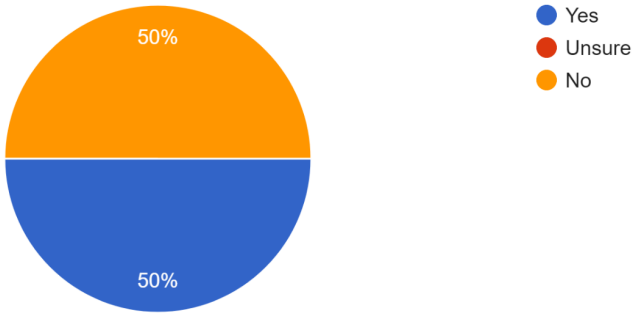
Do you have a positive opinion about Artificial Intellegence (AI)?

14 responses



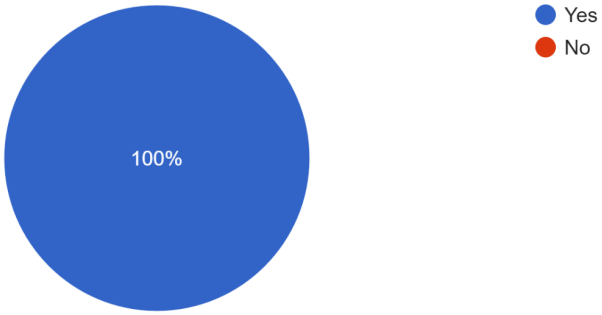
Have you seen any use of AI within your firm/practice?

14 responses



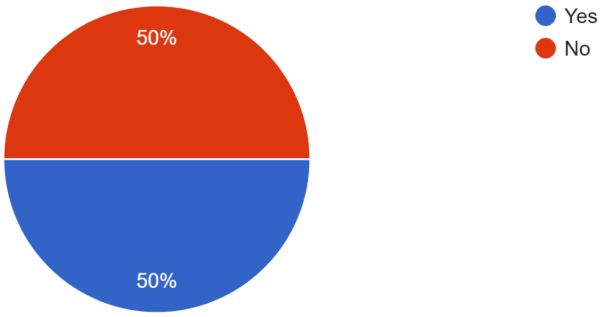
Do you believe we will see AI integration within the architecture practice in the next 5 years?

14 responses



Do you believe AI will have a bigger impact on the architecture practice than BIM (3D modeling in lieu of hand drawing)?

14 responses



Optionally, please discuss why you chose the answer(s) above.

4 responses

AI will only reference designs that are already out there. Given this scenario, new designs might never come to light. Architects are always innovating which is needed for AI to continue to progress as well.

I think we will see increased integration of AI in some aspects of architecture practice. However, I think many of the facets of our practice are too nuanced or challenging to be handled by AI (i.e. project management as team leads over other disciplines, the mentor/apprentice nature of our profession, the rapid pace of some construction/projects).

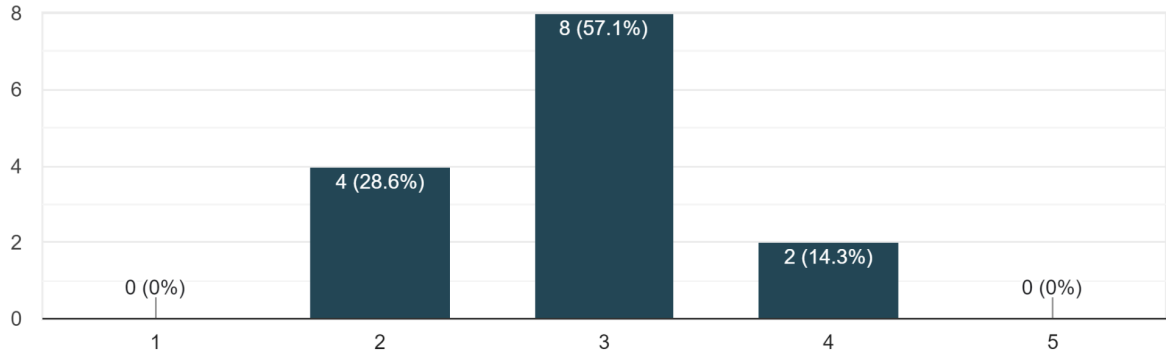
AI is a tool like any other. It does what we tell it to do. It can already do some very helpful tasks. There are not quite AI software such as Rhino Grasshopper with solvers that can be robust, Cliffton Harness Test Fit with similar yet more technical application, and rendering and post production software that are powerful. However, design goes deeper than an algorityhm and at least for the foreseeable future requires humans to make the final decision. In a way, AI is an assistant.

It will certainly have an impact and will no doubt increase some efficiencies but ultimately I think our core professional value is not in the production of drawings.

How would you rate the following categories related to the potential of using AI for design and/or office work?

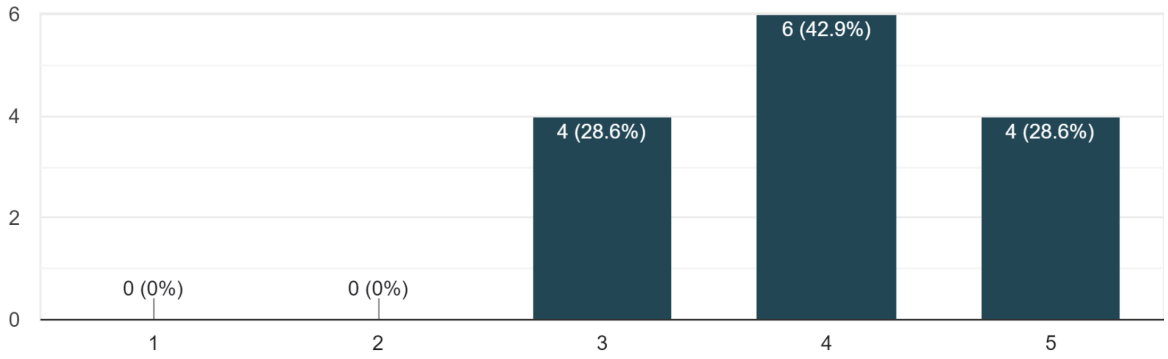
Trust in using any of these AI Tools.

14 responses



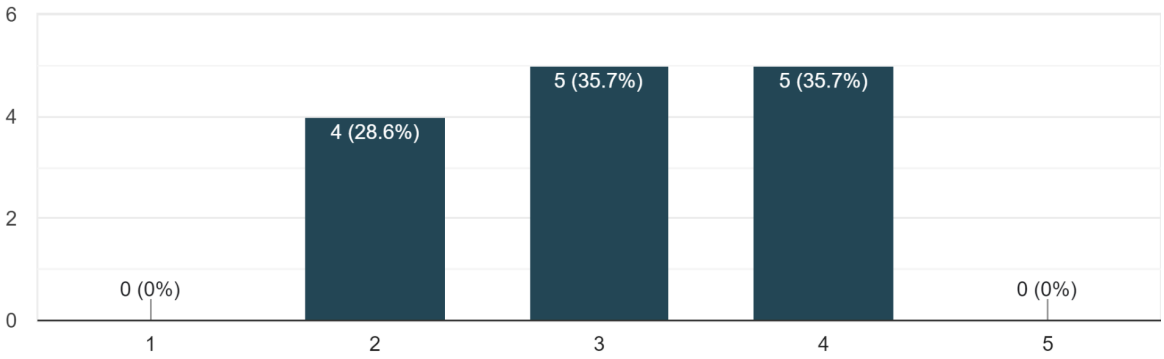
Confidence in your ability to learn and eventually use AI Tools daily.

14 responses



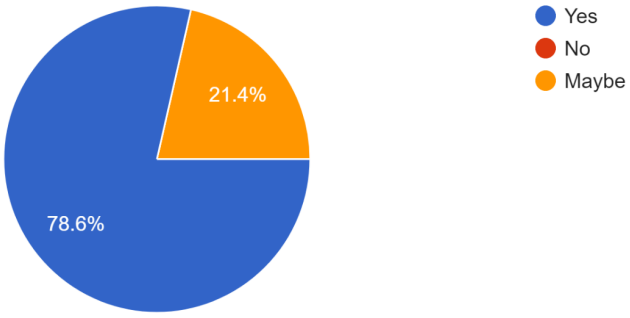
Willingness to offload current work to AI assistance.

14 responses

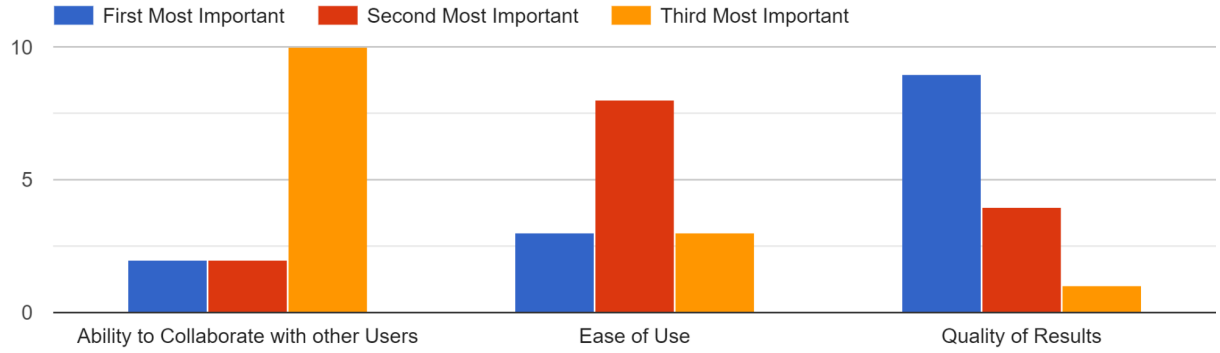


Would you be honest with the client about utilizing AI programs for their project?

14 responses

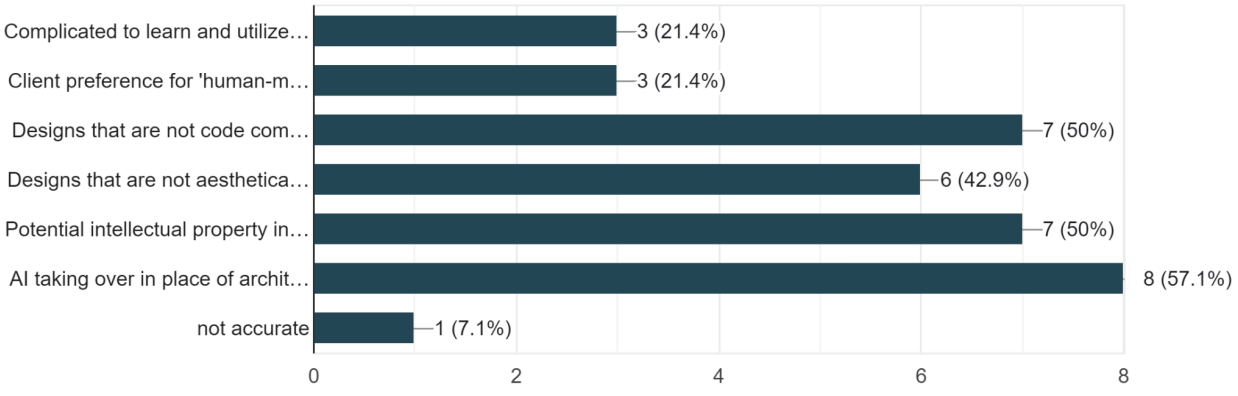


If you were to evaluate an AI program, how would you rank the following qualities?



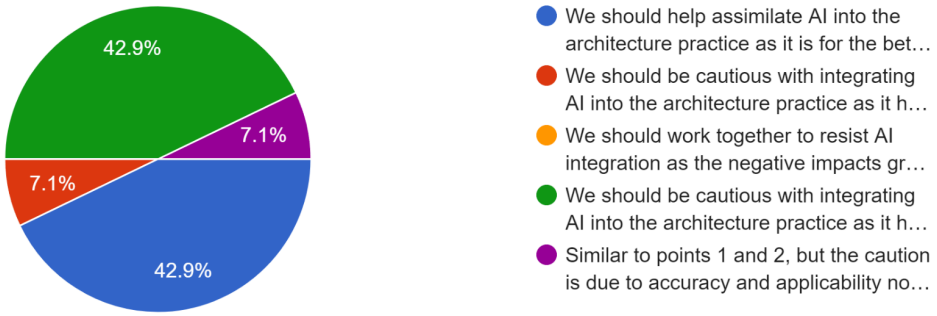
Please identify any hesitations you have with introducing AI into your daily work

14 responses



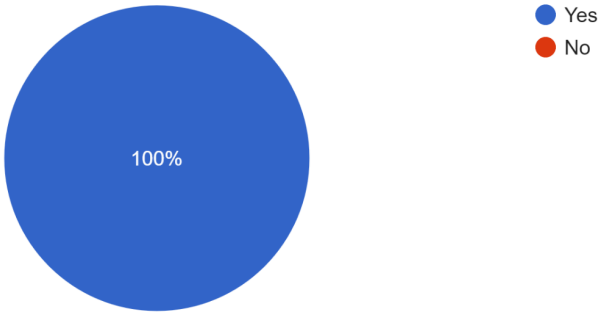
Which choice do you believe to be most true?

14 responses



Would you be willing to work alongside an AI assistant to complete basic office and design tasks with your supervision?

14 responses



Feel free to discuss anything more about AI use within an architecture firm.

0 responses

No responses yet for this question.