Marketplace for the 3D Printable Construction Industry

Final Research Report

Denning Technology & Management Program

Caterpillar Capstone

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Executive Summary

The 3D printing construction industry is projected to experience unprecedented growth. Numerous companies are forming unique solutions for the "Housing Crisis" and attempting to meet the demand for the construction of new homes through additive construction. However, this is an uphill struggle due to the novel nature of the technology, the relative inexperience of the current players in the market, and the lack of adoption from traditional construction companies. Caterpillar strives to enter the blossoming industry of 3D printing construction with to the hope that the innovative technology will raise productivity levels, increase sustainability, and decrease costs in a way that the traditional construction industry has never seen before.

Caterpillar's solution is a 3D printing marketplace – which Caterpillar currently holds patents on – connecting all relevant stakeholders (architects, developers, customers, 3D printing companies, 3D printing mix companies, and contractors). Through Caterpillar's patents, all parties would be incentivized to conduct business and create value using this platform.

The Denning Technology & Management Program capstone team, sponsored by Caterpillar, investigated the viability of a marketplace where users can buy and sell designs for 3D printed structures. Through the marketplace, architects could upload their designs and earn royalties based on the sales volume of their designs. People in the market for a home or other structure could browse through an extensive library of designs, customize existing designs as desired, and download the necessary files to print. Contractors who have the technology to build structures that incorporate 3D/additive methods could offer their services through the platform for a more seamless experience.

The value this platform would provide to Caterpillar can be quantified in three revenue streams. First, Caterpillar will receive a percentage of every transaction made between parties on the platform. For example, Caterpillar will gain a percentage of every home plan bundle sold by architects and home developers. Caterpillar will also gain a percentage of contracted work that is found via the platform. Second, the platform will provide lead generation in favor of the Cat Dealer network, which will encourage and incentivize users to turn to the Cat Dealer network for equipment to perform work such as land excavation and site preparation. Third, Caterpillar will earn revenue through selling "add-on" products such as doors and windows. The marketplace allows Caterpillar to further penetrate and support a rapidly growing industry that is more resource, energy, and time efficient.

The capstone team performed online research combined with market research through interviews with various stakeholders to collect data about user preferences, desired features and functionality, and financial variables. The capstone team analyzed the research and data to iteratively design a prototype of the marketplace using a user interface and user experience (UI/UX) design tool called Figma. The capstone team also performed a financial analysis to

show the platform's viability and profit potential. Over the past six months, the capstone team conducted over 20 interviews with subject matter experts, including architects, potential homebuyers, contractors, emerging technology experts, and other stakeholders. In most interviews, the capstone team performed a demonstration of the current marketplace prototype and collected feedback that was used in aggregate to create the next iteration of the prototype. The capstone team used financial information from the interviews and online research to build an income statement model and an Operating Profit After Capital Charges (OPACC) model, which is an internal method for evaluating possible projects at Caterpillar. Each model included a low-, medium-, and high-usage scenario for 2023 and 2028. The capstone team also relied on interviews and online research to create the breakdown of future estimated costs of a customer ordering a building a home through the platform.

Based on research and analysis, the capstone team recommends that Caterpillar move forward with investing and building the platform to an operational status where a beta version can be launched. The capstone team performed research on strategies to help Caterpillar succeed when launching the platform. First, the platform that the team created integrates numerous different stakeholders into a single interactive and virtual ecosystem. Consequently, the team recommends that Caterpillar first focus on the core value proposition of the platform by acquiring an extensive library of home plan designs by various architects to provide supply for any initial demand by consumers and home developers. While the marketplace connects many other parties, the main value proposition is the connection between the architect's home plan designs and the right consumers or home developers who want to purchase the said designs. Furthermore, the team recommends that Caterpillar will also host a symposium for integral industry players in the 3D printing construction industry as well as the home development industry. Through the symposium, Caterpillar could network with relevant stakeholders and pursue further partnerships. Finally, with newly formed strategic partnerships with 3D printing companies and home developers, Caterpillar will launch a beta version of the platform limited to the Southern region of the United States. According to Zillow's Consumer Housing Trends Report for 2023, new construction home purchases are concentrated in the Southern region of the United States. Launching the beta version of the platform in the South allows Caterpillar to eliminate the challenges of local coding and permit approval processes, adverse weather that affects print schedules, and the complexities of other factors.

Based on the financial analysis, with Caterpillar's initial investment of $1.4 million required to create the platform and launch operations, the capstone team expects Caterpillar to realize $728,000 in profit in the platform's fifth year of operation and to be OPACC positive in the same year. However, depending on Caterpillar's ability to capture a larger market share, the platform could generate over $12 million in profit in its fifth operational year. Caterpillar has an opportunity to leverage its intellectual property within the 3D printable construction industry and could create significant value through investment in developing this platform. Moreover, the

platform will benefit existing Caterpillar operations through the functional ability to generate leads for Cat dealers to lease or sell machinery to assist in the construction process. The platform engages several areas of Caterpillar's existing value chain and provides additional revenue through an industry that is expected to experience a compound annual growth rate of 101.9% until 2030.

Capstone Deliverables

The team was asked to complete the following deliverables as a requirement for the 2023 Caterpillar Capstone Project.

Physical Deliverables:

1. A prototype of the marketplace, functional with features per the patents and interview insights.
2. A sample library of files to be transacted via marketplace to provide a baseline for what would be transacted in a fully functional platform.

Financial Deliverables:

1. Future estimated costs of a customer ordering and building a home and segmentation of such costs.
2. Financial projections based on low, medium, and high usage scenarios.
3. Primer on OPACC (Operating Profit After Capital Charge) and a projection of financial impact for varying levels of platform usage.

In addition to these deliverables, the team chose to conduct extensive market research and analysis on the 3D printing construction industry, craft a market entry strategy, and recommend immediate next steps for the success of the platform.

Background on the 3D Printing Construction Market

In 2022, the size of the 3D printing construction industry was $1.8 million in the United States and $18.2 million globally. The industry is also rapidly growing, with a compound annual growth rate of 100.1% domestically and 101.9% globally. In 2028, the projected size of the industry is roughly $1.2 billion domestically [Grand View Research].

The team chose to perform a SWOT analysis to highlight the strengths and drivers of the market, as well as potential roadblocks to the growth of the industry.

There are many strengths unique to 3D printing that make it an optimal choice compared to traditional construction. First, 3D printing has proven to be a more efficient form of construction

by reducing time, required labor and associated costs, and risk of accident or injury. These benefits are accredited to the increased automation of the construction process. Second, 3D printing construction also has the benefit of building more durable structures due to the concrete mix, which is more durable than the wood used in traditional construction when facing fires, floods, hurricanes, high-speed winds, earthquakes, pests, and other natural disasters. Finally, 3D printing offers a layered exterior aesthetic due to the gantry-style printer.

One weakness is that printing machines and materials are expensive and require a high capital investment from anyone interested in buying or leasing. However, this is indeed an investment, given how time and labor efficient a 3D printing machine is in comparison to traditional construction. Another downside of 3D printing is how reliant the process is on ideal weather conditions to operate. Finally, because 3D printing is such a novel form of construction, there are several permitting and zoning restrictions in place.

There are several opportunities that will drive market growth. First, as the climate continues to worsen, green projects and ESG (environmental, social, and governance) efforts are on the rise, and governments, organizations, and individuals are finding more sustainable ways to grow. 3D printers are resource efficient, and most, if not all, material input goes directly into the structure itself because of the specificity of the G-code (code the printer reads to print structure). Regarding emission reduction, shorter project timelines, lighter transportation loads, and the flexibility to print buildings onsite greatly reduce pollution and related fees. Furthermore, many mixes are created from recycled and more sustainable materials. Second, as the population continues to rise, there is a growing need for affordable housing. Due to the automation and speed of the 3D printer, it is cost and time efficient to build many houses with the modular method, enabling developers to sell houses for a lower price. Other opportunities include a growing construction sector (as well as rapid urbanization) in developing countries, the potential for mass customization, and enhanced architectural flexibility by making changes to the G-code, the code that the printer follows to build the house.

Finally, there are several threats that could inhibit the growth of the 3D printing construction industry. First, because the technology is relatively new, there is a lack of employees and contractors who are educated and able to operate a 3D printer. Second, as mentioned before, there are limitations to the machinery itself, and traditional construction must still be relied on to complete the building. Third, because the process is so automated, there is a risk that fewer human employees working and watching the machine could result in higher safety risks.

CAT 3D Printing Market Place Overview and Business Model

Intellectual Property

Caterpillar has already made many investments in the 3D printing construction industry by acquiring various pieces of intellectual property that take the form of patents. Caterpillar currently possesses patents such as US 9,777,491 B2 (Structural 3D Printing Machine), which is Caterpillar's proprietary 3D printing machine, as well as US 20,160,107,332 A1 (3D Printing System), and other related patents. Most importantly, the team leveraged two patents: US9,959,370 B2 (Network Portal for 3D Printable Structures) granted in May 2018 and US 10,672,045 B2 (Systems and Methods for Processing Orders for Structural Designs) granted in June 2020.

First, patent US 9,959,370 B2 (Network Portal for 3D Printable Structures) is the cornerstone of the entirety of the project that the team was tasked with. The patent references the emergence of additive construction that uses three-dimensional (3D) printing machines. These 3D printing machines work in a way that extrudes building material layer-by-layer to create structures. Currently, architects and designers of 3D printing structures may have difficulty attempting to expose their designs to broad audiences for design review or for possible purchase. The patent also references a separate patent (US 8,161,411) for improved graphical user interfaces (GUIs) for reviewing, browsing, previewing, and purchasing media items. The patent for GUIs is different because it does not allow for the integration and viewing of information for 3D printable structures. The network portal uses the base idea of the patent for GUIs, but it applies the concept to 3D printing more specifically [Figures 1 & 2]. Furthermore, designs can be altered and viewed in a virtual environment that allows 3D virtual tours in addition to traditional static pictures. Another unique feature is the ability for users to make additional subsequent purchases. When a 3D printing machine extrudes materials to construct a building, it only builds the walls. Consequently, there is a need for additional purchases for the doors, lentils, windows, roof, and more to complete the home. There will also need to be additional services to complete the plumbing, electrical wiring, and more. The network portal not only allows for the display of 3D structural designs, but also for the ability for subsequent purchases.

Second, the patent US 10,672,045 B2 (Systems and Methods for Processing Orders for Structural Designs) references the same difficulty for the broad review of 3D structural designs that may be created by architects and structural engineers. This patent furthers the network portal described in the first patent by detailing the systems that a client-server environment will use to process the reviewing, browsing, previewing, editing, and purchasing of 3D structural designs [Figures 3 & 4]. The systems and methods presented in this patent explain how designers will interact with the database of designs. Once a designer uploads a design, it is transformed into the correct format and a value will be assigned to the design that determines the royalty that the designer will receive. If a designer alters an existing design within the database, then a separate royalty, which will be adjusted based on the magnitude of the changes applied to the design, will be calculated.

These royalties will be disbursed whenever payments are processed for ordering these 3D structural designs.

The two above patents represent Caterpillar's initial investment into the rapidly growing 3D printing construction industry. The patents for the network portal and the systems behind it will foster transactions for structures in the residential, commercial, and infrastructure spaces. Caterpillar has not attempted to generate revenue from these pieces of IP, but there is currently a promising entrance available into an industry that is growing at a compound annual growth rate of 101.9% globally.

The patents above described the network portal, which will be referred to as the "marketplace" throughout the rest of this report. Its primary goal is to connect architects selling 3D structural designs and parties interested in purchasing these designs.

Platform Stakeholders

Because the main purpose of the platform is to provide a platform for buying and selling 3D structural designs, the architects and developers are the primary sources of supply and demand. Thus, they are the primary stakeholders. The secondary stakeholders are all the parties that assist in the construction of the building from beginning to end. This group includes 3D printing machine companies, 3D printing construction companies, and 3D printing mix companies, as well as contractors and subcontractors. All these stakeholders will have a presence within the marketplace, and they will interact within the environment with the end goal of providing a 3D printed structure to the end user.

The architects or designers would provide supply by uploading their 3D structural designs to the platform. The architects are incentivized with the expectation of a royalty that will be received for each design sold. The primary motive is to have as many of their designs sold as possible, so they can maximize the revenue made by royalty payments for each design. Additionally, the platform will be an ideal environment for amateur architects to build out their portfolios and gain the attention of larger architectural firms. The architects are integral to the platform because they provide the supply for any transactions to take place on the marketplace.

Home developers, as well as individual consumers looking to 3D print, would provide the demand for the marketplace by buying the designs discussed above. Their main incentive to use the platform is to acquire home 3D build plans in a convenient and affordable manner. An additional incentive would be the opportunity to customize and compare plans from different sellers. After choosing a 3D build plan, consumers can buy add-ons and make subsequent purchases to hire contractors to complete their project beyond the capabilities of the 3D printer. Having all these features in one product will contribute to the convenience and ease of using the

platform. All the steps involved in construction would be included, making it essentially close to a one-stop shop for connecting the consumer with the required parties to construct a house (not including permitting and inspection).

3D printing machine companies create the technology that enables the possibility for the existence of the marketplace. The primary motive of the 3D printing machine companies to participate in the platform is to sell and lease as many of their machines as possible to contractors such as the 3D printing construction companies. In turn, the 3D printing construction companies will then use the 3D printing machine to extrude the walls for the home or structure. Caterpillar's patented marketplace provides a new avenue for printing companies to connect with contractors and increase their number of sales. Key players in the 3D printing construction industry who have already expressed interest in participating in the platform if launched include Apis Cor and Black Buffalo.

3D printing mix companies will use the platform to sell proprietary mixes. Many of the 3D printing machines use proprietary mixes that are typically created by the 3D printing machine companies that manufacture the printer. However, there are companies that work through partnerships with 3D printing machine companies to provide a proprietary mix. For example, Black Buffalo (3D printing machine company) has a partnership with Mapei (a chemical product company for the construction industry). Mapei creates the mix that the Black Buffalo 3D printing machine uses. Consequently, the marketplace will support the inclusion of the 3D printing mix companies that can sell the proprietary mixes to contractors, such as the 3D printing construction companies, who are purchasing or leasing a 3D printer. Like the 3D printing machine companies, their primary incentive in participating is to find a new avenue for making sales.

Contractors and subcontractors will use the platform to offer secondary services to complete the construction of the home or structure. These secondary services will complete the construction and they include the electrical wiring, plumbing, HVAC installation, roofing, landscaping, and many more. This stakeholder group includes the 3D printing construction company, who will use the 3D printing machine company's 3D printer to extrude the mix to construct walls. The main incentive in using the platform for these partners is to find more contractual work opportunities. By offering their services on Caterpillar's platform, they open themselves to additional revenue streams as well as aligning themselves with a more sustainable construction practice.

Finally, the CAT dealers will be stakeholders with the marketplace in a variety of ways. First, the CAT dealers may purchase the 3D printing machines and have them available for 3D printing construction companies to use to print. Second, the CAT dealers may also carry the proprietary mixes from either the 3D printing machine companies or the 3D printing mix companies. Carrying the 3D printers and mixes at dealerships would allow for an additional revenue stream that could also benefit from the maintenance and repair of the machines. Third, when an order is

placed through the marketplace, a lead generation will be sent to the local CAT dealer for the rental of excavators and other similar machines. When an order is placed for a 3D printed structure, the ground will have to be cleared and a foundation will have to be laid before anything can be printed. As a result, the marketplace can leverage and benefit an existing CAT dealer practice as well as add an additional revenue stream.

Multisided Platform

Caterpillar's patented marketplace is a multisided platform, which is a product that creates value by enabling interaction between two or more groups. This type of platform has unique benefits and conventional growth strategies. Examples of popular multisided platforms currently on the market include Airbnb, Uber, and PayPal. One benefit of a multi-sided platform is that it is relatively easy to scale. As the platform grows, Caterpillar does not have to invest resources in creating more inventory or products to supply demand because the sellers (architects and home developers), will be responsible for uploading more designs to meet demand. Additionally, because there is no ceiling on the number of plans that can be bought (the same plan could theoretically be bought by an infinite number of consumers), it is highly unlikely that there will not be enough supply to meet demand. Finally, another key benefit of a multi-sided platform is that it is beneficial for competing sellers to co-locate and sell designs on the same platform because increased quantity and variety in plans will likely increase demand.

One challenge unique to multi-sided platforms, commonly known as the "chicken-egg problem", is the difficulty to grow a base group of sellers with no initial demand, or to grow demand with no initial supply. When starting a platform, supply and demand are both typically low. Strategies for facing this challenge are listed later in the Market Entry Strategy section of the report.

Role and Revenue Streams for Caterpillar

Caterpillar's primary role is to build and maintain a central hub for all stakeholders in the 3D printing construction industry to interact and conduct business. Potential additional roles will be discussed in the Market Entry Strategy section of the report, but Caterpillar can take on additional roles to improve the chance that the platform will be successful, such as providing expert assistance and customer support regarding zoning laws and general business inquiries.

Revenue streams would occur by taking a percentage of all transactions occurring on the platform as well as selling add-ons such as windows, lintels, sills, and doors. Other transactions that would occur on the marketplace include selling and leasing printers, buying and selling home plans, and hiring contractors or subcontractors to finish the building. The platform will also provide lead generation in favor of the Cat Dealer network. This would encourage and incentivize users to turn to the Cat Dealer network for jobs such as land excavation and site preparation.

Methods

The team was initially given a report by the 2021-2022 Caterpillar Capstone Team that served as an investigation of the 3D Printable Structures Industry. The report from the previous team served as a starting block for the current team to comprehend the climate of the current industry and perform preliminary market research on 16 companies that were identified by Caterpillar as stakeholders in the 3D Printable Structures Industry. Furthermore, the team was given two patents granted to Caterpillar for the conception of a novel network portal for 3D printable structures as well as the systems and methods for processing orders for structural designs (US 9,959,370 B2 and US 10,672,045 B2). The team leveraged the previous deliverables of the prior team and Caterpillar's established intellectual property to begin the process of creating a minimum demonstrable concept (MDC) for the network portal for 3D printable structures.

Next, the team used contacts from Caterpillar as well as the contact list from the previous capstone team to talk to industry experts and players. The team utilized an adaptation of the previous capstone team's interview guide for each interview that was conducted [Figure 5]. The questions were based on the related experience and expertise of the interviewee(s), qualitative questions related to the current phase of the marketplace design, quantitative questions poised towards costs and selling points for the financial analysis, and recommendations for future contacts or research sources. The team repeated this process during the discovery interview process.

Caterpillar possessed a primitive concept design for the marketplaces that the team was tasked with creating. Consequently, the team continually updated and added additional features throughout the different generations of the design. The process was intensively iterative and relied heavily on feedback from Caterpillar and industry experts. Congruently, the team constructed a financial analysis that factored in the start-up costs for Caterpillar and estimated the potential return in three scenarios (low, medium, and high platform adoption) in the years 2023 and five years later in 2028.

Finally, the team conducted experiential research through three project-related trips. The first trip to Branch Technology in Chattanooga, TN allowed the team to dive into the potential of additive manufacturing as a whole. The next trip the team attended to Melbourne, FL included a discussion with the CEO of Apis-Cor, an identified stakeholder by Caterpillar and a company awarded the Guinness World Record for the largest 3D printed structure in the world. Lastly, the team took a trip to Caterpillar's Factory in Griffin, GA to ensure alignment with the Caterpillar brand and to encounter Caterpillar's value chain.

Key Interviews & Feedback

Throughout the course of the capstone project, the team had many opportunities to interview a variety of industry experts on topics relating to different components of the project. There was a total of 20 interviews conducted with people from many of the stakeholder groups that are discussed earlier in the report. The team interviewed 3D printing machine companies, architects, home developers, potential users, and many other experts. A few of the most impactful interviews are described below.

Early into the course of the project, the team had the opportunity to travel to Chattanooga, Tennessee and interview David Goodloe, the Program Development Manager at Branch Technologies. Branch Technologies combines additive manufacturing, prefabrication, and digital technology to primarily construct building facades and sculptures. Branch Technology relies on a patented 3D printing fabrication technology that mimics the structure of cells in nature. As a result, Branch is focused on cellular fabrication to solve the increasing labor shortage and offset the rising labor costs. Currently, Branch is focused solely on commercial applications using pre-fabrication methodologies. On the other hand, Caterpillar's marketplace will initially focus on residential applications and on-site fabrication. Because of this, Branch Technologies is not a potential partner within the current scope of the marketplace's function. Nevertheless, Branch Technologies was able to provide valuable insight into code-compliance, the construction process between architects and contractors, and additive manufacturing as a whole.

Furthermore, the team took a trip to Melbourne, Florida to interview Anna Cheniuntai, the co-founder and CEO of Apis Cor. Apis Cor is a 3D printing machine company that manufactures the necessary machines to perform construction with the robotic precision of 3D printing. Apis Cor manufactures the 3D printing machines and then leases or sells these machines for construction companies to independently operate them. Anna provided a current buyer handbook for potential customers. Anna and Apis Cor shared the innerworkings of the industry and all of the red tape that is required to get to a finished home that an individual can live in. 3D printing technology must adhere to the current permitting process in order for buildings to get approved. Furthermore, Anna shared many risks that are associated with launching the marketplace. These risks will be addressed in the Risks section of the report later on. Nevertheless, Apis Cor was able to build a 400 square foot house in Russia in under 24 hours for just over $10,000. Apis Cor has also built the largest 3D printed building in the world for the Dubai Municipality. Through the projects that Apis Cor has completed, they are clearly a major player in the industry, and the company has expressed interest in partnering with Caterpillar's marketplace.

The team also took a trip down the road from Georgia Tech in Atlanta, Georgia to interview Joe Greco, the President of Lord Aeck Sargent. Lord Aeck Sargent is a full-service architecture and design firm that has completed 3,000 projects. Many of the projects they complete are focused on sustainability and energy efficiency, as over 75 projects that they completed are LEED

certified. LEED certification is a globally recognized accomplishment for sustainable achievement in that the certified buildings save money, improve efficiency, lower carbon emissions, and create healthy environments. Joe was able to address the needs of architects within the marketplace. As previously mentioned, the marketplace hinges on the inflow of designs from architects because this is the supply that allows the platform to operate. Joe discussed how architects interact with home developers and general contractors when completing any project. Furthermore, Joe discussed compensation and royalty rates used within the industry. The information that Joe and Lord Aeck Sargent was able to provide was pivotal for the development of the financial analysis and the flow of design plans through the marketplace.

Last of all, the team took time to interview Asha Varghese, the President of the Caterpillar Foundation. The Caterpillar Foundation was founded in 1952 to work alongside CAT dealers and customers to build and provide the social infrastructure that is necessary on a global scope. While the current scope of the project focused heavily on residential applications of the marketplace, Asha was able to speak to the potential expansion of the marketplace to cover infrastructure and incorporate stakeholders such as governments and non-governmental organizations (NGOs). Asha mentioned the interest of a town in Peru using 3D printing construction technology to affordably produce housing. Likewise, 3D printing technology have huge potential within the construction of infrastructure such as bridges in a method that is affordable and both energy and resource efficient. The team used the information from Asha and the Caterpillar Foundation to explore the addition of a filter for infrastructure design builds that can also be supported within the marketplace.

All 20 of the formal interviews that the team conducted as well as many informal interviews and meetings along the way provided a huge impact on the team and the course of the project. The interviews with stakeholder groups, subject matter experts, and potential users allowed the team to fine-tune the marketplace prototype through an iterative development process. Furthermore, all the interviews gave the team more clear and impactful insights into the industry that were used when crafting the financial analysis and the final recommendations for the capstone project.

Minimum Demonstrable Concept (MDC)

The minimum demonstrable concept of the marketplace was originally intended to be a Python code that adheres to the patents and presents them visually. However, the Caterpillar Capstone team opted for a more iterative approach. They utilized a collaborative web-based interface design tool called Figma to develop multiple versions of a clickable interface for the Caterpillar 3D Structures Marketplace. The first version was a basic visualization of the patents, which the team then tested with stakeholders during interviews. Based on the feedback received, they incorporated additional features and made refinements to create two more iterations of the interface. Since the platform should be able to accommodate four different types of users

(architects, customers, developers, and partners), the team designed it in a way that each of these groups has a unique and intuitive user journey through it.

Architect Features

The team conducted interviews with architects and discovered that their primary objective was to gain recognition on the platform. Since the marketplace operates on a system where the most popular designs receive the most attention, the team aimed to create features that would enable all architects to showcase themselves effectively. As a result, the team incorporated various tools to allow architects to present themselves in the best possible way.

Profile Creation

Every architect who wants to upload designs onto the platform is required to fill out a profile to build trust with the customers purchasing their files. Of course, the level to which they fill it out is up to them, however, the team laid out all the possible information they would need to present as professional and successful. In the "edit profile" tab, the architect can upload a photo, enter their name, add their location, upload a resume, link a portfolio/contact information, and write an about me paragraph. All of these sections were based on an existing website called Behance. Through it, architects and designers in different fields can upload work and get featured on the browsing page. This is a tool a lot of current architects use to show off their work, and having a familiar layout will help when working on a new platform. The architect's profile is also linked to every design that they upload, so a customer can easily navigate to it to check their credentials before purchasing the files. The profile page will also show information such as the number of project views, number of builds saved, and number of followers in addition to what they choose to fill in manually from the list above.

Uploading Designs

The design upload process has been streamlined to provide as many simple and understandable guidelines, given that this is an unexplored field. Like profile creation, the team referenced Behance for the upload page to design something architects would find familiar. First, several different files need to be dragged into a provided field. That includes the actual CAD model, g-codes created using slicers for specific printers, and renders. As part of the physical deliverables, the Capstone Team developed a library of sample files of these different formats to set a standard the architects can reference. The next step would be to name the design, price it, enter any keywords/tags to help customers discover them, select which category the build falls under (residential or commercial), and check all the printer models that can complete the build. When that information is filled, the file can be sent to Caterpillar for a quick review before getting uploaded onto the main page.

Getting Connected to Customers

After a customer purchases an architect's design, they will automatically be connected in a group messaging feature together with all the Caterpillar trusted partners who are completing the build. Through that, the architect will be able to give guidance, answer any questions, and edit/transfer additional files between the parties.

Customer Features

Through interviews with homebuyers, the team learned that the customers' main goal is to be able to sort easily and effectively through designs, be able to visualize them, and have the option to get connected with a local team of professionals to build the house.

Searching Designs

The residential builds page can be accessed from the home screen as well as from the toolbar on the top. It allows users to browse through designs in a way that suits them best. They can either use keywords and the search menu or manually sort through the page using a different selection of tools the team integrated into the page. A lot of market research has been done on websites such as homeplans.com to ensure a familiar and intuitive interface design. A sorting tool allows the customers to sort the designs based on price, popularity, ratings, and square footage. A quick search tool allows one to narrow down plans based on square footage, number of rooms, and number of floors. The customer can further narrow down by style of home (cottage, modern, etc.). Once they see a plan they like, they can preview it as an overlay on the same page without having to navigate away.

Full Design Page

Once a customer navigates to the full plan page of the design they like, they will face a lot of information to help them decide if this is the plan they want. There is a more detailed description of the plan, interior renders of the home, a 360-degree virtual tour that helps visualize the space, and a review section with text and photographs from previous purchasers of the plan. From there. the customer can conveniently see similar designs on the bottom of the page or navigate back up to select any add-ons such as doors and windows. Once everything is finalized, they can pay and generate the plan and g-code files that will be used in production.

Getting Connected with Partners and Architects

After purchasing the files, the marketplace will offer potential partners whose capabilities match the needs of their plan. Once both sides agree to work together, a group chat space will be generated so the customer is updated on the progress of the build. They will also be able to see a timeline of the process with estimated times of when each step will be completed.

Developer Features

For the developers, the process of selecting and purchasing builds is entirely the same as for regular homebuyers, except they will be looking at the "commercial builds" page to browse the designs.

Searching Designs

The link to the commercial builds page is located on the main page underneath the link to residential builds. On it, different filtering options are provided due to the nature of the designs posted there (office buildings, restaurants, retail, etc.)

Sustainability Impact

Based on the team's interview with Asha Varghese (President of CAT Foundation), the team also added a sustainability impact page that shows the benefits of 3D printing over conventional construction. This will help developers make a choice when it comes to choosing designs from the Caterpillar Marketplace.

Partner Features

Every party involved in the physical construction of a structure falls under partners. That can be companies who prepare the lot, lease 3D printers, use 3D printers, do plumbing and electrical work, design interior finishes, and perform final inspections. For them, Caterpillar will have a special approval process before loading them into the system and opening their services up to the customers.

Explore Partners

An "explore partners" page will be available for the customers to build trust and show the capabilities and past works of all the partners. Once a partner is approved, they will have a separate section with their testimonies and capabilities, which will allow the customer to decide between the different providers.

Getting Connected with Customers

Once a customer purchases a build and requests a partner with certain capabilities, they will be able to match and enter the shared chat/timeline space. In the marketplace prototype, the team used a plumbing service as an example. Since plumbing doesn't come until later in the build process, the visual timeline provides a visual representation of when the partner must jump in to do physical work on the build. At the same time, they will have the ability to communicate with all the other partners involved to ensure everything is set up correctly before their service begins.

Financial Analysis & Outcomes

Overview of the Model

There are two main parts of this financial analysis: the income statement and the OPACC calculations. In each, the team has projected the financial performance of the proposed marketplace for the years 2023 and 2028 to show potential performance now and when the industry has had several years to grow and mature. Each part shows both projection years and forecasts three scenarios: low sales, medium sales, and high sales. This will provide Caterpillar with enough information to analyze the possibilities and understand how the marketplace would perform in various circumstances. The income statement analysis also includes sensitivity analysis on five important variables, providing Caterpillar with insights into how the marketplace would be impacted if various factors changed.

Model Inputs

There are numerous inputs in this financial model, so it will be helpful to discuss their importance, dependencies, and the team's reasonings for the decisions made. In this section, the team will highlight the six most important drivers of the model and briefly discuss several other inputs. The six key drivers are the projected total industry revenue, Caterpillar's market share, home plans unit sale price, printer materials revenue per sale, add-ons revenue per sale, and Caterpillar additional services revenue per sale.

The projected total industry revenue predicts the size of the entire 3D printable construction industry. This value is used to calculate the number of homes that would be 3D printed, which is used to calculate the total number of sales made through the platform. The input value in the model for this driver is around $37 million, which was calculated using a research report by Grand View Research provided to the team by the corporate sponsor.

Caterpillar's market share is extremely important as it is directly involved in determining how many sales are made through the platform. This number is multiplied by the number of homes that were 3D printed to determine the number of sales on the platform. Caterpillar's market share has been increased by a factor of 10 times between the low, medium, and high sales scenarios to provide Caterpillar with an understanding of the platform's success based on the level of traction it gains in the market.

The home plans unit sales price refers to the average price a buyer would pay to purchase a set of home plans through the platform. This value does not include revenue from any printer materials, add-ons, or additional services provided by Caterpillar. The team decided that $2,500 was a reasonable average sale price based on online research of sale prices of similar products. By comparing several websites and their product offerings, the team decided that $2,500 was an accurate representation and a reasonable assumption. This value is multiplied by the number of

home plans sold to calculate the total revenue generated through sales of home plans on the platform.

The printer materials revenue per sale refers to the average amount that a buyer would pay through the platform to purchase the concrete or other mix that the printer would use to print the walls of their house. Caterpillar will offer this as an easy way for buyers to purchase most or all materials needed to build their house directly through the platform. As Caterpillar will not be performing much work for this offering, Caterpillar will charge a 1% markup for any printer materials purchased through the platform. This could be a large revenue source as concrete mix can be expensive, especially for larger houses. This value was calculated by taking the average U.S. home's exterior wall area of 1,580 square feet and multiplying that by an estimated cost of materials. Apis Cor's buyer's guide estimates the cost of their materials at $12-$15 per square foot. By multiplying the midpoint of Apis Cor's cost estimate by the average home square footage, the team calculated a value of $21,330.

The add-ons revenue per sale refers to the average amount that a buyer would pay through the platform to purchase window frames, lintels, doors, and other materials needed for the completion of the house. The platform will allow buyers to easily add these items to their purchase when they buy their home plans. Not only will this simplify the homebuilding experience for the buyer, but it will also provide Caterpillar with an opportunity to increase the platform's revenue and engage other parts of the value chain such as the Cat Dealers. Caterpillar will charge on average a 20% markup for any add-ons purchased through the platform. The team has assumed that the average revenue per order from add-ons will be $18,000. This number was calculated based on four major categories of add-ons: lintels & sills, windows, interior doors, and exterior doors. For each category, the team found an estimated price range based on internet research and an estimated quantity needed. By multiplying the quantity by the low and high price estimates, the team calculated a range of the total price. The team took the midpoint of this range and multiplied it by 70%, as the team is assuming that 70% of customers who buy home plans will also purchase add-ons. Figure 6 shows the team's calculations.

The Caterpillar additional services revenue per sale refers to the average amount that a buyer would pay through the platform to be connected with contractors who can help with plumbing, electrical work, excavation, pouring the foundation, permitting, and any other required service. This is another service offered through the platform that will simplify the customer experience while also allowing Caterpillar to engage more of the value chain. This number was calculated based on four major categories of additional services: plumbing & electrical, roofing, permitting, and foundation. For each category, the team found an estimated price range based on internet research. This gave the team a range of the total price. The team took the midpoint of this range and multiplied it by 70%, as the team is assuming that 70% of customers who buy home plans will also purchase additional services. Figure 7 shows the team's calculations.

Although not a key driver, another important model input is the designer royalty. The designer royalty refers to the commission that will be paid upon each sale to an architect or designer who sells home plans through the platform. This royalty is 70% of the sale price of the home plan. For example, if a designer sells one plan for $2,500, the designer's royalty will be $1,750 ($2,500 x 70%). The percentage paid to designers is important because it must be significant enough to incentivize designers to create and upload plans, but it must also be low enough to provide Caterpillar with a sufficient portion of the revenue to continue operating the platform. Through online research combined with conversations with architects, the team determined that the designer royalty should be 70%. The team arrived at 70% by considering the amount of time an architect typically takes to design home plans and the average hourly rate an architect is paid. The team considered that a designer would have the ability to create a plan one time and sell it an unlimited number of times. The team also considered that designers would want to be paid sufficiently even if their designs sold less frequently. Ultimately, the team believes that a 70% designer royalty will allow Caterpillar to receive enough income while also encouraging designers to invest their time and resources into selling on the platform.

Discussion of Income Statement Model Outcomes

The income statement model shows that in all three sales scenarios, the platform would have negative net income in 2023, the initial year, but would reach profitability by the fifth year of operation in the medium and high sales scenarios. These outcomes are promising for the future success of the platform. Given the large investment required to start the platform (estimated to be around $1 million), it makes sense that the first year would not be profitable. However, the model suggests that after five years, the platform would generate net income of $728,000 or $12,183,000 in the medium sales and high sales scenarios, respectively. In each of these scenarios, the net income margins are 2.6% and 4.3%, respectively. Across both projection years and in all scenarios, gross margins are 7.4%. The gross margins are largely held lower because add-ons and Caterpillar additional services make up a large majority of the revenue while having low margins.

Discussion of OPACC Calculations & Outcomes

The second part of the financial analysis is the OPACC model. The OPACC model is similar to the income statement model, but it also includes the OPACC calculations for each scenario and both projection years. The inputs remain the same, and the OPACC model is identical to the income statement model until the operating profit line. To calculate OPACC, the team totaled the platform expenses, which includes platform startup costs, platform operation costs, business development / research and development, and credit card processing expenses. This value is multiplied by the cost of capital rate (13%) to calculate the capital charge. The capital charge is subtracted from the operating profit to calculate the incremental OPACC this project would provide to Caterpillar in each year and scenario.

The incremental OPACC line shows that this platform is likely to become OPACC positive within five years. In 2028, both the medium sales and high sales scenarios provide Caterpillar with a positive OPACC. This outcome is very encouraging and shows that this platform has the potential to create significant OPACC for Caterpillar after the initial start-up and development period.

Transaction Revenue Breakdown

As previously discussed, one major input is the average sale price for one home plan on the platform, which the team assumed to be $2,500. As such, the revenue from one sale is $2,500. The largest portion of this revenue goes to the designer, through the 70% designer royalty. The designer is paid $1,750, leaving $750. Credit card transaction fees are $62.50 for this sale. Taxes are $159.50 (based on Caterpillar's tax rate), so the final amount that Caterpillar will receive to cover its fixed costs and contribute to net income is $528, or 21% of the revenue. Figure 8 shows the transaction revenue breakdown.

Sensitivity Analysis Overview

The team conducted a sensitivity analysis on five important variables: projected total industry revenue, projected total industry average home printing price, Caterpillar's market share, business development / research and development expenses, and the designer royalty rate. The image below shows the results of the sensitivity analysis, and more details are available in the financial model Excel file. The team can conclude that the outcomes from the financial model have validity based on the sensitivity analysis. Figure 9 shows the sensitivity analysis.

Market Entry Strategy

First, to tackle the "chicken-egg" problem (described in the Multisided Platform section) on the demand side, the team recommends choosing one major player to provide initial demand and help the platform gain momentum. Caterpillar has done a wonderful job finding 3D printing construction companies who would use the platform. The team recommends Caterpillar find at least one big development company that would be interested in partnering to buy and customize plans. ICON, a 3D printing construction company, has partnered with developer LENNAR to build a community of 3D printed homes in Austin, TX. This has been a successful strategy for the printing company because this partnership will result in many builds. Caterpillar could follow a similar strategy to increase the chance of launch success.

Second, to tackle the "chicken-egg" problem on the supply side, the team recommends working with a select number of architects to build a sizable backlog of building designs before launching the platform. This would provide an initial supply to meet demand.

Third, rather than building a base of contractors from scratch or waiting for them to find the platform, the team recommends partnering with an existing third-party contractor hiring platform that is already an expert in background checking and license verification. One prime example of this is Home Depot's Service Connect, which connects customers with quality contractors near them to meet needs in areas such as plumbing, roofing, and HVAC work.

Fourth, the team recommends Caterpillar initially takes a hands-on approach and heavily emphasize consumer relations from the beginning. The platform will require a lot of trust from early adopters, given how many players must participate to help finish the building. An initial consultation from a Caterpillar representative who is an expert in permitting and zoning laws, the construction process, and 3D printing construction as an alternative will help attract and satisfy consumers and encourage them to return.

Challenges & Risks

While considering an investment in the marketplace for 3D printed structures, it is important to understand the challenges and the risks of 3D printing as a technology and then the challenges and risks of launching a platform to support the sale of these 3D printed designs for construction. The main concerns of the 3D printing technology include limitations on the size of the homes, the requirement of an initial capital investment, and regulatory barriers. 3D printing allows for the feasible construction of novel designs that have never been created because of high costs, high production time, or just pragmatic impossibility with traditional construction methods. While 3D printing is paving the way for new designs, certain limitations exist with the size of the structures that can be constructed. Gantry-style 3D printers have limitations on horizontal and vertical size because they are not capable to print outside of their base frame. Robotic-arm style 3D printers are not capable of printing many vertical floors due to the difficulty of pumping consistent mix to elevated surfaces. The typical 3D printed house is about 1,000 square feet, but the average US home is over 2,500 square feet. Furthermore, these 3D printed homes are listed at expensive , especially the larger the home is. Currently, a 3D printed home is seen as a luxury in the United States and home buyers are paying premium for smaller homes. The second risk is that construction companies incur high capital costs to purchase 3D printing machines. While these machines reduce the amount of labor required, the machines are expensive. This is because the machines are in early stages of production and are not mass produced yet. The construction companies not only need to purchase the machines, but they will also need to purchase the mix that the machines will extrude per each square foot. Last of all, there are regulatory barriers that have proved to be a huge stumbling block for the adoption of 3D printing technology. The 3D printed walls need to pass code-compliance for structural integrity, fire performance, freeze thaw, water proofing, wind load resistance, and many more tests to gain regulatory approval. The governmental regulations have been slow to adopt changes in the construction industry and are inhibiting the widespread use of 3D printing construction.

Next, there are challenges associated with launching the platform to support the sale of these 3D printed designs for construction. The main challenge include slightly changing the current landscape of the construction industry, seamlessly integrating numerous stakeholders into one environment, and obtaining permitting approval. Today, the construction of any building is an intensely high-touch process between the architects and the general contractors. Once the architect produces a design that the developer wants, the general contractor will have to construct the design with budget and time constraints. The plans are typically changed along the way and the architect has to alter the existing plans multiple times over. As a result, the architect is involved for most of the construction process. However, once the architect uploads the design, the marketplace does not require further involvement from the architect. This is because the design will print consistently the same output once the land is cleared and the foundation is laid. While the process of surveying the land will be different each time, the 3D printing of the design will not change. As a result, the marketplace effectively eliminates the high-touch parts of the architect's job. This is a challenge because it means that there is no architect playing an active role in the construction process of the new structure. If there is any need for an alteration to a specific design, there is no architect to fill the role.

The next risk involves the seamless integration of the numerous stakeholders into a single environment. The prototype developed by the capstone team includes different landing page for each stakeholder group (individual consumer, home developer, architect, and partners). The marketplace is attempting to connect all the necessary parties together to complete the construction of a 3D printed structure. Nevertheless, the platform does not consider existing relationships within the contractor landscape. Typically, home developers have trusted contractors that they have been working with for years, and, similarly, the contractors have sub-contractors that they consistently work with. Because of the highly relational nature of the construction industry, it might be difficult for users and home developers to use the specific contractors or sub-contractors that the platform offers. Last of all, 3D printed walls need to reach regulatory approval as a replacement for concrete masonry units (CMUs). Apis Cor was able to reach approval in the entire state of Montana, but this approval would be necessary for every state that the marketplace is available in. The difficult approval process will hinder the expansion of the marketplace to different regions in the US and other countries across the world.

There are also concerns for the launch of the marketplace that would invalidate the results found from the financial analysis performed by the team. These include the 3D printing industry does not reach the current estimated growth projections, the operational costs for operating the platform are more expensive than estimated, and the failure to capture enough market share. The financial analysis that predicts profitability for the medium adoption scenario of the platform in 2028 relies heavily on a few measures. First, if the 3D printing construction industry does not meet the projected growth, then there will be less overall business for the Caterpillar marketplace for 3D printable structures to capture. Second, the team was able to complete research and

conduct an interview with the Associate Director for Create-X, a start-up incubator at Georgia Tech, to create an estimation for platform start-up costs and annual operation costs. If these costs are underestimations, this will also affect the estimated profitability of the platform. Finally, if the marketplace is not able to capture a large enough portion of the market share, then the projected revenue will be incorrect. All in all, these are the three biggest indicators that could cause the marketplace to either underperform or overperform the projections from the financial analysis.

Recommendations

Possible Actions

Caterpillar has three different possible actions to take regarding the marketplace platform presented in this report. Since the marketplace is derived from concepts that are protected by patents, Caterpillar has an effective monopoly on the network portal for 3D printable structure designs. Caterpillar has already made an initial investment of time and money in drafting and submitting these patents. Nevertheless, Caterpillar has taken no action with the intellectual property and can continue to do nothing. By letting the intellectual property sit unused, Caterpillar will experience a high opportunity cost from penetrating an industry that is projected to virtually double in size annually until 2030. Second, Caterpillar can license out the patent to any interested parties that desire to use the concepts for the network portal to build and launch their own version of this platform. However, there are currently no interested parties or prospects to license the intellectual property to. Last of all, Caterpillar can continue the initial investment in acquiring the patents to pursue the creation and launch of a marketplace for 3D printed structures. As outlined in the financial analysis, initial funding of $1.4 million would cover the platform start-up, operational costs for one year, platform promotion, and research & development costs. Based on research and analysis, the capstone team recommends that Caterpillar move forward with investing $1.4 million to build the platform to an operational status where a beta version can be launched.

Final Recommendations

The capstone team prepared strategies to help Caterpillar succeed when launching the platform based on extensive market research and analysis. First and foremost, the platform that the team created integrates numerous different stakeholders into a single interactive and virtual ecosystem. The difficulty with the integration of multiple stakeholders in a single marketplace is the additional complications of seamlessly connecting each party. Consequently, the team recommends that Caterpillar will first focus on the core value proposition of the platform by focusing on the two most important stakeholders: architects and developers. The architects are providing the supply. Therefore, acquiring an extensive library of home plan designs by a variety of architects will be able to satisfy any initial demand by consumers and home developers. While

the marketplace connects many other parties, the key value is added by the connection between the architect's home plan designs and the consumers or home developers who will purchase these designs. It is important that Caterpillar focuses on first building out an extensive library of designs to satisfy the arrival of demand.

Furthermore, the team recommends that Caterpillar will also host a symposium for integral industry players in the 3D printing construction industry as well as the home development industry. Two 3D printing companies that have already expressed interest in partnering with the marketplace include Apis Cor and Black Buffalo. These companies both have different approaches to 3D printing buildings (Black Buffalo uses a gantry-style printer and Apis Cor uses a robotic arm-style printer). Both of these companies only manufacture the printers and do not operate them. Moreover, a few home development companies to consider include D.R. Horton and Alquist. D.R. Horton is the largest homebuilder in the United States, and they have the necessary resources to invest in a technology that has the ability to disrupt the construction industry. Alquist is a home developer that is committed to solving the housing crisis by offering sustainable and affordable housing. Currently, Alquist is focused on using 3D printing to do this and they are partnered with Black Buffalo. The symposium will take place in Caterpillar headquarters over multiple days. Throughout the event, Caterpillar will be able to communicate 3 main points to the key industry players. First, Caterpillar is a successful Fortune 500 company that has a reliable brand name in the construction industry. Second, Caterpillar has a history within the additive manufacturing and 3D printing construction industry. Caterpillar has many patents (some of which are mentioned in the Intellectual Property section of the report. Additionally, Caterpillar has its own unique 3D printer that has been sold to the Corp of Engineers to construct army barracks. Third and most importantly, Caterpillar will showcase the prototype for a 3D printable structures marketplace. Along with an in-depth presentation of the holistic marketplace, Caterpillar will express its willingness to penetrate the industry and develop strategic partnerships with the companies that were invited to the symposium. At the conclusion of the symposium, Caterpillar will have adequate prospects to pursue further partnerships while fully developing the prototype functionality.

When seeking out strategic partnerships, it is important to note that Icon, a 3D printing company constructing homes in Texas, has partnered with Lennar. Lennar is the second largest home builder in the United States. They are working together to scale certain home designs and ramp up production. If Caterpillar can partner with D.R. Horton, the largest home builder in the US, then the combined resources would allow for the marketplace to quickly scale up. Additionally, Caterpillar can seek out a partnership with Alquist. Alquist already has an existing partnership with Black Buffalo and is dedicated almost entirely to home development by 3D printing methods. If Caterpillar is able to build an extensive library of architectural designs partner with these key industry players, then there will be sufficient support to allow for the successful launch of the marketplace prototype. On a separate note, individuals that the team interviewed from

Alquist, Black Buffalo, Apis Cor, and others expressed interest in partnering with the marketplace if Caterpillar made the decision to create it.

While leveraging the newly formed strategic partnerships with 3D printing companies and home developers, Caterpillar will launch a beta version of the platform limited to the Southern region of the United States. According to Zillow's Consumer Housing Trends Report of 2023, new construction home purchases are concentrated in the Southern region of the US. Additionally, concentrating in the South allows Caterpillar to eliminate the challenges of local coding and permit approval processes, adverse weather that affects print schedules, and the complexities of other factors.

Actions for Future Teams

The Denning T&M capstone team, sponsored by Caterpillar, discovered numerous opportunities that are available within the additive manufacturing and 3D printing construction industries throughout the lifetime of the project from October 2022 to April 2023. The team discovered that the compound annual growth rate of the 3D printing construction market is 101.9%, where the market is expected to essentially double in size on an annual basis until 2030. The technology has the ability to disrupt an industry that has experienced little innovation relative to the landscapes of other industries such as virtual reality, artificial, intelligence, and the internet. As a result, the team believes that Caterpillar needs to play a role in the emergence of the 3D printing industry in some capacity. Due to the team's research, the marketplace has potential to be OPACC-positive and produce profits. Nevertheless, Caterpillar also has a 3D printer that has completed successful projects and other patents related to the technology. Furthermore, Caterpillar has a strong network of CAT dealers that have the ability to offer 3D printers and 3D printing mix as newly available products for customers. The team encourages Caterpillar to further explore the industry and to consider a future capstone project, or other related projects, to be conducted on the possibilities for Caterpillar to use its current practices or resources to capitalize on the 3D printing construction industry.

Conclusion

This concludes the synopsis of the work done by the Denning Technology and Management Program's 2023 Caterpillar Capstone Team. The team would like to thank the corporate affiliates, Tony Agusti and Tazio Grivetti. With their continued support, the team was able to fully understand Caterpillar's mission, vision, and value chain and how the team could position the deliverables to meet and exceed the company's needs. Additionally, the team would like to thank the Denning Technology and Management Program's faculty: Robert Burgess, John Stanford, Anne Lynch, and Sheena Brown.

Appendix

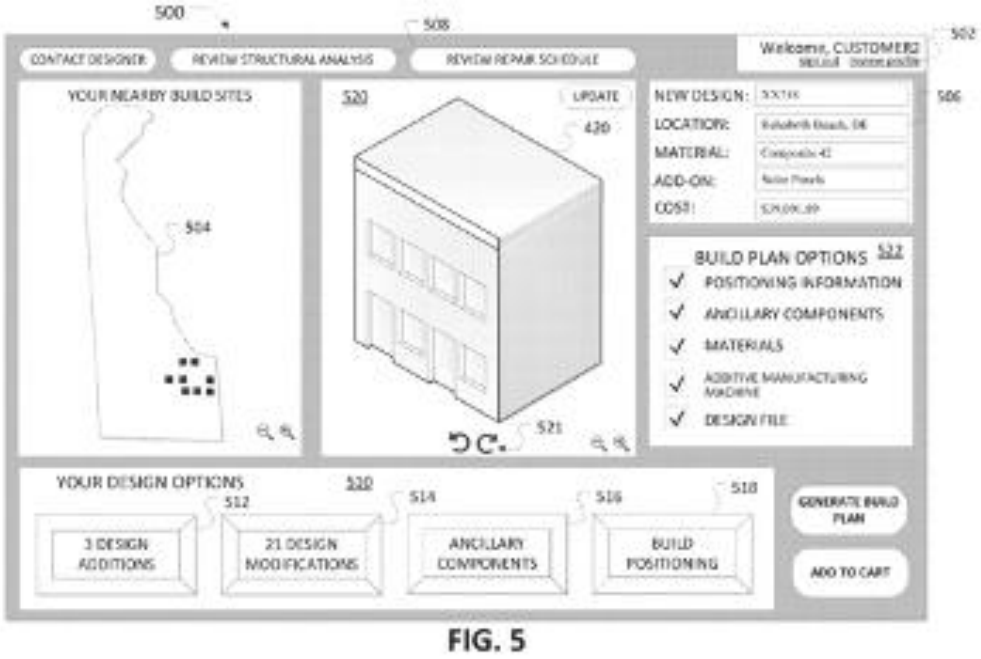

FIG. 5

Figure 1: Figure 5 from US patent 9,959,370 B2 (Network Portal for 3D Printable Structures)

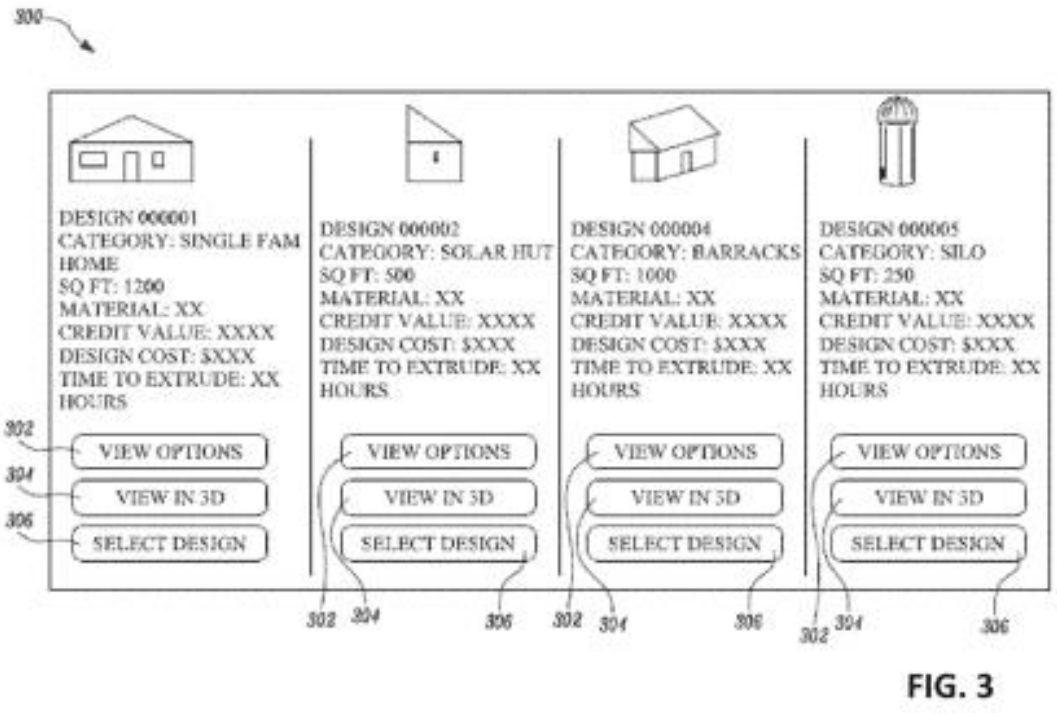

FIG. 3

Figure 2: Figure 3 from US patent 9,959,370 B2 (Network Portal for 3D Printable Structures)

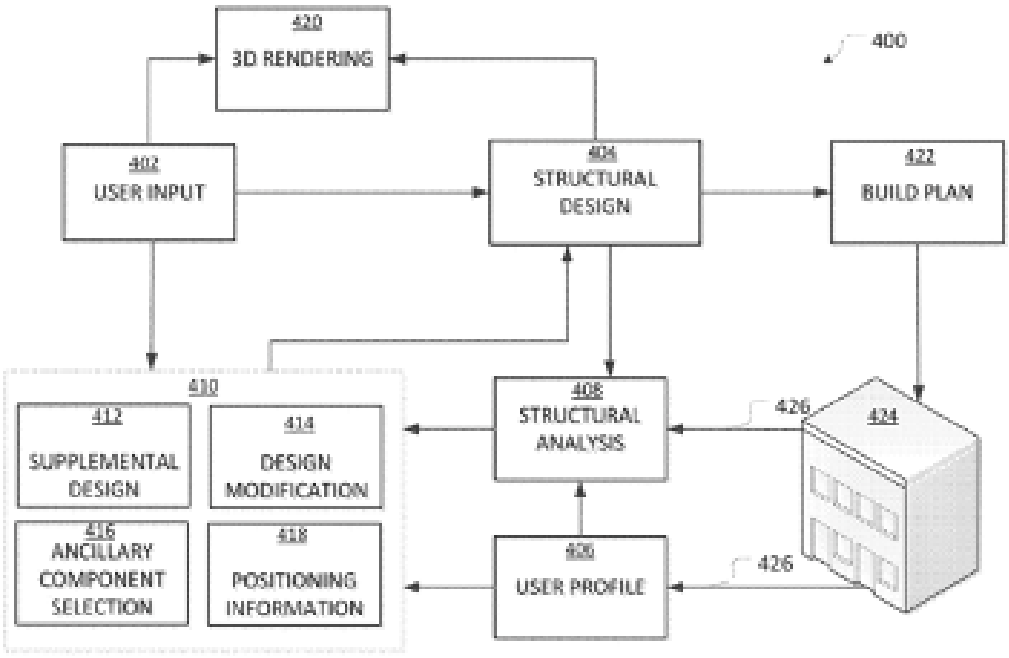

FIG. 4

Figure 3: Figure 4 from US patent 10,672,045 B2 (Systems and Methods for Processing Orders for Structural Designs)

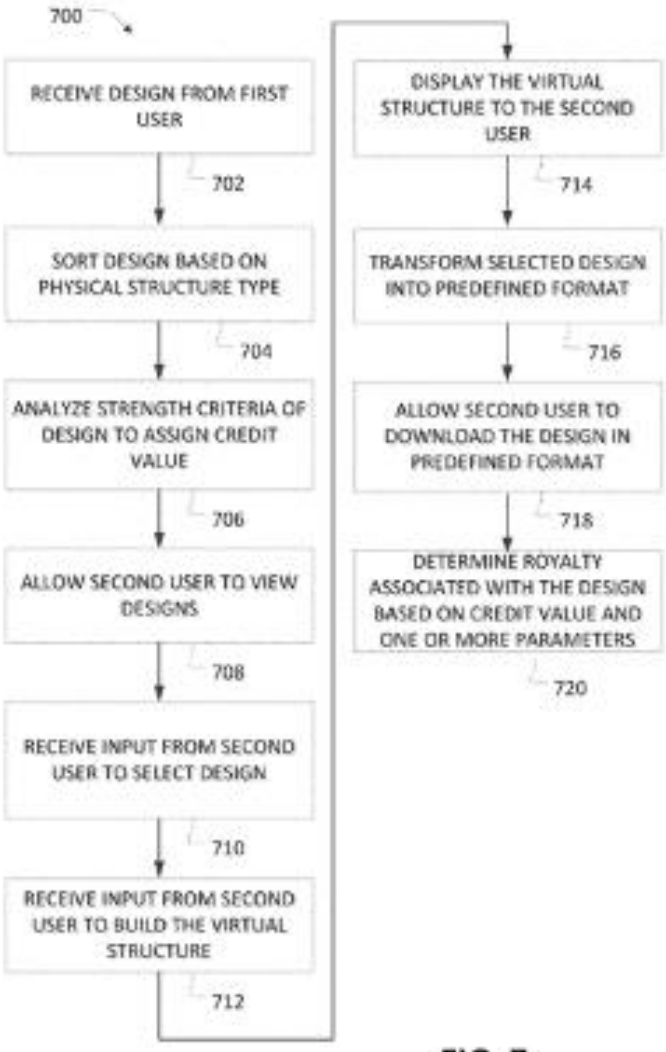

FIG. 7

Figure 4: Figure 7 from US patent 10,672,045 B2 (Systems and Methods for Processing Orders for Structural Designs)

Name	Role	Company	Interview Date
Tazio Grivetti	Emerging Technologies Product Leader	Caterpillar	10/27/2022
Brian Bloomer	UI/UX Designer	CAT Digital	11/10/2022
Wyatt Page	Mobile App Developer	Caterpillar	11/10/2022
Karthik Ramachandran	Professor - Product Development	Georgia Institute of Technology	11/14/2022
Tim Murphy	Head of Business Development	Black Buffalo	11/15/2022
Eric Overby	Professor - Emerging Technologies	Georgia Institute of Technology	11/17/2022
Angela R Christian	Pro Account Sales Associate	Home Depot	11/22/2022
Trevor Ragno	CRO & Director of Building Technologies	Apis Cor	11/28/2022
David Goodloe	Advanced Concepts Team	Branch Technologies	12/13/2022
Alexey Dubov	Chief Innovation Officer & Co-founder	Mighty Buildings	12/27/2022
Emily Salmond	Analyst	Goldman Sachs	1/25/2023
Anna Cheniuntai	Chief Executive Officer	Apis Cor	2/3/2023
Rahul Saxena	Associate Director	Create-X	2/8/2023
Kelly Barton	Potential Homebuyer	N/A	2/9/2023
Todd Barton	Potential Homebuyer	N/A	2/10/2023
Daniel Sergison	Senior Engineer	Caterpillar	2/15/2023
Asha Varghese	President	CAT Foundation	2/20/2023
Joe Greco	Senior Architect	Lord Aeck Sargent	3/8/2023
Cooper Gray	Project Manager	Batchelor & Kimball	3/16/2023
Josh Marx	Development & Acquisitions Manager	Prestwick Companies	4/5/2023

Figure 5: Interview Matrix

Category	Low Price	High Price	Quantity	Low Total Price	High Total Price
Lintels/Sills	$100	$400	29.30	$2,930	$11,720
Windows	$575	$1,225	8.00	$4,600	$9,800
Interior Doors	$375	$1,125	10.00	$3,750	$11,250
Exterior Doors	$525	$1,700	3.30	$1,733	$5,610
Total				**$13,013**	**$38,380**

Proportion of Buyers Also Purchasing Add-ons	70%	Low Price Proportion	High Price Proportion
		$9,109	**$26,866**
Add-ons Revenue Per Sale	**$17,987**		

Figure 6: Add-On Sales Revenue Calculations

Category	Low Price	High Price
Plumbing & Electrical	$42,500	$62,500
Roofing	$5,000	$10,000
Permitting	$400	$2,250
Foundation	$16,000	$72,000
Total	**$63,900**	**$146,750**

	Low Price Proportion	High Price Proportion
	$44,730	**$102,725**

Proportion of Buyers Also Purchasing Add-ons	70%
Additional Services Revenue Per Sale	**$73,728**

Figure 7: Additional Services Sales Revenue Calculations

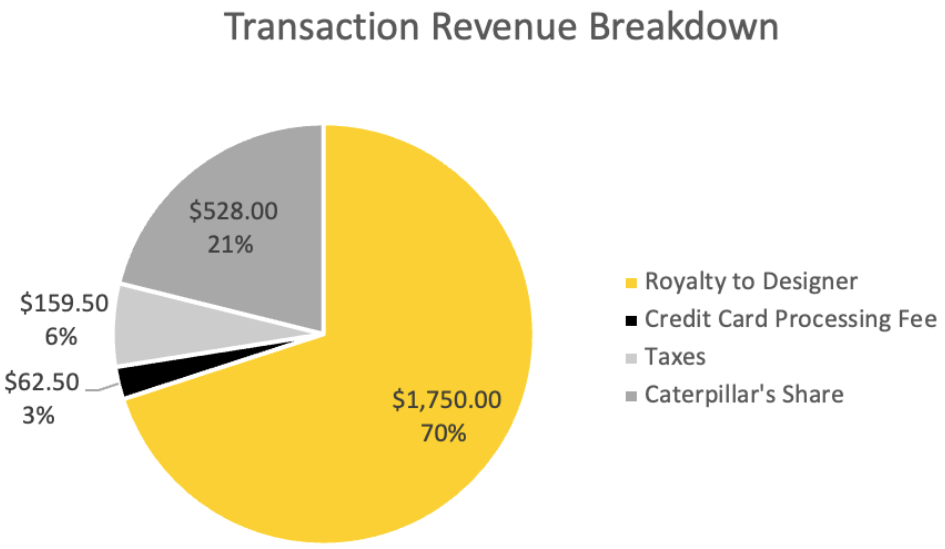

Figure 8: Transaction Revenue Breakdown

Sensitivity Analysis

	2023				2028		
	Low Sales	Medium Sales	High Sales		Low Sales	Medium Sales	High Sales
Projected Total Industry Revenue Impact on Net Income				**Projected Total Industry Revenue Impact on Net Income**			
$ 22,047,480	$ (1,390,000)	$ (1,363,117)	$ (1,094,285)	$ 739,674,339	$ (610,148)	$ 220,961	$ 7,093,708
$ 29,396,640	$ (1,383,279)	$ (1,349,675)	$ (993,473)	$ 986,232,451	$ (573,046)	$ 477,407	$ 9,641,069
$ 36,745,800	$ (1,383,279)	$ (1,342,954)	$ (899,382)	$ 1,232,790,564	$ (543,365)	$ 728,154	$ 12,182,732
$ 44,094,960	$ (1,383,279)	$ (1,329,513)	$ (798,570)	$ 1,479,348,677	$ (506,263)	$ 984,599	$ 14,730,093
$ 51,444,120	$ (1,383,279)	$ (1,322,792)	$ (697,758)	$ 1,725,906,790	$ (476,582)	$ 1,241,045	$ 17,271,756
Projected Total Industry Average Home Printing Price				**Projected Total Industry Average Home Printing Price**			
$ 150,000	$ (1,383,279)	$ (1,309,350)	$ (570,062)	$ 150,000	$ (402,379)	$ 1,799,527	$ 22,873,672
$ 200,000	$ (1,383,279)	$ (1,329,513)	$ (771,686)	$ 200,000	$ (476,582)	$ 1,212,551	$ 17,021,009
$ 250,000	$ (1,383,279)	$ (1,342,954)	$ (899,382)	$ 250,000	$ (521,104)	$ 864,925	$ 13,510,551
$ 300,000	$ (1,383,279)	$ (1,349,675)	$ (980,031)	$ 300,000	$ (550,785)	$ 625,575	$ 11,168,346
$ 350,000	$ (1,383,279)	$ (1,356,396)	$ (1,040,518)	$ 350,000	$ (573,046)	$ 460,310	$ 9,492,901
Caterpillar's Market Share				**Caterpillar's Market Share**			
0.25% / 2.5% / 25%	$ (1,390,000)	$ (1,363,117)	$ (1,141,330)	0.25% / 2.5% / 25%	$ (624,988)	$ 95,587	$ 5,822,876
0.50% / 5.0% / 50%	$ (1,383,279)	$ (1,342,954)	$ (899,382)	0.50% / 5.0% / 50%	$ (543,365)	$ 728,154	$ 12,182,732
0.75% / 7.5% / 75%	$ (1,383,279)	$ (1,316,071)	$ (650,712)	0.75% / 7.5% / 75%	$ (461,742)	$ 1,366,419	$ 18,548,286
1.00% / 10.0% / 100%	$ (1,383,279)	$ (1,289,188)	$ (402,042)	1.00% / 10.0% / 100%	$ (372,698)	$ 2,004,684	$ 24,908,142
Business Development / Research & Development Expenses				**Business Development / Research & Development Expenses**			
$ 600,000	$ (983,279)	$ (942,954)	$ (499,382)	$ 152,040	$ (143,365)	$ 1,035,354	$ 12,489,932
$ 800,000	$ (1,183,279)	$ (1,142,954)	$ (699,382)	$ 352,040	$ (343,365)	$ 881,754	$ 12,336,332
$ 1,000,000	$ (1,383,279)	$ (1,342,954)	$ (899,382)	$ 552,040	$ (543,365)	$ 728,154	$ 12,182,732
$ 1,200,000	$ (1,583,279)	$ (1,542,954)	$ (1,099,382)	$ 752,040	$ (743,365)	$ 574,554	$ 12,029,132
$ 1,400,000	$ (1,783,279)	$ (1,742,954)	$ (1,299,382)	$ 952,040	$ (943,365)	$ 420,954	$ 11,875,532
Designer Royalty				**Designer Royalty**			
50%	$ (1,382,779)	$ (1,339,454)	$ (862,882)	50%	$ (531,220)	$ 822,698	$ 13,129,450
60%	$ (1,383,029)	$ (1,341,204)	$ (881,132)	60%	$ (537,293)	$ 775,426	$ 12,656,091
70%	$ (1,383,279)	$ (1,342,954)	$ (899,382)	70%	$ (543,365)	$ 728,154	$ 12,182,732
80%	$ (1,383,529)	$ (1,344,704)	$ (917,632)	80%	$ (549,437)	$ 680,881	$ 11,709,373
90%	$ (1,383,779)	$ (1,346,454)	$ (935,882)	90%	$ (555,510)	$ 633,609	$ 11,236,014

Figure 9: Sensitivity Analysis on Five Important Variables