BRDG Innovation Challenge

XyloBench: Bridging the Gap Between Urban Spaces and Green Infrastructure

Team 1: Greengineers

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EXECUTIVE SUMMARY

The XyloBench is a multifunctional urban bench that combines seating with an auto-irrigated planter system to bring greenery into shared spaces while conserving water. It captures rainwater and greywater in a built-in reservoir and uses sensors to automate irrigation, reducing reliance on external water sources. Designed to address urban challenges such as heat, poor air quality, and limited access to nature, the XyloBench offers a low-cost, sustainable solution compared to existing alternatives. Its applications span campuses, housing developments, senior care facilities, and community gardens, enriching public spaces while promoting environmental awareness. In the long term, the XyloBench has the potential to support decentralized water reuse and groundwater recharge, advancing climate resilience in resource-limited communities. At an estimated price of $600, it delivers affordable, scalable infrastructure for healthier, greener cities.

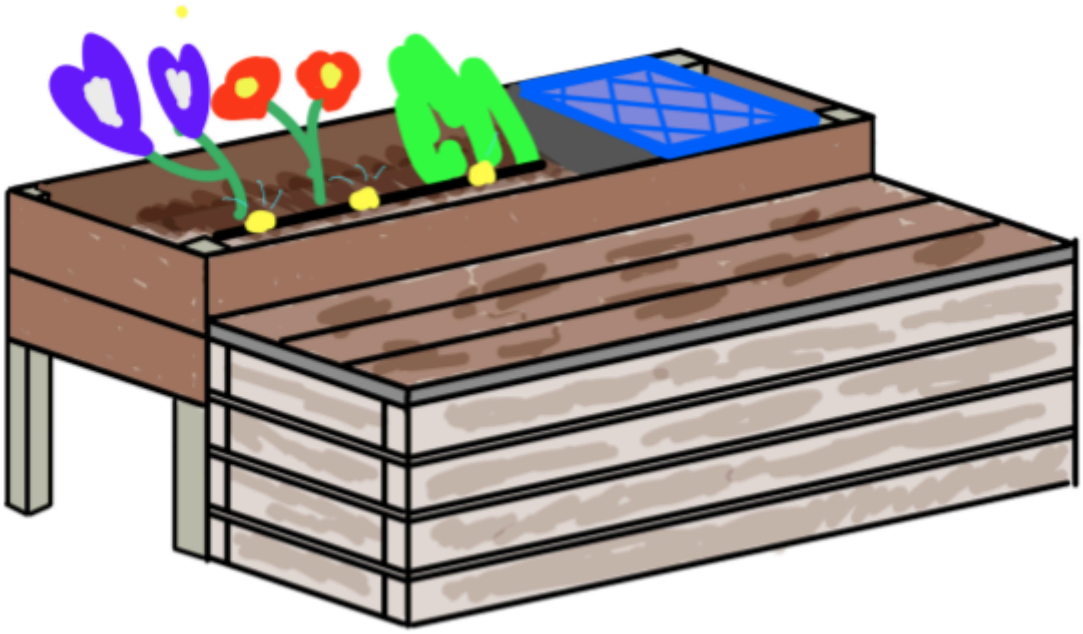


Fig. 1: XyloBench

THE GREENGINEERS TEAM

The Greengineers team comprises undergraduate students from various fields, including economics, computer science, and nearly all major engineering fields. There exist two co-leads, Adrian and Helen, who assist in overall project management through facilitating communication between group members and coaches, delegating tasks, and providing feedback on necessary items.

Adrian Abraham
Computer Science, California State University, Long Beach
Throughout Phase 1, I led weekly meetings, shared updates, and delegated tasks to keep our project on track. In Phase 2, I transitioned from the team lead role to focus on conducting competitive analysis and contributing to the electronics assembly. Recently, I've become passionate about AI, especially its mathematical foundations, and I aim to pursue a career as an AI/ML engineer or researcher.

Arian Partovi
Computer Science, California State University, Northridge

For this competition, I will be focusing on the front-end development of an interactive website. My primary goal is to design and implement a user-friendly website that allows users to feel more connected to the product and know more about the product and the people behind it. My career aspirations are to obtain my Ph.D in bioinformatics and lead a team of bioinformaticians, combining technical expertise with leadership to drive meaningful scientific discovery.

Jonathan Fuentes
Computer Engineering, California State University, Long Beach
In this phase of this project, I supported the creation of our embedded electronic system and the building of our prototype. I primarily worked on integrating inputs on the microcontroller with low-level programming to ensure expected outputs. My career interests lie in embedded systems, firmware development, and software engineering. Specifically, I have an interest in embedded software for biomedical applications, such as medical devices, to improve patient outcomes.

Nancy Vu
Economics, International Development Studies, and Chinese,
University of California, Los Angeles

Coming from an economics background, I find myself more equipped to analyze data and changes in the market than designing and building a working website or prototype. Despite discrepancies in our disciplines of study, however, I find the

dynamic collaboration with different team members both novel and rewarding. In Phase 2 of the project, I primarily focused on tailoring a marketing scheme towards our target audiences and correcting the budget plan to accommodate our design simplifications. I also accompanied the engineering team whenever possible to assist with non-technical tasks during the prototype construction stage. In the future, I see myself as an analyst or in a similar occupation, likely in an industry that provides public services to the community.

Helen Yajaira Estrada
Aerospace Engineering, Santa Ana College

As the team's co-leader, I focused on initiating conversations with Subject Matter Experts and delegating tasks alongside structuring meetings both online and in-person. I supported the building of the physical prototype and helped with drafting the redesign of XyloBench. My career aspirations are to obtain a PhD and work as an aerospace engineer where I will work hands-on to build spacecrafts, rovers, and satellites. I see myself among the diverse scientists and engineers driving the discovery of new worlds.

Sandra Ramirez
Mechanical Engineering, San Jose State University

In this phase, I focused on the long-term aspect. My long-term aspiration is to become an Automotive Design Engineer, working on high-performance vehicles in motorsports, particularly Formula 1. I'm passionate about automotive engineering, with the ultimate goal of launching my own brand of innovative electric cars that push the boundaries of performance, efficiency, and sustainability.

Steven Doan
Electrical Engineering, University of California, Irvine

In this phase, I supported the redesign of the Xylobench prototype, research on hardware components, and building the physical product. My future career aspiration is to work in the automotive industry to design hybrid and EV technology. This stems from my passion for vehicles and drive to pursue more sustainable technologies for a more carbon-free future. Similarly, I am open to exploring more innovative ways to harness other forms of renewable energy, such as solar.

INTRODUCTION: A CASE FOR THE XYLOBENCH

Urban environments often lack access to greenery, a deficit that contributes to negative effects on an individual's physical and mental health. Not only does the lack of nature contribute to higher rates of chronic illness, stress, and anxiety, but it also undermines social cohesion and overall community resilience. Conventional gray infrastructure dominates these spaces, intensifying urban heat, diminishing air quality, and offering limited opportunities for restorative outdoor activity. Additionally, existing green infrastructure initiatives are often expensive, difficult to maintain, or fail to reach the most marginalized communities. To address these persistent challenges, we present the XyloBench, a multifunctional bench equipped with a self-sustaining gardening system. The XyloBench incorporates auto-irrigation through sensor use, and an integrated reservoir system that collects rainwater and graywater, enabling continuous support of plant life even in resource-limited settings. We hypothesize that widespread implementation of XyloBench can provide affordable, accessible greenery that not only improves the physical environment but also enhances community well-being. Specifically, the presence of XyloBench in public spaces will increase everyday exposure to nature, enhance community well-being by offering attractive and inclusive gathering spots, and promote sustainable water usage and green infrastructure to those unaware of these principles, providing long-term environmental benefits while remaining cost-effective to produce and deploy in a wide variety of shared spaces.

THE MISSING GREEN

Many cities, especially under-resourced neighborhoods, struggle with a shortage of trees and green spaces, and the absence of this natural infrastructure leaves a measurable impact on health and quality of life. Research shows that greenery can lower stress, strengthen social ties, and reduce chronic illnesses, while its physical effects—such as cooling hot streets, filtering pollutants, and slowing stormwater—make urban areas more livable. Shade and the release of water from plants into the air can lower surface temperatures by as much as 20–45°F and decrease peak summer air temperatures by ~2–9°F, which reduces the urban heat island effect, lowers energy bills, and prevents heat-related illnesses. Without access to greenery, communities not only face harsher physical environments but also higher risks of anxiety, stress, and social isolation. The environmental consequences of missing greenery are equally significant. Vegetation filters particulate matter, absorbs carbon, and improves overall air quality. Trees intercept rainfall, reduce runoff, and minimize flood risk, providing natural stormwater management that concrete infrastructure cannot replicate. Yet these benefits are not shared equally across urban landscapes.

Research from American Forests' Tree Equity Score demonstrates that low-income neighborhoods and communities of color almost always have less canopy cover, higher heat exposure, and poorer air quality. These disparities are rooted in decades of unequal investment, redlining, and zoning practices that left some communities with lush tree cover and others

dominated by pavement and gray infrastructure. Los Angeles offers a clear example of this imbalance. According to the 2025 ParkScore Index, only 62% of the population in Los Angeles lives within a 10-minute walk of a park. Parks are unevenly distributed, with neighborhoods of color having 33% less park space per person than the city average and 72% less than predominantly white neighborhoods. Just 14% of LA's land is dedicated to parks, leaving many residents without ready access to restorative outdoor environments. The city's tree canopy is estimated at ~25% within Los Angeles and 18% countywide, but research shows that LA lost ~11% of its canopy between 2000 and 2021, especially in the neighborhoods already most vulnerable to extreme heat. These disparities leave residents in hotter, less healthy environments, where even small differences in shade can mean several degrees of temperature difference on the ground.

City leadership has begun to respond to these gaps. Los Angeles' Green New Deal sets a target of increasing the canopy by 50% in the highest-need areas by 2028, backed by programs to expand planting and maintenance. However, challenges remain: planting large numbers of trees is costly, requires long-term care, and must account for water use in a region often facing drought. Moreover, increasing canopy equitably means focusing on the communities that have historically been left behind, rather than adding trees only to neighborhoods that already have them. When Los Angeles is compared to other cities, its challenges become even clearer. Washington, DC, ranks #1 nationally on ParkScore, with 99% of residents living within a 10-minute walk of a park and about 37% canopy cover, along with an official target of 40% canopy by 2032. San Francisco offers 100% park access to residents, with 21% of its land dedicated to parks. New York City currently has 23.4% canopy and a legally codified goal of 30% by 2035, while Portland sits at 29.8% canopy as of 2020, despite recent declines. Even Phoenix, one of the hottest cities in the country, has committed to raising its canopy from about 11% to 25% by 2030, with a focus on shading bus stops, sidewalks, and other critical pedestrian areas. Compared with these examples, Los Angeles ranks lower in both access and canopy equity, and the gaps fall along socioeconomic and racial lines.

INNOVATION OVERVIEW: ORIGINS OF THE XYLOBENCH

The concept of our model is based on the model of vertical farming, where, in urban environments, the space constraints from vegetation are mitigated by farming upward instead of horizontally. However, unlike vertical farming, our bench offers the benefit of urban livability with a low-maintenance irrigation system. Our focus is also on introducing greenery into urban environments, not for sustainable farming. We designed our Xylobench using principles of biomimicry, modeling its water flow system that uses the veins of a plant to transport water and nutrients up against gravity. Our design mimics this by having a DC pump, connected to a filter, that transports water upward against gravity, for the irrigation of our native California greenery. Another major part of our inspiration is from the Sponge City concept, which is an urban planning concept that uses urban infrastructure to manage rainwater. Ultimately, our goal was to merge concepts found in nature with urban infrastructure to integrate greenery while promoting environmental well-being.

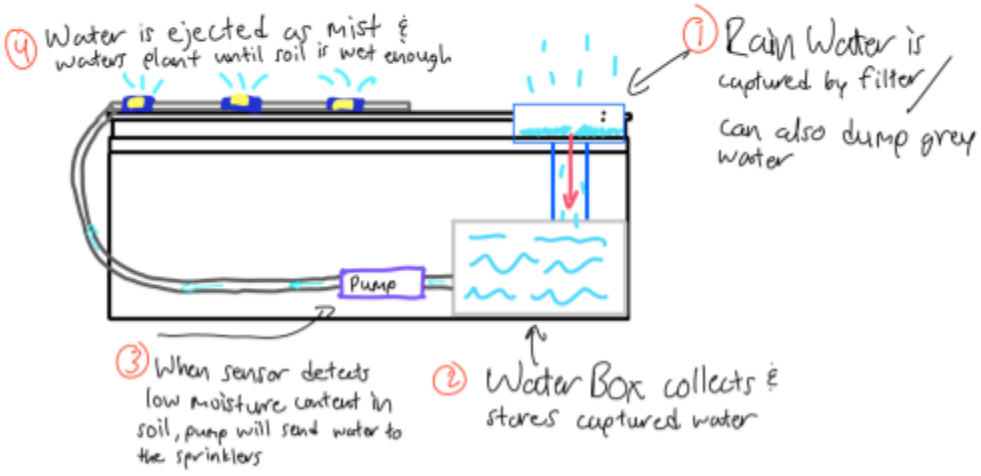


Fig. 2: Water Movement Configuration

DESIGN OVERVIEW

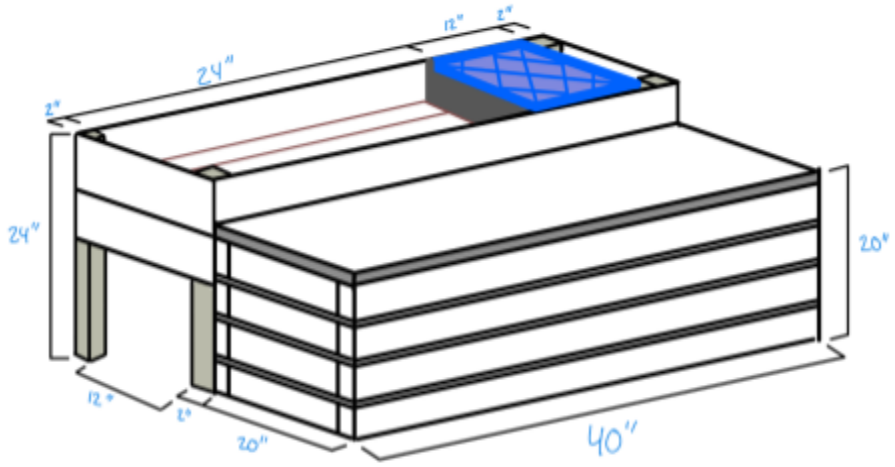


Fig. 3: Prototype Dimensions

The Xylobench consists of two main compartments: the seating bench and the planter box. In the design above, the bench is measured to be a total 40” x 20” x 20” (L x W x H). The main storage compartment below the bench contains the electronic box, pump, and water tank below the seat, which can be accessed by lifting the seat handle. Furthermore, the team plans to design an elevated planter box with similar dimensions of around 40” x 16” x 24” (L x W x H), and have rainwater and recycled gray water captured by a pre-filter situated within the planter box. This water is then funneled through a pipe that connects to the main tank below, as seen in Figure 2. In addition, a water pump will be used to transport water from the water container through ¾” PE tubing pipes. This pipe is connected to the outlet of the pump and then lined outside on the planter box, where a few mist sprinklers are attached along the pipe.

The team has selected to use a combination of Douglas Fir and cedar wood, known for their versatility, weather and rot resistant properties, and durability for outdoor environments at an affordable price. The inside of the planter box will be surrounded with a pot liner to help retain soil moisture, protect the wood from degradation, and control plant growth. Holes will also be drilled into the bottom of the planter to provide a passage for excess water to escape and prevent root rot.

ELECTRONICS

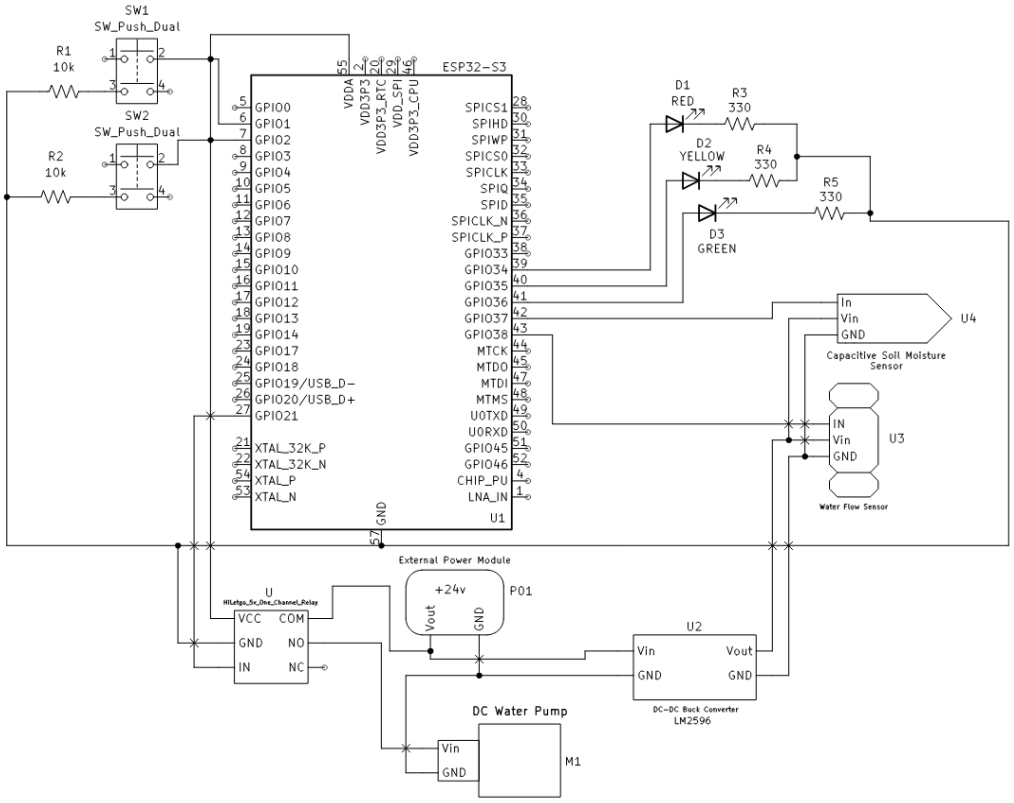


Fig. 4**:** Schematic Diagram of Electronic Circuit.

Figure 4 above is a schematic drawing of the electronic circuit, containing a battery power supply, a microcontroller, a relay module, a pump, and two sensors. The team plans to use a 24V aquarium pump rated at 20W with a maximum lift of 9ft. The team selected a 24V 2.6mAh rechargeable battery to serve as the project's main power source and to accommodate the pump's voltage requirement of 24V. The relay module is a device that operates similarly to a switch and serves to turn off and on the pump through the ESP32 microcontroller's logic when conditions are met. A voltage regulator is connected between the battery and microcontroller to decrease the voltage to a safe level of 5V that the microcontroller can operate at. Furthermore, two sensors—the soil moisture sensor and water flow sensor—will be connected to the ESP32-S3 so that data can be read. All components will then be grounded back to the battery.

To ensure that the XyloBench works efficiently, we plan to incorporate an overflow diversion system and a warning signal light. Once the water container reaches full capacity, the excess water will be redirected outward via an overflow hole. The hardware in the container is also tightly integrated with software that gathers real-time data from the sensors to inform the system's behavior. Such software includes the use of a flashing LED light to alert users of

immediate maintenance problems, a much more user-friendly alternative than the original dashboard users must log into.

To further strengthen the system, a manual override feature would be included. In the case where the sensors or pumps stop working, the property manager or maintenance team would be able to manually operate the valves, pumps, and controls. This ensures that water can still be managed if any of the components fail. This fail-safe feature is crucial to preventing unintentional damage or system failure and adds an extra layer of security to the design.

WEBSITE

Beyond the bench engineering, our team is developing a website to enhance customer interaction with the product. The platform features a dedicated FAQ section, allowing customers to quickly find answers to common questions or connect for additional support. It also includes a purchasing section, making it easy for customers to buy the product directly through the site. In addition, the website highlights the people behind the project, giving customers a sense of transparency and trust. Together, these features improve accessibility, streamline the buying process, and create a more engaging user experience. Attached is a link to the website: https://studio--studio-3477173669-dff99.us-central1.hosted.app

PACKAGING AND SHIPPING

Packaging is an essential part of delivering the XyloBench to our buyers with utmost customer satisfaction in mind. We opted to package our product in corrugated boxes sourced from biodegradable kraft material, offering better protection during shipping and handling, while retaining our emphasis on sustainability. We will also optimally package each component by using specially designed inserts and paper void fill to reduce material costs and minimize void space.

For ease of transportation, our product will be disassembled into multiple flat parts, which can be easily reassembled. To keep parts organized, a separate cardboard box will be used to contain electronic components that can be easily plugged into a singular device for simplicity. A foldable manual will be included in the box with step-by-step instructions on how to assemble the bench and planter box. A QR code will also be imprinted on the manual and package to access the product’s website. Each piece will be labeled for ease of identification and accessibility.

TARGET CUSTOMERS AND USAGE

The XyloBench is designed for a wide range of shared urban spaces where benches are both practical and essential. Its natural design makes it a fit for college campuses, apartment complexes, shopping plazas, senior care facilities, community gardens, and other communal environments with regular staff presence for upkeep. Private ownership in these spaces allows for easy management and maintenance, while the shared nature of these settings ensures that the benefits extend to entire communities rather than just individual households.

The XyloBench was originally conceived to help beautify neighborhoods lacking green coverage and continues to do so by targeting private developers of various urban public spaces. While priced competitively against traditional benches, the product still represents a meaningful investment for individual families. For this reason, the model is best suited for purchase by institutions or property managers, who can distribute its benefits across the communities they serve.

Different audiences may benefit from the Xylobench in slightly different ways that directly align with their needs. In addition to its basic function as a place to sit and rest, the XyloBench enhances architectural appeal and provides a functional, sustainable amenity with minimal added costs. By adopting this model, college campuses will attract students interested in the schools' sustainability missions and programs while showcasing the potential of student innovation. At the same time, the XyloBench's unique features will attract clients seeking modern and environmentally friendly living spaces, an added benefit to property developers. For residents of senior care facilities and apartments, they will benefit from the calming presence of greenery, a natural means of stress relief and relaxation. Community gardens that integrate the XyloBench into their spaces can grow some flowers, herbs, or fruits in the planter to complement existing plants while producing supplementary nutrition for growers. Across all of these applications, the XyloBench offers a shared asset for healthier living that enriches communities and promotes reconnection with nature.

EXPECTED IMPACT

SHORT TERM

In the short term, the Greengineers aim to establish the XyloBench as a visible and accessible source of greenery in urban communities that lack regular contact with nature. By placing these benches in targeted shared spaces, they introduce restorative pockets of plant life into areas where greenery is scarce. Each installation serves not only as functional infrastructure but also as a community symbol,

Fig. 5: Concrete Bench, CSULB

showing how sustainable design can make neighborhoods both more livable and more beautiful.

Early introductions to communities will also act as catalysts for engagement. Residents, students, and caretakers will interact daily with the greenery, experiencing its calming effects and tangible improvements to air quality and the surrounding atmosphere. While a single bench may seem modest, the cumulative impact of XyloBenches, especially when paired with other greening initiatives, helps absorb carbon dioxide, reduce urban heat, and expand the green coverage on maps of dense city environments.

At the same time, the XyloBench's natural design offers more than utility: it provides a space for people to slow down, rest, and even connect with those around them. Unlike metallic or concrete benches that signal brief stops, the wood and planter combination invites longer moments of ease, stress relief, and reflection. From beautification to health and wellness, the XyloBench reimagines one of the simplest forms of public infrastructure, the seating bench, as a tool for diversifying the urban landscape.

LONG TERM

Looking ahead, the Greengineers hope to improve the XyloBench beyond the current design to create a more long-lasting, sustainable, and inclusive product. While the current prototype focuses on proving the value of adding plant life to shared infrastructure, future versions may integrate solar panels, charging stations, and glass-lined water containers to improve the bench's durability and reduce its carbon footprint. These features are currently not included in the prototype due to cost, packaging, and expertise constraints, but the team considers them potential extensions to the bench once it enters production and sales. For instance, investments in solar energy will limit the hazardous waste generated from used batteries, providing a more sustainable source of energy. Meanwhile, charging stations will increase comfort and convenience for those who sit on the XyloBench. To ensure the longevity and sustainability of the tank itself, we also propose testing glass-lined materials, which are durable and rust-resistant despite constant exposure to environmental elements. The durability of this material guarantees a long operational lifespan while also requiring low maintenance and associated costs, making it an economical solution for urban communities. Therefore, the team aims to explore glass and recycled material substitutes in place of the current wood foundation to ensure that the XyloBench grows even more durable and environmentally responsible over time.

Just as importantly, the Greenginers intend for future versions of the XyloBench to strengthen community ownership and participation. Cities and community groups would be able to adapt the benches to local needs by working with our team to include additional tailored features. For instance, many bus stops prioritize an overhead cover to provide shade and rain protection to travelers. Our team has considered this feature several times throughout our design stage, but decided against it because it will compromise the filter's ability to collect rainwater and pose installation challenges for generic buyers. Furthermore, some of our targeted audiences, namely,

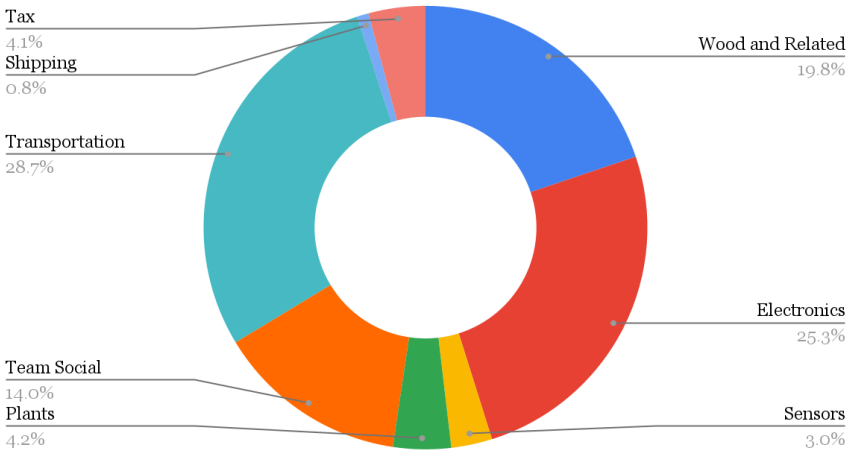
shopping plaza owners, will prefer to cut costs and installation times rather than include shade covers for some minor weather protection. The current XyloBench prototype and original design for sale will not include this feature, but in the long term, our team is willing to explore mesh and other canopy materials to accommodate the needs of bench contractors for transportation hubs and buyers who value the comfort of shade coverage.

In addition to long-term design changes, another key goal is accessibility for underserved and low-income communities, where green infrastructure is most lacking. Despite many simplifications, the Greengineers recognize that sales of $600 benches to low-income households are still unrealistic. By reducing costs per unit of production and seeking sponsorship from government grants, the Greengineers aspire to further reduce production costs and eventually extend an impactful, yet budget-friendly model of the XyloBench to low-income communities. As more benches are installed, their collective impact will become increasingly visible. Each unit could help absorb carbon dioxide and contribute to cooler surroundings, while also inviting residents to pause, rest, and connect. Taken together, these contributions would make poor urban communities healthier and more livable, with greenery and comfort woven into familiar public spaces.

Ultimately, the XyloBench is only the beginning. We see it as one step among a broader set of green infrastructure initiatives that blend functionality with sustainability. The XyloBench may just be one product, but in collaboration with other community projects, our team hopes to see gradual change towards the way that we envision our dream communities to look like. In the long run, we envision entire neighborhoods dotted with products like the XyloBench, working together to transform overlooked urban spaces into vibrant, healthy, and environmentally resilient communities.

BUDGET PLAN

Fig. 6: Budget Breakdown



While a detailed breakdown of our budget proposal can be found here, Figure 6 summarizes the general allocation of our expenses, with about $476.10 of our budget devoted to physical materials for the construction of the prototype and the remaining money to travel and team social expenses. Transportation costs occupy a significant fraction of the current spending breakdown due to commutes for in-person team meetings and an allocated $100 for travel expenses following this report's submission. Field research came at no cost because we primarily toured California State University, Long Beach, for comparative bench designs. Meanwhile, prototype testing only requires our team members to sit on the bench and examine the components ourselves. Based on the costs of raw materials, we expect the XyloBench to sell for about $600 after a price markup. Compared to our previous design, estimated at $1500-$2000, this simplified prototype offers a much more affordable and marketable product for customers.

Phase 1 long-term maintenance and operational expenses of $656.16 annually have also decreased significantly to about $10-$50 every other year after we eliminated cloud services on our software side and the wall attachment on our engineering side. Customers will need to do minor upkeep with the filtered debris, battery replacement, and some routine maintenance check-ups, but there will be no major costs to the customers. If any equipment breaks down, customers may refer to our website's FAQ section for basic repair information or search online for instructional videos. Customers may also leverage artificial intelligence tools to their advantage to speed up the repair process with quick identification of mechanical problems and the necessary steps to resolve them. All of our components are purchased from digital platforms and stores easily accessible to the general public, so replacements should not be difficult to come across. As the team expands in its production of the XyloBench, our team hopes to continue lowering costs to make the sales price even more affordable for all community members.

MARKETING AND SALES

To launch test sales of our initial XyloBench model, the Greengineers have developed a dedicated e-commerce website for customers to place orders. This digital platform minimizes the operational costs of a physical store while allowing us to scale sales beyond our immediate geographic region in Southern California. To address the challenge of product visibility, the Greengineers will schedule pilot installations in select public spaces to ensure that potential buyers can interact with the bench firsthand. Demonstration events will remain part of our marketing strategy, but will be complemented by the lasting visibility provided through these public placements.

Given Los Angeles's geographic proximity and its Green New Deal commitment to expanding canopy coverage, local communities represent a strong initial test market. The Greengineers will engage city officials to explore partnerships that align with the government's sustainability and green infrastructure goals. Using landscape mapping, the Greengineers will then identify several

other cities with similar strong green programs to appeal to. Collaborations with Los Angeles will provide lessons and testimonials that the Greengineers can leverage when pitching to new cities and buyers. City archives and public planning documents will guide our outreach process to ensure that our marketing strategy aligns with local needs and development goals.

At the same time, the Greengineers will target private buyers such as housing developers, senior care facilities, and shopping plazas to serve as early adopters of the XyloBench since they often have shorter decision timelines than bureaucrats. This dual approach reduces reliance on slower city contracts while broadening the customer base. To appeal to multiple audiences, the Greengineers will pursue a diversified approach that combines pilot community installations, demonstration events, and strategic digital marketing. Demonstration events on special occasions like Earth Day will offer limited discounts or special add-ons to encourage an immediate increase in sales, whereas year-round advertisements at local events and sustainability fairs will maintain the bench's market visibility. While these demonstration events establish the bench's presence in person, the Greengineers will also collaborate with sustainability bloggers and influencers to expand our audience reach online on social media accounts. Content will be tailored for eco-conscious consumers on platforms like Instagram, and case studies will be shared on LinkedIn to target developers and business professionals. Short installation videos, product updates, and promotional videos will be shared on these media accounts as well to supplement the official notices on our website.

While local officials and private developers are important client considerations, local nonprofits and grassroots organizations are also essential allies to strengthen community trust. In collaboration with well-known local stakeholders, the Greengineers will seek to form co-branded sponsorships with them. Customers may not recognize the Greengineers or the XyloBench as foreign introductions to the local neighborhoods, but association with existing organizations will help with name recognition and increase the likelihood of purchases. The Greengineers will also establish donation-matching programs with broader community organizations to expand partnerships beyond sustainability-focused groups. For example, the Greengineers can pledge to contribute supplies or money to community programs for every sales benchmark reached. Such joint events enable the team to leverage the organization's local networks for credibility and reach while mutually benefitting from the matching program.

The XyloBench is not just a traditional bench for outdoor seating–it is an investment in individual wellness, local property value, and a sustainable future. It offers a beautiful model of urban green integration beneficial to all ages in a community, a differentiation that will certainly be highlighted across all marketing channels.

COMPETITIVE ANALYSIS AND PRICING

XyloBench stands alone in a fragmented market where existing products address only partial parts of the problem. At the low end, conventional benches with built-in gardens are commonly found at popular retailers and typically cost $100–$350, but they lack irrigation capacity. Users must water manually or install separate systems, limiting convenience, sustainability, and long-term plant health. Unlike these basic models, XyloBench integrates an autonomous irrigation system with its own rain- and greywater-fed reservoir, making it both self-sustaining and uniquely suited to environments where external water access is limited. There do exist planter benches that utilize self-watering beds, which rely on capillary action, a process in which water gradually moves upward through the soil from a hidden reservoir to keep the roots moist. While this method improves water efficiency and reduces maintenance, and eliminates the need for any sort of electronics that the XyloBench implements, it is limited to being effective for only small plants with shallow roots, cannot scale to larger or more diverse types of plants, and lacks the automation and greywater reuse that XyloBench provides. Additionally, with prices ranging from $1,499 to $4,500, these benches are far too costly for communities with limited resources. With the parts list curated for the XyloBench, the bench is aimed to sell for around $600, a price point that balances affordability with technology. This range is significantly lower than existing planter benches with self-watering beds while still covering the cost of integrated irrigation hardware, filtration components, and sustainable construction materials. By keeping the price within this bracket, XyloBench remains accessible to low-income and resource-limited communities, aligning with its mission to deliver both functionality and social impact at a fraction of the cost of comparable alternatives.

Though not designed as furniture, several products resemble the auto-irrigation function of XyloBench. Leading companies like Rain Bird, Hunter Industries, and Rachio offer programmable systems for gardens, landscapes, and container plants that operate through smartphone scheduling and external water connections, making them effective for tech-savvy users. However, the communities XyloBench targets are less likely to adopt such systems due to their complexity and infrastructure requirements. In addition, these products depend on municipal water supplies and Wi-Fi, which restricts where they can be deployed. XyloBench overcomes these barriers with a built-in reservoir for rain and greywater storage and electronics that function independently of internet access. Other companies, such as Claber, offer systems that eliminate electronics by using a gravity-fed drip mechanism, where water droplets fall naturally onto the soil to maintain consistent moisture levels. While this simplicity can benefit plant health, these systems are limited to small plants and pots and do not scale to larger installations. As a result, they offer minimal flexibility in plant choice compared to the XyloBench, which supports more diverse and expansive setups.

Current market trends show rising demand for outdoor furniture that is both functional and visually appealing, particularly in public urban spaces. The global public bench market is

projected to nearly double from USD 2.3 billion in 2023 to USD 4.8 billion by 2033, reflecting a steady 7.8% annual growth rate (Verified Market Reports, 2025). Municipalities and community organizations are increasingly investing in durable benches that enhance parks, streetscapes, and recreational areas, with multifunctional designs such as integrated planters or storage becoming more desirable. At the same time, the broader smart city infrastructure market is projected to grow at an impressive 22% annually from 2023 to 2033, signaling rapidly expanding demand for sustainable, technology-enabled solutions in public areas. While the market for public benches is highly competitive, XyloBench is positioned ahead of the curve by uniting seating, autonomous irrigation, and sustainable water sourcing in a single, affordable product that delivers both social and environmental value for underserved communities.

In conclusion, there is no existing competitor that offers a system unifying seating, auto-irrigation, and sustainable water sourcing like the XyloBench, and with a clear and growing demand for greenery in urban communities, the product is positioned to fill a critical gap by delivering affordable, scalable, and environmentally conscious infrastructure where it is most needed.

RISK MANAGEMENT

The team has previously identified potential risks affecting four main categories on our prototype: mechanical, hardware, software, and operations. As such, the team has continued to monitor and develop strategies to mitigate each subsystem risk. Risks are labeled and tracked on a Risk Matrix, shown in Fig. 7, based on how likely the risk will occur and how severe its impact will be to the project. This is all graded on a scale from one to five, with ‘one’ being of the lowest concern and ‘five’ being of the highest concern.

MECHANICAL

This section pertains to mechanical risks that can be present on the project and the methods the team has employed to mitigate each risk. The project can encounter issues with pipes clogging from the buildup of fallen leaves and debris in the collector (Risk ID: M1). Consequently, this can lead to backups and pressure build-up, leading to leakage and damage of the product (Perry A.J.). To mitigate the issue, the team has implemented a collector with a removable pre-filter grill and a smaller secondary mesh grill to prevent large debris, such as leaves or plastic objects, from entering. In addition, we installed a flow sensor between the pump and tank to help detect any potential impedance in the pipe flow. A trigger within the embedded code will warn us if such an issue arises through the use of LED lights. To ensure proper pipe protection, we used sealant tape around the connections and kept a consistent pipe diameter of ¾” to further minimize leakage.

Another major concern is overflow of water during harsh weather conditions (Risk ID: M2). In seasons when heavy rain is frequent, water can overflow in the container and cause water to spill

across the bench. To mitigate the issue, the team included a small overflow hole near the top of the water container to divert excess water out of the box. In addition, the wood will be stained to extend the bench's longevity in outdoor places when exposed to the environment.

HARDWARE

Inadequate power is a hardware risk (Risk ID: H1) due to the possibility of high power demand or an aging power source, where the battery may not be able to handle the power requirement as needed. This can cause the system to underperform and sensors to function abnormally. To mitigate the issue, the team has selected a rechargeable 24V 2.6mAh battery with an adequate current buffer to ensure that the entire system receives ample power over its long cycle. In addition, a buck converter and voltage regulator will be used to consistently provide a constant voltage to the smaller components and ensure that no voltage spikes occur.

A massive hardware risk is the possibility of the electrical circuit coming into contact with moisture (Risk ID: H2). Due to its proximity to the water pump and water tank, there is a potential chance of water entering the enclosure, which can permanently fry and short the electronics if not properly insulated. The team mitigated the issue by isolating the electronics in a separate watertight housing, with minimal openings for wires to pass through, to prevent possible entrances for water. Likewise, we created a special enclosure for our moisture sensor and applied silicone to insulate and waterproof the exposed PCB from coming into contact with water when placed in the soil.

SOFTWARE

One risk involves inconsistent readings of sensors (Risk ID: S1) due to a faulty product or incorrect installation. This could possibly reduce the effectiveness of the sensor, which would cause issues with monitoring plant health and possibly require the sensor to be replaced soon. To mitigate the risk, we selected a robust sensor capable of being placed in outdoor environments. Likewise, the team will ensure that the wiring of components is properly configured and will perform testing to discover whether or not the sensor is working properly.

OPERATIONAL

In addition to the many risks previously identified, the project can be accompanied by other non-engineering risks such as user error, time constraints, or work location issues. One risk involves the handling of the product and its components (Risk ID: O1). Given that users may be unfamiliar with assembling the product or are unsure of how to operate the system, the product can be unintentionally damaged. To mitigate the problem, the team will provide an online website for guidance on how to provide periodic maintenance, how to understand the bench's interface and functionality, and other relevant FAQ information, such as shipping or durability of the product.

A second operational risk follows scheduling difficulties with the team (Risk ID: O2). Given that each team member has other commitments, such as academics, employment, and other obligations, it can be difficult to find a suitable time where everyone is available to meet and collaborate on the project together. To mitigate the issue, the team plans to use *When2Meet* to gauge each person's availability to find a time that works best for the majority of the team. Likewise, the team will attempt to maintain frequent communication and engage with the project to maintain activity. Therefore, the risk has been deemed low.

The final operational risk identified involves difficulty with finding a suitable workspace for building and testing the project (Risk ID: O3). Given the team's limited access to facilities and expensive equipment, it can be difficult to find a location where the product can be built and tested before the competition. To mitigate the issue, the team has approached the problem by using their school's engineering makerspace to access machine tools. In addition, the team will convene at home and use any available tools, such as saws and drills, without having to allocate money towards purchasing expensive equipment. This situates the risk as a low risk.

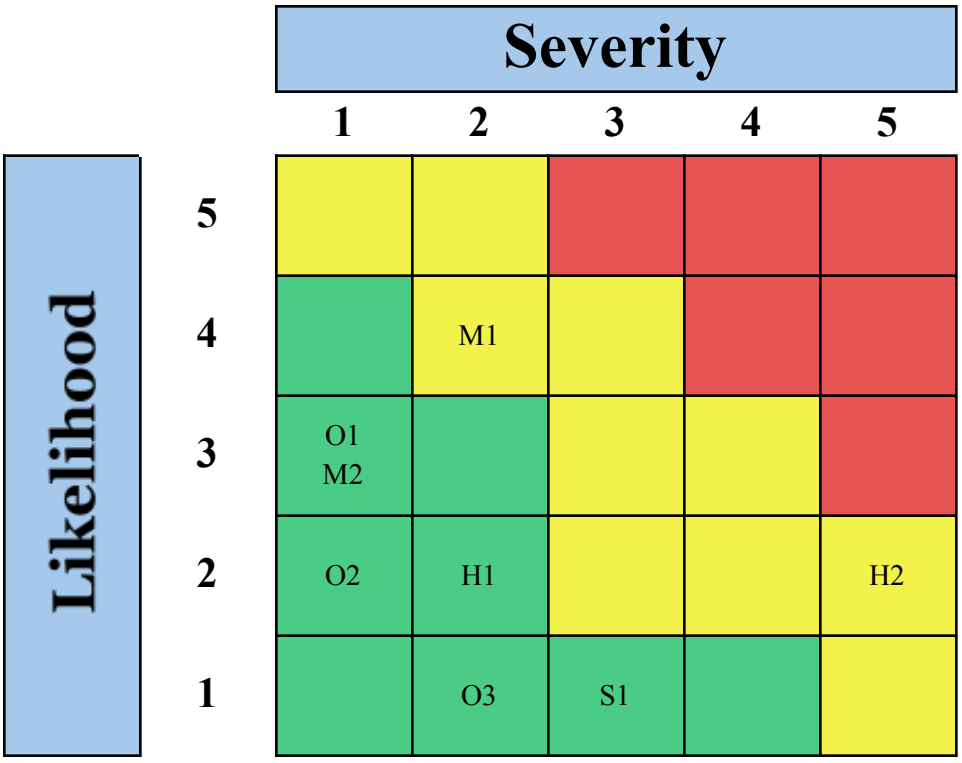


Figure 7: Risk Matrix

PHASE 2 TEAM REFLECTIONS

During Phase 2, our team meetings were structured around solving our challenges from Phase 1 in order to align all components toward a fully functional and market-ready prototype. The team identified the importance of communication and would frequently share updates about both our strengths and areas for improvement. The Greengineers maintained consistent communication about their availability for online and in-person meetings despite our busy schedules as students and discrepancies in quarter and semester systems. Another major success was our responsible and effective use of Artificial Intelligence, particularly through tools like Perplexity and ChatGPT, widely known for their web searching abilities, which aided in gathering and summarizing research sources before validating them through direct review, and improved flow and word choice for our report. This not only organized our research process but also helped us practice critical evaluation skills. We diversified our approach to project management by developing and maintaining a Gantt Chart to track progress and timelines. Our engagement during workshops and training presentations was steady, with an average workshop attendance of four members. We ensured active participation and collaboration. Additionally, input from Subject Matter Experts (SMEs) enriched our work by providing practical insights and professional perspectives. The SMEs that our team met with were Jane Louie, who supported us with defining the “why” behind our prototype and how that would create real community value and lasting impact. We also met with Bruce Watanabe, who assisted with clarifying our branding and ability to reach target audiences in interactive ways. The Greengineers are planning to meet with our third and final Subject Matter Expert, Dr. Amip Shah, next week on September 30th over a Zoom call. Through these experiences, the team strengthened its project management, research, and critical thinking skills, while also recognizing opportunities to further improve efficiency and consistency in future projects.

CONCLUSION

In conclusion, the XyloBench represents more than just a functional piece of outdoor furniture; it is a step toward reshaping urban infrastructure into something more sustainable, inclusive, and restorative. By uniting seating, greenery, and autonomous irrigation in one accessible design, it addresses both the environmental and social inequities that define many city landscapes. While the current prototype lays a strong foundation, future iterations hold the promise of even greater resilience, affordability, and adaptability for diverse communities. Ultimately, the XyloBench represents a vision for how cities can reconnect people with nature, improve quality of life, and create a greener future for generations to come.

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