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Agriculture: Innovations in Vertical Cultivation Systems for Community Development

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Abstract. This paper explores potential barriers to the adoption of soil-less, small-scale hydroponic systems operated through digital technology within gardening communities and related projects. It investigates whether these communities view a technology-driven approach to food cultivation as limiting. The backdrop of the COVID-19 pandemic highlights interconnected challenges spanning food security, climate change, and economic turmoil. Disruptions in global supply chains and economic activities resulting from the pandemic have precipitated an economic crisis, income disparities, and increased food insecurity. Agricultural disruptions have exacerbated food security issues, while climate change-induced extreme weather events further jeopardize food systems. This economic crisis impedes effective climate change mitigation and adaptation. A holistic approach is crucial, integrating sustainable agriculture, resilient food systems, and climate change strategies. Collaboration among governments, researchers, and communities is vital for enduring food security and sustainable economies. The Hydroponic Verticulture System (HVS), a modern urban agricultural technology, offers a practical solution that fosters urban farming, ensures food quality, and supports community engagement. A full tank of water or mixed organic material of 13.5 Liter with 5rm speed provided sufficient watering for effective nourishment and hydration throughout the vertical system. Furthermore, HVS contributes to climate change mitigation by reducing CO_2 and increasing O_2 levels through smart urban farming practices, aligning with environmental sustainability goals.

1 Introduction

A vertical hydroponic system is a method of urban farming that involves growing plants in a vertical arrangement, often indoors or in limited spaces, using a hydroponic growing technique. Hydroponics is a soilless method of cultivating plants that relies on a nutrient-rich water solution to deliver essential nutrients directly to the plant roots. The Covid 19 pandemic has caused the Malaysian monetary system to change due to the activities of companies that had to be temporarily stopped during curfews or movement restrictions (MCO). Food safety

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is one of the areas that has been significantly affected by Covid 19 as stated by (Tan et al., 2022). There are trade restrictions, supply chain disruptions and lower agricultural production as a result of the economic challenges it poses. This situation has affected the Malaysian economy as well, putting many households in a difficult financial situation.In a vertical hydroponic system, plants are stacked in layers, often using shelves or towers, allowing for efficient use of vertical space. This approach is particularly valuable in urban environments where land space is limited, and growers need to maximize their production in smaller areas [4,15]. The worst case, continuous and intensive cultivation can lead to soil erosion, loss of soil fertility, and degradation of arable land, reducing its long-term productivity. Moreover, the conventional farming often relies heavily on water resources, which can lead to over-extraction of groundwater and depletion of water bodies, contributing to water scarcity in certain regions. In addition, reliance on synthetic pesticides and fertilizers can lead to soil and water pollution, as well as the development of resistant pests and weeds, posing risks to human health and the environment. Basic vertical hydroponic system normally works as the planting medium. Instead of traditional soil, plants are usually grown in inert planting mediums like perlite, coconut coir, or rock wool [1,12]. These mediums provide support to the plants and allow for proper root development. A nutrient solution containing all the essential nutrients required for plant growth is circulated through the planting medium to provide the plants with the nutrients they need. This solution is often recirculated to minimize waste.

[21] posit that Internet of Things (IoT) systems have significantly enhanced agricultural productivity by boosting yields. The previous 60 peers-reviewed publications (2016-2018) proved the intervention of sensors and technologies for water management and crop management enhance the productivity efficiency. Nevertheless, this research interest has the present knowleadge gap in scalability, diversity considerations, architectural aspects of IoT systems, extent of land or agricultural coverage, and energy provisions constitute the various dimensions encompassing IoT system dynamics. Further, smart agriculture presents a route to realizing Sustainable Development Goal 2, offering inventive avenues for cultivating a more economically viable, adaptable, and environmentally conscious agricultural and food framework. Additionally, an emphasis on regional strategies emerges as instrumental in ensuring food security [2, 5, 12]. [22] had developed an intelligent gadget designed to automate the cultivation of vegetables named of MicroCEA within the confines of urban indoor residences in the United Arab Emirates, a region where approximately 80% of the food is brought in from outside sources. Indeed, the IoT system intervention in smart farming eased many people either indoor or outdoor cultivation. Further, [23] also supported that technology like artificial intellegence (AI) enhanced the complicated challenges in soil and crop management dynamically. Incorporating AI technology into soil and crop management, the Multiponics Vertical Farming (MVF) system shows great potential for enhancing cultivation productivity.

Vertical hydroponic systems offer several advantages for urban farming such as space efficiency. By growing plants vertically, we can produce a larger volume of crops in a smaller footprint compared to traditional farming methods. Moreover, hydroponic systems generally use less water than traditional soil-based farming because water is recirculated within the system. Indoor hydroponic systems provide better control over environmental factors such as light, temperature, and humidity, which can result in more consistent and predictable crop growth. With the right lighting and environmental controls, you can grow crops year-round, regardless of external weather conditions. Vertical hydroponic systems can be customized and scaled to fit different spaces and crop varieties. However, setting up and maintaining these systems can be complex and require careful attention to detail. Proper knowledge of hydroponic techniques, plant biology, and system management is essential for successful urban farming using vertical hydroponics. Since vertical hydroponic systems are often used indoors or in spaces with limited natural sunlight such as flats, apartments and condos, artificial lighting sources like LED grow lights are used to provide the necessary light spectrum for photosynthesis. Basically, plants are arranged vertically in layers to maximize space utilization. This arrangement allows for higher plant density and increased yield per square foot. Monitoring parameters such as nutrient levels, pH, temperature, and humidity are crucial to ensure optimal plant growth. Many modern systems include automated controls to maintain these factors within the desired ranges.

Agriculture has historically been a significant sector of employment, particularly in developing countries where large portions of the population are engaged in farming, livestock raising, and related activities. The exact percentage of the global population working in agriculture can vary depending on the region, economic development, technological advancements, and other factors. Most notably, agriculture is essential to the existence of the majority of people in South and Southeast Asia. This shows the importance of agriculture as an element in preventing interruptions in the food supply. A statement issued by [12] increased urbanization across the continent, resulting in a lack of available land and a lack of local production of green vegetables, food security and sustainability is a major challenge for all regions. Meanwhile, natural resource scarcity and climate change pose a threat to global food security. To overcome this problem, the Hydroponic Verticulture System (HVS), was developed for urban communities in urban agriculture activities with guaranteed food quality and human health, is a modern urban agriculture technology that most practical. Importantly, smart urban agriculture has potential for reducing the amount of CO_2 and increase the level of O_2 in balancing the environmental sustainability. According to [8,16] vertical agriculture tailored with the sustainability of our cities and food security to cater demand of growing urban population [20].

2 Introduction

2.1 Material Selection

To provide a comprehensive and informative experience for users, Transparent Perspex (acrylic sheet) was selected as the best material for VHS to cover all sections of the frame, including the sides and the top, adhering to the specified dimensions. The decision to utilize this particular material serves a crucial purpose: it allows for clear visibility into the inner workings of the tank and enables users to observe the mechanical functions and monitor the water level. The selection of Transparent Perspex empowers users with the ability to witness and comprehend the intricate processes and functionalities that take place within the tank. This deliberate choice of Transparent Perspex not only serves a practical purpose but also highlights the project's commitment to transparency, education, and providing an engaging user experience.

2.2 Data Collection

Derived from an expansive inquiry conducted using a Google Form, numerous creative concepts for structured vertical farming have surfaced. The outcomes of the survey encompass a wide array of viewpoints and understandings, laying the groundwork for the subsequent impactful declaration: By leveraging the potential of thorough surveys, our advanced notions for systematic vertical cultivation are motivated by a wealth of knowledge, nurturing groundbreaking products that transform the trajectory of agriculture in the days ahead. The operational system of vertical hydroponic system (VHS) as illustrated in Figure 1.0.

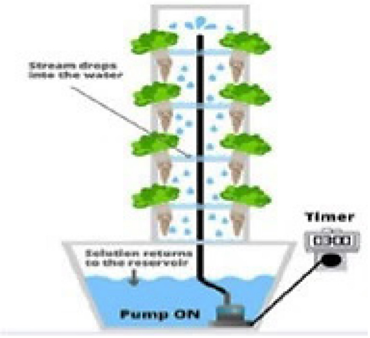

Fig. 1. The operational system of vertical hydroponic system (VHS)

2.3 The Development of Vertical Hydroponic System (VHS)

Utilizing Computer-Aided Design (CAD) streamlines the design and measurement process, offering enhanced simplicity and versatility. The CAD design ensures compatibility with the manufactured size, while the precise and organized layout facilitates accurate representation. Figure 2 showcases the 3D CAD drawing created using SolidWorks software, accurately reflecting the correct size and dimensions. Figure 3 (a) presents the front view of the product, while Figure 3(b) and Figure 3(c) depict the top and side views, respectively, providing a comprehensive visual representation of the designed product. While the entire component of the VHS as illustrated in Figure 4 and Table 1.0.

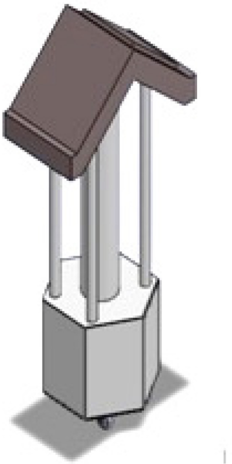

Fig. 2. Rendering

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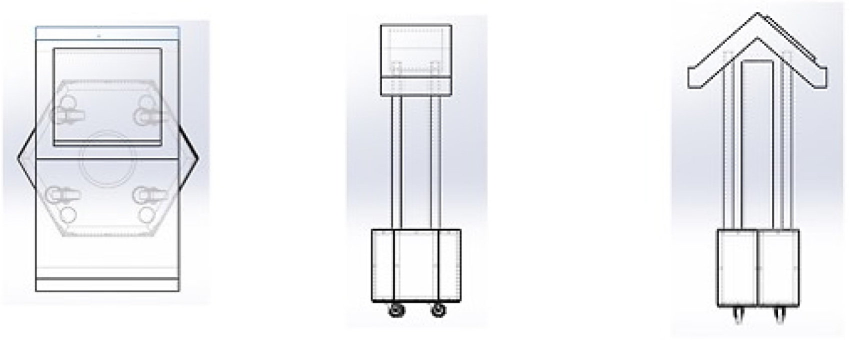

(a) (b) (c)

Fig. 3. (a) Top view, (b) Front view and (c) Side view

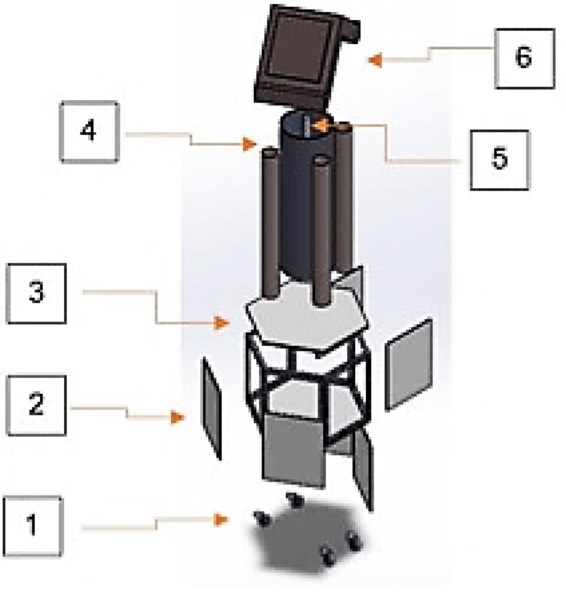

Fig. 4. Components of VHS

Table 1. Product Components.

Item no.	Component
1	Wheel
2	Perspex
3	Frame
4	Pipe PVC
5	Water Hose
6	Stand Solar

Leveraging the design capabilities of SolidWorks, Hydroponic Vertical System (VHS) was developed through meticulous development process, ensuring precision in design, sensors system installation and appropriate material selection. This product nexus of many elements of manufacturing and systems installation. The Node MCU ESP32 is a popular development board that integrates an ESP32 microcontroller with built-in Wi-Fi and Bluetooth capabilities. It provides a convenient platform for prototyping and building Internet of Things (IoT) projects. With its powerful dual-core processor, GPIO pins for interfacing with various components, and support for programming environments like Arduino IDE and ESP-IDF, the Node MCU ESP32 enables developers to create connected devices and applications that can connect to wireless networks, communicate with other devices, and perform a wide range of IoT tasks. This commitment to excellence has resulted in an exceptional product that combines innovation, functionality, and optimal performance. A completed vertical hydroponic system (VHS) embedded with Node MCU ESP32 and micro phyton and solar panel as in Figure 5.

Fig. 5. A completed vertical hydroponic systems (VHS) embedded with Node MCU ESP32 and micro phyton and solar panel.

This research product utilized the programming an ESP32 Node MCU involves utilizing Micro Python, an embedded variant of the Python programming language that has been meticulously optimized for microcontrollers. With Micro Python, developers can seamlessly write and upload code to the board, enabling them to leverage Python's simplicity and user-friendliness for their IoT projects. Through this language, the interaction of GPIO pins, control peripherals, establish Wi-Fi or Bluetooth communication occurred, and executed other specific tasks of monitoring the soil moisture, light intensity and water level in the tank or container essential to their project from mobile phone [23]. The code, authored on a computer, is then transferred to the ESP32 Node MCU board, where it is executed by the Micro Python interpreter, empowering the board to carry out its intended functionalities. A soil moisture sensor is a device used to measure the moisture content or the water level in the soil. Its main function is to provide information about the soil's moisture level, which is crucial for various applications such as agriculture, gardening, and environmental monitoring. The primary function of a soil moisture sensor is to measure the electrical conductivity or resistance of the soil, which is directly related to its moisture content. The sensor consists of two electrodes that are inserted into the soil. When the soil is dry, it has higher resistance, while when it is wet, it has lower resistance. By measuring the resistance, the sensor enabled determine the moisture level of the soil. A water level sensor was installed to measure and indicate the level of water in a container or a body of water. Instead of its main function on providing information about the water level, however it allowing for various applications such as water tank monitoring, and water level control systems [14, 15, 16, 22].

The primary function of a water level sensor is to detect the presence or absence of water at a specific level. It typically consists of a sensor probe or probes that come into contact with the water. The sensor utilizes various principles, such as conductivity, ultrasonic waves, or pressure, to determine the water level accurately. It provides essential data for tank monitoring. By accurately measuring the water level, the sensor enables efficient control, monitoring, and management of water resources of VHS. The DHT22 temperature and humidity sensor serves several functions related to monitoring and optimizing environmental conditions for plant growth. The DHT22 sensor data was used to determine the moisture requirements of plants indirectly. Temperature and humidity readings of VHS indicating the evaporative demand of the environment, allowing the user or household to adjust watering schedules accordingly. Maintaining appropriate humidity levels can help prevent overwatering or underwatering, optimize water usage, and minimize plant stress. A light-dependent resistor (LDR), also known as a photoresistor or photocell, is a sensor that detects and responds to changes in light levels. Its main function is to measure the intensity of light in its surroundings. The resistance of an LDR varies based on the amount of light it is exposed to, allowing it to be used in various applications. The primary function of an LDR sensor is to provide information about the light levels in the environment. The resistance of the LDR decreases as the intensity of light increases, and vice versa. A water pump with a 5m lift and DC 12V refers to a specific type of pump that to lift water vertically to a maximum height of 5 meters using a direct current (DC) power supply with a voltage of 12 volts.

In addition to the other materials, PVC pipe plays a significant role in this project. With a diameter of 3 inches and a length of 4 feet, the PVC pipe offers an affordable and accessible solution for the intended purpose. This versatile component was employed to accommodate black plastic cups used for planting. By utilizing the PVC pipe, a hydroponic system can be constructed with remarkable efficiency. The design allows for the balanced placement of up to 15 cups, facilitating the cultivation of multiple plants simultaneously. The PVC pipe's structural integrity and affordability make it an ideal choice for this application, providing a cost-effective and practical solution for creating a hydroponic environment. Through the integration of PVC pipe, the project combines affordability and functionality, enabling the successful implementation of a productive and sustainable planting system.

Another important use of UV LEDs in agriculture is for pathogen control. UV-C light, particularly at wavelengths around 254 nm, has germicidal properties that can effectively kill or inhibit the growth of bacteria, fungi, viruses, and other pathogens. By implementing UV-C LED systems, users can sanitize and disinfect various surfaces, irrigation water, greenhouse environments, and even the air to minimize disease incidence and reduce the reliance on chemical pesticides or fungicides. UV-C LEDs offer a non-chemical approach that is safe, environmentally friendly, and can help maintain a healthy growing environment. While UV LED technology in agriculture is still a developing field, ongoing research and technological advancements hold great promise for its future applications. As our understanding of plant-UV interactions and pest behaviors deepens, UV LEDs have the potential to contribute to sustainable and environmentally friendly practices in agriculture by reducing reliance on chemical inputs and optimizing plant health and productivity.

This VHS completed with Solar PV as another innovation approach different from the traditional farming practices such as rooftop VF. This solar panel could store the energy for seven days as and essentially required during rainy or bad weather where the sunlight intensity reduces to activate the artificial light for plants growth. It is gaining popularity because of the large amount of solar used that is accessible in metropolitan areas written by [20]. Normally, photosynthetically active radiation increases food development in VF, but it is not sufficient. According to [19], solar power must be captured by a group of mirrors from urban structures to reduce the need for additional artificial light. As a result, VF is investigating alternative energy sources such as solar PV. The Motor Viper (Figure 6) and sensors (Figure 7) represents an innovative solution for rotating polyvinyl chloride (PVC) pipes in VHS plant-growing system. This mechanism ensures that plants receive consistent and optimal exposure to light rays. By employing this dynamic rotation mechanism, the enhancement of the growth potential of the plants achievable, ultimately resulting in healthier and more robust yields.

Fig. 6. Motor Wiper of VHS

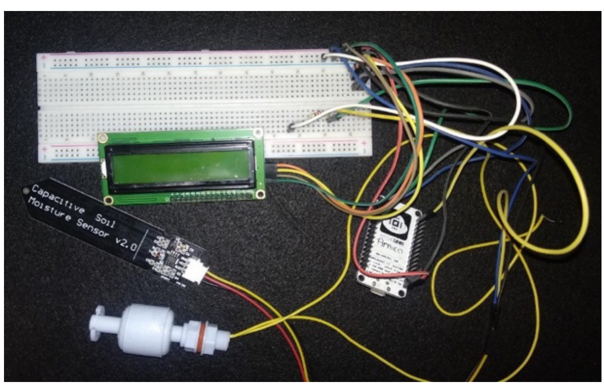

Fig. 7. Sensors of VHS

Vertical hydroponics, a specialized and technologically advanced system, revolutionizes plant cultivation by combining traditional hydroponic techniques with cutting-edge technology. With the integration of sensors and mechanisms, this innovative system ensures food safety, precise fertilizer usage, and effective prevention measures, resulting in outstanding and secure outcomes. By leveraging technology, vertical hydroponics offers a sustainable and reliable solution for vertical plant growth, delivering exceptional results with enhanced efficiency and safety.

Table 2. Label and Function of Sensors for VHS.

No.	Type of Electronic	Function
1	Water Level	The advanced technology enables precise measurement and monitoring of the water content volume in the tank. By employing state-of-the-art sensors and monitoring systems, ensuring accurate and real-time determination of the water level, facilitating efficient management and maintenance of the tank.
2	Soil Moisture	The cutting-edge system enables accurate assessment of the moisture level of plants under specific conditions. Through sophisticated sensors and monitoring mechanisms, precise measurements of plant moisture, allowing for informed decision-making regarding irrigation schedules, ensuring optimal plant health, and maximizing productivity were provided.
3	Node MCU ESP 32	Node MCU is an open-source firmware and development kit is heart of the VHS. ESP32 performed as a complete standalone system or as a slave device to a host MCU, reducing communication stack overhead on the main application processor.
4	Wire Jump	The purpose-built design facilitates seamless transmission of sensor data to the breadboard. By implementing efficient channeling mechanisms, smooth and reliable transfer of critical sensor information, enabling effective data analysis, processing, and utilization for enhanced system performance and informed decision-making could be performed.
5	LCD Screen	The state-of-the-art system seamlessly displays real-time information from diverse sensors, presenting an intuitive and comprehensive overview of their respective conditions. With a user-friendly interface, this solution enables effortless access and interpretation of sensor data, empowering users with valuable insights for informed decision making and proactive monitoring.
6	Bread Board	This groundbreaking design incorporates seamless integration of multiple sensors into a single circuit. By consolidating all sensor functionalities into one streamlined circuit, our solution offers enhanced efficiency, reduced complexity, and optimized performance. This integration enables comprehensive data collection, analysis, and synchronization, providing users with a cohesive and holistic view of their system's operation.

3 Results and Discussion

The primary concept behind FEA is to divide a complex geometry or system into smaller, interconnected subdomains or elements, and then approximate the behavior of these elements using mathematical models. These elements are connected at specific points called nodes, forming a mesh. The behavior of the entire system is then determined by solving the mathematical equations associated with each element, considering the interactions between neighboring elements. The VHS design is subjected to comprehensive numerical analysis using SolidWorks software to assess its structural integrity. SolidWorks performs strain and stress analysis on the selected material, determining the steel's resistance. Figure 9 illustrate the simulation, with a constraint set at the bottom of the VHS structure or column. The stress levels and tensile strains were measured at various locations. These measurements revealed that when a force of 30 Newtons (equivalent to a 3-kilogram force) was exerted on the stainless-steel structure supporting the VHS, accounting for the weight of the plant, motor, and the volume of the water tank used for watering, the findings pertained to the lower structure of the VHS where design reinforcements meet the structure's safety and integrity (blue plots). These simulations likely show visual representations of stress and strain distributions within the VHS structure under the applied load. This meticulous analysis ensures the product's durability and reliability under varying load conditions. The primary goal of this analysis is to assess the structural integrity of the VHS design, particularly focusing on its ability to withstand stresses and strains associated with its intended use.

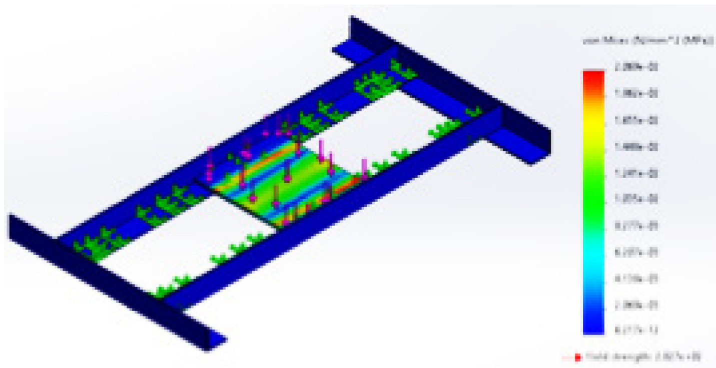

Fig. 8. The colour plots for different colour maps for stress and strain values for vertical hydroponics system (VHS) to the respective FEA (stress magnitudes)

This part has undergone a thorough evaluation under pressure conditions to assess its ability to endure the intended load. Remarkably, the force exerted during testing reached 441.30 Newtons, corresponding to a remarkable 45 kilograms. The resultant color display predominantly showcases revitalizing tones of green and blue. The captivating array of colors exhibited in this portion stands as a resounding achievement. It signifies that the lower frame has exceeded expectations, showcasing its impressive capacity to handle the envisaged load. The appearance of green and blue hues in the analysis underscores the structural strength and resilience of this vital component, attesting to its steadfast aptitude to withstand the forthcoming weight. This outstanding performance guarantees that the lower frame boasts not just the intended strength, but also remarkable durability. The exceptional result leaves no room for doubt that the lower frame embodies a fusion of exceptional design and performance. Its capacity to endure the projected load, complemented by the captivating spectrum of colors, instills unwavering assurance in the overall structural soundness of the project. This accomplishment serves as a testimony to the meticulous engineering and exceptional artistry invested in shaping the lower frame, establishing it as an indispensable and reliable cornerstone of the entire structure.

This procedure repeated for VHS body structure from the established the 3D design prototype's mechanical reliability, as evidenced by its ability to sustain the force applied in the stress-strain analysis. The similar forces exerted during testing onto the body structure of VHS. It was indicated clearly from the FEA certain regions were initially red tones due to the weight and forces applied (Figures 10) that eventually transformed into localized spots. To accurately assess the weight capacity of the iron responsible for supporting the loads of plants, motors, and water tanks, further stress and strain studies have been conducted. The utmost force that the body structure support of VHS could withstand signifies that this structure meets the design’s safety and integrity.

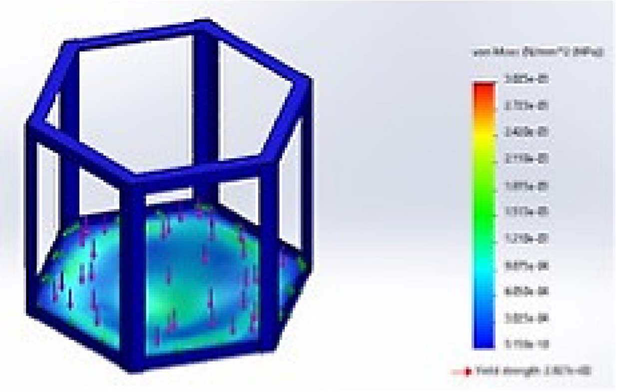

Fig. 9. The colour plots for different colour maps for stress and strain values of VSH body structure.

In this hydroponic experiment, four different portions of the system were employed, each featuring a distinct lighting setup. The objective was to study the impact of supplemental lighting on plant growth. Three types of LED light sources were used to complement natural sunlight in three sections of the system: red LEDs (640–660 nm), blue LEDs (440–450 nm), and a combination of red and blue LEDs at a 1:1 ratio. The fourth section served as the control group, relying solely on natural sunlight as the primary light source. Throughout the experiment, all sections of the hydroponic system received 16 hours of photoperiod daily, using LED illumination starting from 4 a.m. until 8 p.m. Plants in the sections with additional LED treatments were positioned 25 cm below the LED lights to ensure optimal light exposure. On average, each plant received approximately 4 hours of direct sunlight and 5 hours of ambient light per day. Furthermore, the lettuce seedlings in the experiment were exposed to approximately four hours of solar radiation daily. The use of supplemental LED lighting allowed researchers to assess the effects of specific light spectra on plant growth and development. By comparing the growth patterns, morphology, and overall health of plants in each section, valuable insights into the role of different light sources in hydroponic systems were obtained.

The results of this experiment are anticipated to contribute significantly to the understanding of optimized light conditions for hydroponic plant cultivation. It may shed light on the potential benefits of using specific LED spectra to enhance plant growth, yield, and nutrient uptake in controlled environments. The comprehensive data gathered from this study could have practical applications in the field of indoor and vertical farming, where artificial lighting plays a crucial role in plant production. Overall, this well-designed experiment with meticulous lighting setups and controlled exposure times provides a solid foundation for discussing the influence of supplemental LED lighting on hydroponic plant growth. The findings may pave the way for more efficient and sustainable agricultural practices, contributing to global efforts to address food security challenges and optimize resource utilization in the realm of crop cultivation.

3.1 Volume of Water

Full tank of water or mixed organic material of 13.5 Liter @ 13500 milliliter, ensures sufficient watering for sustainable vertical cultivation. This volume of water facilitates optimal conditions for plant growth, allowing for effective nourishment and hydration throughout the vertical system. These findings contribute to the development of sustainable irrigation practices, promoting efficient resource utilization and supporting the success of vertical cultivation methods. It was also recorded the volume of water required for watering crops at different time (minutes)as tabled in Table 3 to ensure an adequate amount of water is supplied to facilitate effective irrigation.

Table 3. Volume of water required for crop's watering at different time.

Time (minutes)	Volume of Water (liter)
5	1.895
10	3.75
15	5.25
28 minutes 49 second	4.55

These observations provide valuable insights into determining the appropriate minute rate for achieving sufficient water volume during each watering session in the vertical cultivation system. The recirculating pump shall recirculate the water from the water tank throughout the pipes to the cultivating crops to keep it readily available at the faucet and does not waste water. The nutrient solution, which contains water mixed with essential plant nutrients, is pumped to the top of the system. The nutrient solution is distributed to the plants using a drip system or a continuous flow system. In a drip system, small tubes or hoses with emitters deliver the solution to each plant. In a continuous flow system, a thin film of the nutrient solution flows over the roots, ensuring constant contact with nutrients. After the nutrient solution has been delivered to the plants, it flows through the growing medium and is collected at the bottom. Gravity allows it to drain back into the water tank for recirculation. On the minutes of 28, the water level in the crops maintained, however water volume in water tank has dropped to 4.55 liter.

3.2 Rotation using Motor Wiper

The motor wiper, along with the attached controller, plays a vital role in facilitating vertical farming operations. The motor wiper is responsible for the rotational movement of the plants or growing medium, ensuring uniform exposure to light and optimal distribution of water and nutrients. The controller speed enables precise control over the rotational speed of the motor wiper, allowing for customized settings based on the specific requirements of the crops. This control mechanism ensures that plants receive adequate and consistent rotation, promoting even growth and maximizing their access to light and resources. The integration of the motor wiper and controller speed enhances the efficiency and effectiveness of vertical farming, enabling better management of plant growth and improving overall crop yield. The 4-foot-long PVC pipe, carefully crafted to exacting standards, serves as the foundation of the system. With 15 strategically positioned holes, each housing plastic culture pots with expanding foam medium, the system efficiently supports plant growth.

3.3 Light for Intensity

The impact of rotating the plant at different speeds, 5rpm or 10rpm, to receive sunlight or ultraviolet (UV) lighting is a complex issue that hinges on various critical factors. One of the primary determinants is the specific type of plant under consideration, as different plant species have unique light requirements and responses to varying light intensities. Additionally, the duration of light exposure and the plant's natural light needs also play significant roles in this scenario. If the plant's light requirements are adequately met with the 5rpm rotation, increasing the speed to 10rpm might not yield any additional benefits. In fact, it could potentially lead to unnecessary stress on the plant, causing adverse effects on its growth and overall health. It is crucial to avoid subjecting the plant to excessive light exposure, as it can lead to photooxidative damage and hinder its development. On the other hand, some plants may demand more sunlight or UV lighting than what they receive at 5rpm. In such cases, elevating the rotation speed to 10rpm could be beneficial, enhancing light exposure and positively impacting the plant's growth and vitality. Increased light availability may lead to improved photosynthesis, nutrient absorption, and overall plant development.

To make an informed decision about the optimal rotation speed, a comprehensive understanding of the specific plant's characteristics is essential. Factors such as light sensitivity, growth patterns, and environmental conditions must be carefully considered. Monitoring the plant's response and behavior during adjustments to the rotation speed is vital to ensure that it thrives and maintains its health throughout the process. Ultimately, a balanced approach that caters to the plant's unique requirements while avoiding excessive stress is key to achieving successful results. The dynamic interplay between light exposure, rotation speed, and the plant's adaptability must be carefully managed to create an environment that fosters healthy growth and optimal performance. In conclusion, the choice of rotation speed in the context of sunlight or UV lighting should be a thoughtful and well-informed decision based on the specific plant's needs. By carefully considering all relevant factors and closely observing the plant's response, growers can create an ideal environment that maximizes its potential for robust growth and long-term well-being (Figure 10).

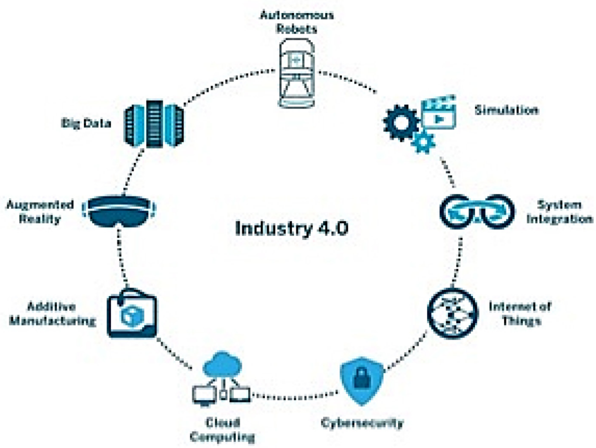

Fig. 10. Industry Revolution 4.0

4 Conclusion

The hydroponic vertical system stands as an essential initiative poised to support urban populations grappling with restricted land availability, notably those residing in condos, flats, apartments, and public housing programs (PPR). With a dual focus on current and impending food supply challenges within urban environments, this project advocates for the implementation of a Vertical Hydroponic System—a dynamic solution that holds the potential to revolutionize urban agriculture. At its core, the Vertical Hydroponic System adopts a spiral structure that accommodates plant placement, enabling a full 360-degree rotation. A full tank of water or mixed organic material of 13.5 Liter @ 13500 milliliter provided sufficient watering for sustainable vertical cultivation. This volume of water facilitates optimal conditions for plant growth, allowing for effective nourishment and hydration throughout the vertical system. This ingenious design ensures equitable sunlight exposure for each plant, fostering uniform and harmonious growth patterns. Central to the system's efficacy is its automated watering mechanism, streamlining the vital task of plant hydration and significantly easing the burdens of urban maintenance. By orchestrating simultaneous watering cycles, this feature not only promises efficiency but also offers a tangible time-saving advantage for users. In essence, the articulated Vertical Hydroponic System proffers a viable avenue for urban communities grappling with spatial limitations to embrace methodical vertical cultivation. Addressing the intricacies of light dispersion and watering logistics inherent to vertical setups, this innovation presents an elegant and accessible route for city dwellers to partake in self-sustained food production. The plant's light requirements are adequately met with the 5rpm rotation for healthy cultivation yield. Unfortunately, by increasing the speed to 10rpm it was not yield any additional benefits to the crops. In fact, it could potentially lead to unnecessary stress on the plant, causing adverse effects on its growth and overall health This VHS provide modern connectivity with the integration of the NodeMCU and micro-phyton into the VHS player, allowing it to access the internet. In addition, the solar panel provides the energy saving for LED lighting of VHS during night time particularly.

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