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Benefits of Modular Green Roof Technology in Urban Ecosystem

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Abstract
There are good economic benefits for society from the contemporary urbanization brought on by the rapid expansion of urban structure, notably massive structures for commercial and residential uses. On the other side, negative effects such as environmental problems and issues, as well as the shrinking of green spaces in urban areas, are the main concern.

The study focuses on identifying the advantages of modular green roof technology in urban settings. There weren't many local studies and research available in the Philippines that focused on the technological advantages to market the system for stakeholders and community adoption, even though the technology had been around for a while and had already been adopted by many countries around the world.

A total of 188 technical respondents—including technology sellers, technical users, non-technical users, regulators, and trend-setters—were selected at random for the study. To ascertain the contributions of modular green roof technology in urban areas for technological adoption, an assessment of respondent profiles and the benefits of modular green roofs was made. In the study, a variety of research methods were used. The Statistical Package for Social Sciences (SPSS) was used to process and analyze the gathered data from the frequency and percentage distribution, weighted mean, and standard deviation statistical tools.

According to the study, modular green roof technology provides numerous advantages for the environment, society, and economy when it is adopted and used properly. Due to their ability to address the urgent environmental difficulties and challenges that urban residents currently face; environmental benefits were discovered to be the most appreciated advantages in urban regions.

Keywords: Modular Green Roof Technology, Sustainability, Green Building, Green Roof Benefits

1. Introduction

Urbanization and climate change are two of the serious environmental issues and challenges that the community is currently grappling with. For instance, rapid development of physical building infrastructures for business in Metro Manila is inevitable. this development contributes positively to the economy, but it directly affects the environmental sustainability of urban ecosystem.

In order to address the pressing environmental issues and challenges including the declining green spaces in Metropolis, the utilization and adoption of Green Building Technology, specifically the modular green roof technology is seen to be the most fitted response.

Green Building Technology refers to the application of sustainable building materials from projects pre-development up to utilization and maintenance (Gaur,2020). On the same way, a living roof known as a "green roof" uses the space above building covers to grow greenery, either ornamental plants or food crops for sustainability purposes (Rouse, 2016). This technology is a potential replacement of the dwindling green spaces and a best management practice due to numerous socio-economic and environmental contributions to the urban areas.

In other parts of the world, different studies of green roof technology which focuses on identification of technology issues and challenges prior to adoption, technology utilization considerations and technological benefits were established to fully adopt the technology based on the needs of the community. In the Philippines scenario, the technology was introduced even before, but the utilization was not significantly seen due to the limited number of local research and studies which focuses on the technological benefits to market the technology for stakeholders and community adoption.

The study is carried out to comprehensively response to the current environmental issues and challenges that the urban areas is experiencing including the degradation of the urban green spaces due to urbanization particularly in Metro Manila, Philippines. Identified Modular green roof technology benefits plays an important role to encourage different types of stakeholders and urban communities for technological utilization and adoption. The researcher is able to gather the data needed through the conduct of interviews and surveys to the different types of stakeholders in an urban area. Furthermore, to establish the identified technological benefits, all of the data coming from surveys were consolidated and analyzed. The data acquired serve as a guide to encourage different types of stakeholders for technology adoption. On the someway, private and public institutions plays an important role to materialize the technology adoption

2. Statement of the Problem

The study aims to address the pressing environmental issues and challenges in an urban areas through the identification of Modular green roof benefits that can be utilized for technological adoption.

Specifically, it aims to answer the following questions:

1. What is the profile of the respondents in terms of the following?
a. Age
b. Gender
c. Length of time for green roof technology utilization

2. How do the respondents assess the modular green roof benefits in terms of;

a. Social Benefits
b. Economic Benefits
c. Environmental Benefits

3. What is the most valued benefits of Modular Green Roof Technology?

3. Review of Related Literature and Studies

This section presents the related literature and studies essential for the identification of Modular green roof benefits which are valuable for the study.

Green Roof Technology

A green roof is a structure covered in plants and erected on top of a flat or gently sloping roof (Liu & Minor, 2005). The three primary types of green roof technology are extensive, intensive, and semi-intensive. Intensive green roofs are frequently used on commercial buildings whose owners desire to create expansive gardens or green spaces with a variety of sizes and varieties of carefully chosen plants (Craig, 2011). Intensive green roofs are made of significantly deeper substrates, providing a far greater opportunity to build and plan more intricate and expansive gardens onto concrete structures (Wallbarn.com, 2020).

The extensive green roof is the most typical style of green roof for single-family residences. Its light weight meant that less structural alterations were required to make it. The wide green roof is not good for producing vegetables and is not intended for regions with high pedestrian activity. It's possible, though, that the benefits of a sizable green roof will make it a really lovely addition to your current structure or one that will go well with your unfinished growth plans (Liu & Minor, 2005).
A semi-intensive green roof system is characterized by small herbaceous plants, ground covers, grasses, and miniature bushes that need regular watering and direct maintenance (Wilson et al., 2006). Semi-intensive green rooftops require a more profound soil layer, but the payoff is within the sorts of plantings that can be utilized. In expansion to the greeneries, grasses, and sedum of broad rooftops, semi-intensive plantings incorporate herbs, blooming plants, taller grasses, and little bushes (Archtoolbox.com, 2022).

Green Roof Benefits

The use of modular green building technology offers its own benefits for the economy, environment, and society (Wilson et al., 2006). The economic benefits include; energy efficiency - lowering building heating and cooling costs; increased solar panel efficiency; prolonged membrane durability and longevity - safeguarding the membrane; fire prevention; lowering community opposition to new developments; meeting regulatory requirements for water treatment of urban runoff; and LEED and opportunity for local, regional, and national market exposure (Korol & Shushunova, 2016).

The construction and protection of habitats, biodiversity expansion, temperature regulation, air quality improvement, stormwater management, water runoff reduction, and water filtration to eliminate particles, pollutants, and control temperature are all included in the environmental benefit (Wilson et al., 2006). The Social Benefit also includes Urban Agriculture - Food Production in the City, Public Education, Reduction of Waste Volumes, Improved Health and Horticultural Therapy, Noise Reduction,

Blocking Electromagnetic Radiation, Creating Ballast Against Wind Uplift, and Horticultural Therapy for Improved Health (Lameraa et al., 2014).

Community and Social benefits

Aesthetics & New Amenity / Recreational Space

In the past generation, most of the western cities have observed the changes to urban development due to the densification of urban structures and urban land fill (Johnston, 2004). Development of residential subdivisions have contributed to the convenience of shopping, working and public transportation in the city. The development of urban set up has become visually uniform with little difference in shape and materials of the concrete building structure that the people use for working, living, shopping, playing and other day to day activities (Mangunsong, 2018).

Green rooftops have been credited with the capacity to essentially improve the magnificence of buildings and to appeal to the senses of individuals. A green roof could be a way to distinguish your building from the rest and can moreover offer assistance to veil the ugliness of a typical roof (Feng & Hewage, 2018)

Modular green roof technology encourages thoughtful approach to city planning by providing additional amenities and green space. It also encourages the community to maintain environmental sustainability by advocating the installation of garden space for urban dwellers (Kuo, 2001). It has suggested that including the vegetation in the urban area reduces stress and patient recovery time (EPA, 2020) One of the benefit of green roof technology includes offering a place to actively join other activities that will advocate social collaboration and physical exercise, stress reduction, improving individuals mood and attention, and having positive effects on anxiety and mood problems.

Proximity to green spaces and greeneries has already proven to increase productivity in the workplace (isurv.com, 2018). Increase the value of the property and has been linked to a crime reduction. One study completed in Manchester, Connecticut claimed that the expansion of green space and trees to a property increases its value by an increment of 6%. This study matches the results found by greenroofs.org that saw an increment of 6-15% within the esteem of homes with green roofs (Feng & Hewage, 2018).

Urban environments can be made strides by the presence of green rooftops, which can be acknowledged as a green zone (park, public garden), particularly when they are also accessible by non-building owners (Dunnet & Kingsburry, 2008). Their presence contains a positive impact on people's quality of life and well-being (Benzkotzen, 2018). The benefits also infer from the presence of animal and plant species (biodiversity) (Feng & Hewage, 2018) that live in these green spaces and the plausibility of being able to observe them closely.

Improve Health and Horticultural Therapy

The accessibility of amenities and other outdoor spaces for viewing of greeneries has proven to have a positive impact on individuals health. studies of (Ulrich, 2016) have found out that even visual access to a natural environment resulted in the reduction of stress, sick leave and ailments and has improved overall individuals health, job satisfaction and productivity . According to Fettig (2006), the collaboration of individuals to the natural environment revealed to increase pride of place and pushes social and physical activities. To be in a green environment is a catalyst for building camaraderie and has been correlated toa reduction of discriminatory behavior, violence and even vandalism. According to Livingroof.org (2020), there is increasing proof that visual and physical exposure to natural greeneries provides a range of benefits to people. These include both mental health benefits like stress reduction and physical health benefits including cleaner air. Access to Green areas can bring positive improvements in a person's heart rate and blood pressure, and can aid the overall wellbeing. According to Sempergreen (2021), Greenery empowers faster recovery for patients, coming about in a shorter clinic stay. A person's resistance to pain is higher in a green environment. This is often also known as a 'healing environment'.

Noise Reduction

The sounds we listen to end up clamor when they are unwanted when sounds interfere with thinking, concentrating, working, talking, tuning in, or sleeping. With dynamic populaces, street activity, industry, and development, cities are expectedly boisterous places. Still, noise could be a driving source of disappointment for city residents. Urban noise influences more than quality of life issues; the level of commotion in numerous cities can cause serious and long-term harm to health (Bhatia, 2014).

With respect to acoustic preferences, green roof frameworks have been regarded as an imperative structure in the reduction of noise pollution, particularly in urbanized zones (Omer, 2009). It is the combination of both substrate and plants, beside the layers of caught air inside green rooftops that make it a hopeful solution for integrating as a normal sound separator barrier (Sempergreen, 2021). This same delicate layer of sedum cover on your green roof too improves the building's sound insulation properties, hence moreover reducing sound pollution within (Renterghem, 2018).

Understandably the degree of typically subordinate on the system that you simply have chosen and the substrate depth The International Green Roof Affiliation (IGRA) demonstrates that on average your green roof can diminish sound reflection by up to 3 dB and make strides sound separator by up to 8 db. Typically extremely advantageous, indeed more so to those who dwell close to such foundations as air terminals or loud mechanical areas (Turfonline.co.uk, 2021).

Based on the study conducted by Bhatia (2017) on noise pollution reduction and control provided by green Living systems in urban areas, it was found out that, the amount of sound energy propagating over rooftops from noisy sides to quite sides is primarily determined by the height and width of buildings, and also materials utilized in building envelope. Green living rooftops on the top of buildings can be assumed as absorbers particularly for diffracted sound waves between parallel streets. Growing mediums used in green living systems are highly-porous, and permit acoustic waves to enter the medium, which

could be a necessary property of a sound absorbing material. Due to an expansive number of interactions between the waves and the strong stage of the substrate attenuation happens (Van Renterghem, 2018).

Urban Agriculture- Food Production in the city

The vicinity of urban centers to agrarian generation has amplified itself to the point that the normal location of food items travelled over miles away before it comes to the consumer (Pirog, 2003). The blend of urban horticulture and green rooftops has yet to be completely realized, but the extra accessible space that a roof can give for nourishment generation ought to not be ignored. By connecting food generation in urban zones, composting and perimeter cultivating facilities together, locally delivered food can empower cities to be autonomous of the massive food dissemination model right now. (Sherman, 2005). Green rooftops cannot supplant expansive scale farms, but can help in creating a demonstration for small scale nourishment production. Community gardens found on housetops can be places for instruction and nearby distribution, as well as an exhibit for commercial endeavors such as eateries utilizing the roof for kitchen gardens (Richard & Sutton, 2003).

Green rooftops for food generation require little modification from the standardized framework, but many issues have to be considered such as depth of growing medium, waterproofing membrane, fertilization process, safety and quality of process and greeneries Green rooftops for food generation require little modification from the standardized framework, but many issues have to be considered such as depth of growing medium, waterproofing membrane, fertilization process, safety and quality of process and greeneries (Herman, 2003).

The utilization of green roof innovation in urban horticulture has the potential to lighten a few of the current pressing urban issues without antagonistically influencing the benefits given by urban agribusiness (Leigh & Whitting, 2011). it would not as it were to empower the utilisation of land for improvement and farming but may too encourage the arrangement of formal space and water utilisation agreements. and empower the conveyance of ground level assets among urban agriculturists. This seems to diminish the utilization of contaminated land and water at ground level and reduce wellbeing concerns(Leigh & Whitting, 2011). Green roofs used as a means of agriculture also “provide aesthetic and physiological benefits for people in urban areas (Kortright, 2011).

Green roofs, once converted to produce food-bearing vegetation, create a social atmosphere mimicking that of a community garden. The practice of utilizing green rooftops for horticulture isn't something that's as it were predominant within the United States, in reality Japan is seen by numerous as a pioneer in green roof horticulture innovation. The Roppongi Slopes building in Tokyo contains a rice paddy on the roof that's planted and cared for by local school children, and produces 60 kilograms of rice per year (Oberndorfer et al., 2007).

Public Education

Same with the conventional garden, Green roof provides different educational opportunities. For the economy and public to understand that a green roof is not only built for beautification but also a system

that may positively impact the environment. The aspects of the educational system on green roofs is one of the most common functions that could give an encouraging sample for developers in the other citywide applications (Tolderlund, 2010). This technology could provide data and platform that the public may use to assess and validate the importance of natural environment for sustainable community and economy (Tolderlund, 2010).

Reduction of waste volumes

The simple act of building something to last for a prolonged period of time is one of the key ways to diminish the hundreds of millions of tons of waste that reach North American landfills each year (Saiz, 2008). Green rooftops are anticipated to final up to 2.5-3.0 times as long as conventional rooftops by dragging out the life of the membrane, in this manner redirecting more than half of the materials for re-roofing within the lifetime of the structure. The improved proficiency of the warming and cooling frameworks of the building from the additional insulation of the green roof may result in less frequent replacement of HVAC frameworks, moreover diverting waste from landfills (Carson et al., 2012). Astute use of reused green roof components guarantees that they don't have any trace of poisons and heavy metals, nor any fabric with fine grained residue, as both make challenges for plant survival (Saiz, 2008).

Given the modular green roof growing popularity, there is an opportunity to realize extra benefits by utilizing reused and waste materials in Green Roof substrates. More particularly, the potential to decrease urban waste streams, decrease the general cost of Green Roof development, improve construction compared to commercially available media, lower Green Roof plan loads, and win extra LEED development focuses (Carson et al., 2012). The deployment of green roof is a proof of sustainability wherein less construction material wastage since the filtering substrate were all prefabricated materials which reduces waste material before and after modular green roof preparation (Saiz, 2008).

Economic Benefits

Energy Efficiency

Poorly insulated roofs result in building wasteful aspects by permitting warm air to escape within the winter and be retained within the summer. Green rooftops are able to reduce the energy consumption to warm and cool the structure by moderating the heat stream through the roofing system (Krajčovičová D, 2007). A green roof can decrease the heat stream through the roof by 70% to 90% within the summer and 10% to 30% within the winter, lowering the energy requirement for space cooling within the building up to 75% (Liu & Bass, 2007). Modular Green roof technology doesn't only provide conditions to the building structure, hence, it also reduces ambient air temperature on the surface of the rooftops which contributes to the HVAC positive performance.

The Modular green roof technology savings and efficiency considerations includes the following; electricity cost, selection of plants, Thickness of insulation, Efficiency of HVAC, coverage percentage, medium depth, irrigation, local climate condition and roof to wall ratio (Leonard & Leonard, 2005).

A more later study of household buildings in North East German with level rooftops proposes that there's a 3-10% winter decrease on fuel bills. The results of the study over five years suggest that there's a greatest saving of 6.8kWh/m2 (1.5kg/m2 CO2 e tons) and a least decrease of 2.0kWh/m2 (0.44kg/m2 CO2 e tons) amid the winter. This connects with the Ottawa study alluded to over, which compared an ordinary roof system with a green roof system (Livingroof.org, 2020).

Energy Performance may be a key advantage of green rooftops. While green rooftops are vital for cooling cities as a entirety, a green roof can also have a positive effect on the vitality performance inside any given building. Typically especially important in the event that a building has destitute separator and destitute ventilation. This will lead an increment air conditioning and thus maximizing energy utilization (asla.org, 2021).

Prolonged Membrane Durability and Longevity

Depending on the climatic condition and waterproofing technology used, a green roof can last up to 2.5-3.0 times as long as conventional and traditional roofing installation. In Germany, some of the existing green roofs have lasted up to 30-40 years and some even longer than it is.in North America, the green roof lasted for almost 10-15 years (Liu & Minor, 2005).The green roof provides protection to the waterproofing membrane using organic and inorganic insulation. With the use of green roofs, roofing membranes, especially waterproofing, may be protected from severe temperature fluctuations (Suryawanshi, 2018). These are very important considerations in semi-arid and arid climates where freeze-thaw cycles, day to night temperature differences, and the possible exposure to ultraviolet rays may be extreme (Liu & Minor, 2005).

Fire Prevention

An efficient and effective Green roof adoption and site installation can mitigate the spread of fire if any circumstances happened. Even though some selected greeneries are not fire resistant than any other materials, layers of organic matter and even minimal moisture can be effective in preventing the spread of fire. It is very important to maintain and provide fire breaks to limit the flammability of all roofs (Tolderlund, 2010). It should also be noted that a few green rooftops require a regular burn to guarantee germination of the plants on the roof. This should be done with supervision from the nearby fire division and can become a seasonal safe and fun community event (Santamouris, 2007).

Based on the article from Greenbuildermedia.com (2015), professionally installed green roofs may provide fire resistive vegetative systems and explained that the green roofs have an excellent history of resisting fire damage. Green roofs can actually be a great fire mitigation method. The following must be considered to help green roof technology mitigate the fire risk; Proper plant selection, removing of dried

and dead greeneries like weeds etc., Prohibition of smoking in the area and securing green roof irrigation. It should also be noted that many of the waterproofing layers required for proper installation of green roofs have built in fire retardant materials. This can be especially helpful in protecting the building below (Tolderlund, 2010). Proper planning, implementing and green roof deployment onsite will still be the most important part to consider to fully utilize green roof technology not only as a fire safe but also a fire resistant.

Local Job Creation

New employment related to the fabricating, establishment, plan and support of green rooftops rose by over 80% between the years of 2004-2005. This quickly developing industry will require and make occupations, both inside the profession and from the subsequent work creation of utilizing space in profitable ways such as rooftop eateries and recreational offices (Tolderlund, 2010). The development of green roof markets gives new work openings related to fabricating, plant development, plan, establishment, and support, American Streams proposes that a USD $10B investment might make 190,000 occupations by building 48.5 billion-square-feet of green roof region, or fair one percent of the Joined together States' roof space in each community over 50,000 in populace, There is critical potential for new development in thick urban zones that were already unusable (Greenroof.org, 2020).

Meeting Regulatory Requirements for Water Treatment of Urban Runoff

Urban runoff is water that has been contaminated due to contaminants that are picked up on the way, such as engine oil, pet waste, pesticides and other waste. As our cities proceed to develop, ranges with concrete, black-top and roof covers are expanding the volume and speed of urban runoff (Shapiro, 2019). Green roofs are great for slowing down the speed of the runoff during events and can help clean the water in the process, before slowly releasing it to rivers and streams (Davis, 2015).

As policies are being implemented to help slow and clean water at the source, green roofs can be a great investment to meet future requirements. Other benefits may happen as a result. For example at the EPA (Environmental Protection Agency) Region 8, a 20,000 square foot 4”deep modular green roof on top of the building helped downsize the required vault in their basement and in turn allowed for a few additional parking spots to be built in the area gained. Ongoing research to test the efficiency and rate at which the green roof is retaining and cleaning the water is currently being conducted. Depth and type of growing medium, type of plant species and type of drainage system are all factors that are important to consider when designing a green roof system for water treatment (Tolderlund, 2010).

Reduce Community Resistance to New Developments

Urban areas are becoming congested and more dense, construction of concrete structure may provide a great controversy to any of the residents in the area, for the benefit of urban occupants, the use of green roof technology may provide positive outlook on each individual that the rise of the structure may not negatively impact the environment, hence this would be a great platform for sustainability (Davis, 2015).

Green roofs can help reduce the resistance to new development in providing interesting views with aesthetic and seasonal value for adjacent residents and business owners (Tolderlund, 2010).

To finally encourage the urban residents to adopt the current urban changes like rapid urban development, the implementation and installation of modular green roof technology may provide them the idea that the development alone may not have only the negative impact but a beneficial effect to every occupants and residents for which, this vertical structure may be using green roof for a healthy city (Benzkotzen, 2018).

LEED

The Canada Green Building Board is now implementing Leadership in Energy & Environmental Design (LEED), a rating system that was possibly developed in the United States (CGBC). The main goal of LEED is to establish standards, requirements, and prerequisites for "green" buildings across the nation. Each category receives points, which add up to a final score that will determine what LEED level you will achieve. in line with (Dinsdale et al., 2006).

A green roof can help a building owner get one LEED point within the feasible site category. There's moreover potential for a green roof to win points in other categories. The aim of the roof is to reduce the heat island effect while also making a difference to play down the warm angle impact on the climate and human/animal habitat. The requirement is that 50% of your roof be secured with a green/vegetated roof. A green roof is an perfect way to win LEED credits, since it can be something your tenants can take advantage of and utilize. Green rooftops are another way to turn your roof into a cool roof (and lower the warm island impact) and can moreover advance biodiversity for the encompassing environment (Kloepple, 2019).

Environmental Benefits

Creation and preservation of habitat and increasing and increasing biodiversity

Majority of Population now resides in urban areas (United nations, 2014). As the Population of human residents continue to grow, the urban ecosystem are expected to expand as the human residents needs space for their daily living (United nations, 2014).The continuous expansion of human habitat and building infrastructure may lessen green areas for animals and insects that will somehow affect the biodiversity of an environment (Magura, 2009).

Urban pressing environmental issues and challenges has influenced the wellbeing of ecologic frameworks by disturbing movement passages and manipulating the assets and vegetation in natural environments. Green rooftops can carry on as a halfway connection for relocation for species of insects and fowls, utilizing the urban environment as stepping stones for natural life development (Dunnet, 2008). The potential for biodiversity depends on plant species and stature, surface variety, nourishment sources and building height.

Expanding Urban Communities , construction of business establishments and other concrete structures may have an impact on bird communities (Calvert, 2013). In urban ecosystems, birds may use rooftop gardens and green roof systems for their habitat given the natural ecosystem of the said technology (Moore, 2005). The green roof may not only provide habitats for birds but also to arthropods, and bats (Parkins , 2015).

Green roofs can cater large amounts of arthropod communities same with the natural system set up (Macivor, 2015). Differing and copious arthropod communities have the potential to be utilized by insectivorous fowls and other winged creatures which supplement their food with arthropods as a nourishment source amid movement and the breeding season (Evans, 2015). Whereas green rooftops have the potential to supply living space for urban winged creatures, small is known approximately how birds really utilize green rooftops (Wang et al., 2019).

Understanding if moving and breeding birds are utilizing green rooftops in urban scenes is fundamental to evaluate on the off chance that green rooftops can be a compelling fowl preservation apparatus (Williams, 2015). Furthermore, green rooftops provide higher quality living space for birds and insects, compared to the conventional roof (Washburn, 2016).

Temperature Regulation- Reduce urban heat island effect

Inorganic surfaces such as buildings, standard rooftops and stopping parts that cover an urban environment are related to a rise in encompassing temperature, known as the Urban heat Island (UHI) Effect. Lack of vegetation, tall buildings and impermeable surfaces anticipate normal cooling by wind and evapotranspiration (Banting, 2005).Subsequently, cities reach higher temperatures and stay hotter longer than the encompassing environment (Peck, 2018).

This condition has illustrated negative impacts since of extreme warmth in urban environments. In addition, chemical reactions of gaseous outflows caused by expanded temperature have contributed to ground level ozone formation, causing respiratory and cardiac disturbance. The rise in temperature too contributes to a more noteworthy demand in air conditioning and energy production (Banting, 2005).

The incorporation of green rooftops can diminish UHI by presenting vegetation onto some of the hottest surfaces in urban ranges(Dunnet, 2008). By means of evapotranspiration and essentially covering the roof with a less retaining surface, temperatures can be decreased. Green roof scope will interpret into critical financial picks up by the reduction in energy costs related with building cooling systems (Kohler et al., 2007).

According to Peck (2018), The sum of heat radiated can be diminished by green rooftops. When daylight falls on a leaf of a plant, it is utilized within the taking after ways: 2% is ingested and used in photosynthesis to form biomass and oxygen; 48% passes through the leaf and is put away within the plant's water system, 30% is utilized as heat in transpiration, and as it were 20% is reflected. Since

less sun powered energy is emanated back into the air when plants are displayed, green rooftops reduce air temperatures surrounding them.

A green roof, or rooftop garden, may be a vegetative layer developed on a rooftop (Banting, 2015). Green rooftops give shade, expel heat from the air, and decrease temperatures of the roof surface and encompassing air. Utilizing green rooftops in cities or other built situations with restricted vegetation can direct the warm island impact, especially during the day. Green roof temperatures can be 30–40°F lower than those of customary rooftops and can diminish city-wide surrounding temperatures by up to 5°F (EPA, 2019).

Based on the study conducted by, Souza et al., (2018), on their study entitled Green roofs and their contribution for the reduction of room temperature in buildings in Cascavel-State Paraná green roofs and energy efficiency, they have found out that, The green roof caused a mean reduction of 4.96°C, demonstrating that green rooftops contribute to decreasing indoor room temperature and thermal lag promoted by the green cover, where the heat input takes longer to happen when compared to the ordinary roof.

Improved air quality- Filter the air

The combination of vehicles, Commercial and manufacturing pollutants and establishments waste as well as hoisted surrounding temperatures result in poor air quality due to expanded particulates and air contaminants. Air quality in cities sometimes suffer temperature reversals where contaminated air is trapped for periods of time causing a significant decrease in air quality (Currie, 2008). Green rooftops help in combating poor air quality, making buildings more efficient and creating less outflows whereas reducing the summertime air temperature on the roof and retaining gasses and particulates through vegetation (Clark, 2008). Depending on the variety of greeneries, leaf surface and leaf tissue, the commitment to air quality by capturing and filtering airborne poisons by vegetation can be significant (Currie, 2008).

Based on the study conducted by (Currie, 2008), on the estimates of air pollution mitigation with green plants and green roofs using UFORE Model that, adopting green roof technology could provide additional building shades, lowering the ambient of air temperature and reducing the concentrations of atmospheric pollutants, Greeneries act as filtering system to gaseous contaminants and sticky leaves can remove particulate matter from the air. The study of Currie, 2008), concluded that, trees and shrubs are the most effective means of reducing contaminants to the air, they also suggested that in the developed urban ecosystem where the decrease of greeneries is very significant, installing and adopting modular green roof technology will be a great option to replace the natural greeneries to combat pollution and filter the air .

Storm Water Management

Stormwater is the precipitation that falls on invulnerable surfaces, spilling to the slightest point as surface runoff. The larger part of the stormwater that passes on from a housetop interior and urban

setting washes into the metropolitan storm sewer framework (Banting, 2015). The sum of impermeable surfaces in an urban environment is specifically connected to volume and quality of stormwater run-off. Since urban environments tend to have a low rate of penetrable surfaces, a bigger volume of stormwater is sent through different administration components (e.g. channels, trench and tunnels) that in the long run lead to waterways, streams and lakes(Jackson, 2020).

This increment of runoff volume as well as the expanded recurrence of runoff causes contamination and disintegration in our waterways and streams. Green rooftops can offer moderate and minimize stormwater run-off (Carter & Jackson, 2007). The runoff redirection for green rooftops is both a work of the plan and the rain design of the local climate. Efficiency of water run-off diversion is regularly related to the profundity of the framework and media composition. The EPA Locale 8 green roof could be a 4" measured plate framework and runoff have been diminished by 85% for all storms 0.5" or less (Gregory, 2018).

According to Richard and Sutton (2014), Green roof technology is considered to be a stormwater best management practice to its capacity on in processing or impervious roof surface with a high rate and volume of runoff into a surface that absorbs precipitation which reduces the amount of runoff and delays when the greatest amount of runoff occurs. Based on the article coming from epa.gov (2020), Green rooftops have a layer of plant fabric that retains water like a wipe. They capture water when it downpours, gradually discharging it through vanishing and plant utilization happens (Sutton, 2014).

Green rooftops can essentially diminish the sum of rain water that would otherwise run off an impenetrable roof surface. Green rooftops can offer assistance to diminish building vitality utilization and clamor levels while expanding the strength and life expectancy of the roof compared to customary roofs. Green rooftops are being progressively utilized in urban ranges where space imperatives restrain the utilization of other stormwater administration practices (EPA, 2018). Green rooftops have a layer of plant fabric that absorbs water like a sponge. They capture water when it downpours, gradually discharging it through vanishing and plant utilization. Green rooftops can essentially decrease the sum of rainwater that would otherwise run off an impenetrable roof surface.

Green rooftops are being progressively utilized in urban zones where space imperatives constrain the utilization of other stormwater administration practices (epa.gov, 2020). A green roof is considered a stormwater best administration practice (BMP) due to its part in turning an impenetrable roof surface with a high rate and volume of runoff into a surface that absorbs precipitation which diminishes the sum of runoff and delays when the greatest amount of runoff happens (Sutton, 2014). Green roof technology will intercept between 15 and 90% of runoff from rooftop during the rainy season.

Absorption of rain water runoff into installed green roof framework will vary between 50-60% and it will also depend on the growing medium and plant cover variability. Variation of rates of absorption can be as 50% based on differences in temperature, wind rates of evapotranspiration and the quality of greeneries installed (lakesuperiorstreams.org, 2018). A green roof technology can typically contribute to the reduction of stormwater run-off by 50% to 90%.For instance, the highest flow volume will be reduce

and the peak flow period will be delayed as much as four hours, minimizing the impact on existing drainage systems (lakesuperiorstreams.org, 2018).

4. Methodologies

Research Design

The study employed a mixed type of research methods. First, technical employees from the chosen stakeholders, were interviewed. Their contributions are valued as essential components in creating survey questionnaires with consideration to the identified related literatures and studies. In addition, the study used a descriptive approach to describe the quantitative aspect of the survey results. A survey instrument that focuses on the determination of the Modular green roof technology benefits for technology adoption in urban areas is developed as part of the process. A statistical analysis was done after the quantitative data was gathered.

Population and Sample

The study considered 188 technical respondents from different types of stakeholders including technology sellers, Technical users, Non Technical users, regulators and trendsetters in the Philippines specifically in Metro Manila.

Sampling Technique

The group of people on which the study is focused are referred to as populations, and the individuals chosen for the study are referred to as the sample. Purposive random sampling was used in the study to the selected participants.

Validation of Questionnaire (Pre-Testing, revision of Questionnaire)

Members of the research committee (panelists, the chair of the oral defense, and the adviser) were given the opportunity to comment on and make adjustments to the survey tool before the study tool was actually used to collect data. To ensure the final research findings are of the highest caliber, all suggestions for enhancement and revision are taken into account.

Data Gathering Procedure

An online survey was employed to gather pertinent data for this study. The research survey is comprised of a number of pertinent and multifaceted questions that are based on the perspectives of stakeholders representatives' experiences, theoretical and professional knowledge, as well as their own perceptions on the application of modular green roof technology in urban ecosystems. Included are works of literature from various cultures as well as domestic and foreign research.

The proponent sought consent from the panel members and chair of the oral defense, as well as advice and support from the technical thesis advisor, prior to the actual data collecting.

The approved study questionnaire was sent to the respondents via email and other internet channels. When it is most convenient for them, the responders complete the printed questionnaire (as needed). Email, phone, and other forms of communication were used to follow up with the replies to reschedule. Any emails that go unanswered should be followed up with a polite email to the appropriate media.
The survey questionnaire has an introduction outlining the purpose of data gathering. After completing the questionnaire, the respondents' comments and recommendations are highly respected and taken into account to improve the study. Results were assessed and interpreted using the Software Program for Social Statistics (SPSS).

Description of Research Instruments used

In order to conduct the survey, the researcher used two (2) different techniques: first, in-person interviews (if necessary), and second, online questionnaire distribution. The researcher organized an in-person interview with the responders to make sure it was available. For a hassle-free online survey, the researcher creates a template for an online questionnaire and uses the Google platform to distribute it to respondents.

The survey questionnaire prepared is composed of two parts. The first part is the identification of respondent's profile and the second part is the assessment of the different types of respondents with regards to Modular Green roof technology benefits for industry adoption.

For the survey, the researcher employed a 5-Point Likert scale. The participants were instructed to check the boxes adjacent to the responses they had given at the beginning of the survey. The scale shown below was utilized by the researcher.

Part 2 scores range from (1) Disagree to (5) Strongly agree with the respondents assessment on the degree of benefits in adopting modular green roof technology.

Degree of benefits in Adopting Modular Green Roof Technology

Rating	Description	Percentage	Range Interval
5	Extremely Beneficial	Between 96 - 100 %	4.20-5.00
4	Very Beneficial	Between 75 - 95 %	3.40-4.19
3	Beneficial	Between 50 – 74 %	2.60-3.39
2	Least Benefits	Between 25- 49 %	1.80-2.59
1	No Benefits	Below 25 %	1.00-1.79

Statistical Treatment of Data

To generate an accurate and reliable result with regards to the determination of modular green roof technology benefits for technological adoption, statistical treatment of data is very important. It was considered to utilize SPSS, an existing statistical package for social science, to analyze the data. The following statistical tools were used to present, examine, and evaluate the data gathered for this study:

a. Frequency and Percentage Distribution
b. Weighted Mean and Standard deviation

5. Discussion of Results

The study considered technical representative from different types of stakeholders which are Technology sellers, Technical Users, Non -Technical Users, Regulators and Trendsetters.

5.1 Profile of the Respondents

5.1.1 Type of Stakeholders

Table 1 Represents the frequency and percentage distribution of respondents according to the type of stakeholders.

Table 1 Distribution of Technical Respondents According to type of Stakeholders

Type of Stakeholders	Frequency	Percentage
Technology Sellers	33	17.49%
Technology Users-Technical	45	23.95%
Technology Users-Non-Technical	42	22.43%
Regulators	33	17.49%
Technology Trendsetters	35	18.63%
Total	**188**	**100%**

A total of 188 respondents were Involved in the study. Within the 188 respondents, most of them are technology users-technical with a frequency of 45 or 23.95%. It is a clear indicator that there is a high number of Technology users-Technical respondents due to the availability and accessibility of technical professionals which was caused by the increasing number of building projects around Metro Manila from 2020 to 2021 (PSA, 2022). This has brought also the increase of design professional in Metro Manila such as civil engineers and architects (Mynimo.com, 2022).

5.1.2 Respondents Age-Group

The frequency and percentage distribution of respondents according to their age group is presented in table 2.

Table 2 Distribution of Technical Respondents According to their Age-Group

Age-Group	Frequency	Percentage
25 Years Old and Below	14	7.60%
26-31 Years Old	57	30.42%
32-37 Years Old	52	27.76%
38-43 Years Old	36	19.39%
44-49 Years Old	22	11.41%
50 Years Old and Above	7	3.42%
Total	**188**	**100%**

The table above shows that the biggest number of participants (30.42%) came from the age cluster of 26-31 years old and the lowest with 3.42% were 50 years old and above. The findings indicate that the majority of the respondents are Millennials working in a corporate set up in both government and private offices. According to Bluedorn (2019), young people are important for economic development and growth. They contributed to one third of an overall working population mostly in developing countries. Young age individuals have significant contributions to the economic development due to the timely know-how of an existing technology. Their up-to-date learnings may contribute to their fruitful output in a company (Lagarde, 2019).

5.1.3 Respondents gender

The frequency and percentage distribution of the Technical Respondents according to their gender is presented in Table 3.

Table 3 Distribution of Respondents According to their Gender

Gender	Frequency	Percentage
Male	132	70.3%
Female	56	29.7%
Total	**188**	**100.0%**

The table above shows that the majority of the respondents are male with a frequency of 185 or 70.3%. It is a clear indication that ,male interest in engineering work and activities particularly on green roof design, development and maintenance are relatively considered.

Williams (2015) asserts that there is startlingly little gender diversity across industries. Even while women only make up 11% of the workforce, many of them hold desk jobs, frequently in management, design, or secretarial positions. Approximately 89% of workers are men on actual construction sites. The ratio of women to men in the sector has been quite stable for a long time. There

are some industries, such as design, where conditions are considerably better. However, the percentage of women in manual occupations is utterly negligible. Sexism was the primary culprit in the issue.

5.1.4 Respondents length of time for Green Roof Technology Utilization

The distribution of Respondents according to their Length of time for green roof technology utilization is presented in Table 4.

Table 4 Distribution of Respondents according to their length of time for green roof technology utilization

Year-Bracket	Frequency	Percent
1-5 Years	97	51.71 %
6-11 Years	67	35.74%
12-17 Years	16	8.37%
18-23 Years	4	2.28%
24 Years and Above	4	1.90%
Total	**188**	**100.0%**

Based on the table above, the group with 1-5 years of experience relative to the utilization of modular green roof technology has the largest among the divisions with a frequency of 97 or 51.71% respectively. Meanwhile there are only four (4) respondents or 1.90% with 24 years and above experience.

According to numerous international studies on the social, economic, and environmental impacts of green roof technology, it is evident that the technology has been around for a while but has not yet been properly utilized, embraced, and installed in the nation (Salazar, 2011). The idea of green roofs is not new. They have been around for a while and are still popular in many parts of the world. That's because of the benefits they offer (Walters, 2018).

5.2 Assessment of Modular Green Roof Technology Benefits in Metro Manila

5.2.1 Social Benefits

The respondents assessment of Modular green roof technology Social Benefits is presented in Table 5.

Table 5 Respondents Assessment of Modular Green Roof Technology- Social benefits

Modular Green Roof Technology- Social Benefits		
Indicators	**Weighted Mean**	**Description**
a. Modular green roof provides electromagnetic radiation blocking and noise reduction.	3.48	Very Beneficial
b. It creates collaborative activities between	3.77	Very Beneficial

contractors and the clients on the proper utilization of the technology.		
c. It creates a collaborative interaction between the contractors and regulators.	3.81	Very Beneficial
d. It develops new specialization for technical professionals.	3.91	Very Beneficial
e. It creates collaborative interaction between contractors and end users in a form of public information drives.	4.01	Very Beneficial
f. It provides knowledge to technical professionals on sustainable technology for building integration.	3.94	Very Beneficial
g. It provides significant aesthetics and a good finish on the overall developer's project design.	3.89	Very Beneficial
Overall Weighted Mean	**3.83**	**Very Beneficial**

The table above depicts the respondents assessment of modular green roof technology-Social Benefits. All of the Indicators for modular green roof social benefits were assessed as very beneficial when it comes to social benefits with an overall weighted mean of 3.83. It is a clear indication that the proposed technology is very valuable in the society. The statement " It creates collaborative interaction between contractors and end users in a form of public information drives." Gained the highest weighted mean of 4.01, followed by the statement "It provides knowledge to technical professionals on sustainable technology for building integration. Then " It develops new specialization for technical professionals." With weighted mean of 3.94 and 3.91 respectively.

One of the benefit of green roof technology includes offering a place to actively join other activities that will advocate social collaboration and physical exercise, stress reduction, improving individuals mood and attention, and having positive effects on anxiety and mood problems. Proximity to green spaces and greeneries has already proven to increase productivity in the workplace (ISurv, 2018)

Same with the conventional garden, Green roof provides different educational opportunities. For the economy and public to understand that a green roof is not only built for beautification but also a system that may positively impact the environment. The aspects of the educational system on green roofs is one of the most common functions that could give an encouraging sample for developers in the other citywide applications (Tolderlund, 2010). This technology could provide data and platform that the public may use to assess and validate the importance of natural environment for sustainable community and economy (Yuliani et al. 2020).

New employment related to the fabricating, establishment, plan and support of green rooftops rose by over 80% between the years of 2004-2005. This quickly developing industry will require and make occupations, both inside the profession and from the subsequent work creation of utilizing space in profitable ways such as rooftop eateries and recreational offices (Tolderlund, 2010). The development of

green roof markets gives new work openings related to fabricating, plant development, plan, establishment, and support.

5.2.2 Economic Benefits

The respondents assessment of modular green roof technology Economic Benefits is presented in table 6.

Table 6 Respondents Assessment of Modular Green Roof Technology- Economic Benefits

Modular Green Roof Technology- Economic Benefits		
Indicators	**Weighted Mean**	**Description**
1. Modular green roof provides alternative projects to developers and contractors which increases their operational revenue.	3.72	Very Beneficial
2. It generates job and livelihood during development/ construction.	3.77	Very Beneficial
3. It increases building property value due to the modular green roof aesthetics.	3.82	Very Beneficial
4. It has the capacity of protecting and prolonging membrane durability.	3.97	Very Beneficial
5. It provides cooling effect for the building resulting to energy efficiency.	4.16	Very Beneficial
6. Its rainwater retention capacity helps lessens drainage installation.	3.96	Very Beneficial
7. It generates financial incentives to successful adaptors and implementors in the form of income tax holiday from Board of Investments.	3.79	Very Beneficial
8. It provides LEED Credit for successful adaptors and integrators.	4.05	Very Beneficial
9. It protects property from fire accidents.	3.88	Very Beneficial
Overall Weighted Mean	**3.90**	**Very Beneficial**

The table above presents the assessment of modular green roof technology- Economic benefits. As the table indicates, all of the respondents assess the very beneficial of all the green roof economic benefits with an overall weighted mean of 3.90. This is a clear indication that, if the technology when properly utilized will definitely provide value in the economy for the different aspects. The statements "It provides cooling effect for the building resulting to energy efficiency" gained the highest weighted mean of 4.16, followed by the statement "It has the capacity of protecting and prolonging membrane durability" and "Its rainwater retention capacity helps lessens drainage installation" with weighted mean of 3.97 and 3.96 respectively.

National Research Council of Canada Studies (2003) have shown that a green roof can decrease the heat stream through the roof by 70% to 90% within the summer and 10% to 30% within the winter, lowering

the energy requirement for space cooling within the building up to 75% (Liu, 2005). Modular Green roof technology doesn't only provide conditions to the building structure, hence, it also reduces ambient air temperature on the surface of the rooftops which contributes to the HVAC positive performance. The Modular green roof technology savings and efficiency considerations includes the following; electricity cost, selection of plants, Thickness of insulation, Efficiency of HVAC, coverage percentage, medium depth, irrigation, local climate condition and roof to wall ratio (Leonard et al., 2005).

The green roof provides protection to the waterproofing membrane using organic and inorganic insulation. With the use of green roofs, roofing membranes, especially waterproofing, may be protected from severe temperature fluctuations (Suryawanshi, 2018). These are very important considerations in semi-arid and arid climates where freeze-thaw cycles, day to night temperature differences, and the possible exposure to ultraviolet rays may be extreme (Liu, 2005).

5.2.3 Environmental Benefits

Table 7 Respondents Assessment of Modular Green Roof Technology- Environmental Benefits

Modular Green Roof Technology- Environmental Benefits		
Indicators	**Weighted Mean**	**Description**
1. Modular green roof increases the level of oxygen in urban areas.	4.14	Very Beneficial
2. It optimally utilizes rainwater due to its retention capability.	4.34	Extremely Beneficial
3. It provides a balance in the over-all urban ecosystem.	4.34	Extremely Beneficial
4. It helps develop and preserves the habitat of insects in urban areas.	4.07	Very Beneficial
5. It helps reduce the effect of climate change.	4.05	Very Beneficial
6. It cools the urban environment.	4.19	Very Beneficial
7. It improves urban air quality through filtration of bind dust.	4.16	Very Beneficial
8. It serves as a catalyst for the cultivation of local plant production due to its increasing demand.	4.13	Very Beneficial
9. It reduces carbon dioxide and other air pollutants.	4.22	Extremely Beneficial
10. It helps protect the environment particularly in waste disposal, since it uses biodegradable materials.	4.34	Extremely Beneficial
Overall Weighted Mean	**4.20**	**Extremely Beneficial**

The table above presents the respondents assessment of Modular Green Roof Technology-Environmental Benefits. As depicted in the table above, majority of the indicators was assessed by the different types of the respondents as Extremely beneficial with an overall weighted mean of 4.20. The statements "It optimally utilizes rainwater due to its retention capability", "It provides a balance in the over-all urban ecosystem" and It helps protect the environment particularly in waste disposal, since it uses biodegradable materials, garnered the highest assessment (Extremely Beneficial) with the same weighted mean of 4.30, while the statement "It helps reduce the effect of climate change" gained the lowest mean of 4.05 but still in a very beneficial assessment.

According to Sutton 2018, Green roof technology is considered to be a stormwater best management practice to its capacity on in processing or impervious roof surface with a high rate and volume of runoff into a surface that absorbs precipitation which reduces the amount of runoff and delays when the greatest amount of runoff occurs. Based on the article coming from epa.gov (2018), Green rooftops have a layer of plant fabric that retains water like a wipe. They capture water when it downpours, gradually discharging it through vanishing and plant utilization happens (Sutton, 2014).

The incorporation of green rooftops can diminish urban heat Island and provide balance to overall ecosystem by presenting vegetation onto some of the hottest surfaces in urban ranges (Dunnet, 2008). By means of evapotranspiration and essentially covering the roof with a less retaining surface, temperatures can be decreased. Green roof scope will interpret into critical financial picks up by the reduction in energy costs related with building cooling systems (Kohler, 2004).

Base on the overall result with regards on the assessment of the Modular Green Roof Benefits, The Environmental benefits are considered as the most valued benefits followed by Economic and Social benefits with an overall weighted mean of 4.20, 3.90 and 3.83 respectively.

6. Conclusions

The following conclusions are drawn from the results of the study.

1. Most of the users of the modular green roof technology were men between the ages of 26 and 31 who had experience with its use for one to five years. This is a blatant indicator that due to the abundance of building activity in urban regions, a significant proportion of professionals outnumber technical respondents. Millennials are also among the respondents since their current understanding of usage is crucial for acceptance of technology.

2. Majority of the respondents assess that the modular green roof technology provides social benefits. The five most significant social benefits among others are as follows:
   a. "It creates collaborative interaction between contractors and end users in a form of public information drives".
   b. "It provides knowledge to technical professionals on sustainable technology for building integration".
   c. "It develops new specialization for technical professionals".

d. "It provides significant aesthetics and a good finish on the overall developer's project design".
e. "It creates a collaborative interaction between the contractors and regulators".

It is a clear indication that the proposed technology is very valuable in the society

3. The respondents assessed that the modular green roof technology when properly utilize, it will be very beneficial to the economy. Based on the result of the study the top five contributions of the proposed technology are as follows:
   a. "It provides cooling effect for the building resulting to energy efficiency".
   b. "It has the capacity of protecting and prolonging membrane durability".
   c. "Its rainwater retention capacity helps lessens drainage installation".
   d. "It increases building property value due to the modular green roof aesthetics"
   e. "It generates financial incentives to successful adaptors and implementors in the form of income tax holiday from Board of Investments".

   This is a clear indication that, if the technology when properly utilized will definitely provide value in the economy for the different aspects.

4. Modular green roof technology offers significant environmental benefits. The following top five environmental benefits are as follows:
   a. It optimally utilizes rainwater due to its retention capability
   b. It provides a balance in the over-all urban ecosystem.
   c. It helps protect the environment particularly in waste disposal, since it uses biodegradable materials.
   d. It reduces carbon dioxide and other air pollutants
   e. It cools the urban environment

5. Environmental benefits are the most valued modular green roof contributions in an urban environment, followed by social and economic benefits. The fact that technology can handle pressing environmental issues and challenges in metropolitan areas, notably in Metro Manila, is what led to this outcome. When this technology is used for what it was intended, not only will the Philippines but the entire world benefit from its contributions.

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