Preserving natural elements in spatial design: challenges and solutions for rainwater leakage through trees. (case study: Tanmu Coffee Bogor)

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Abstract. In architectural and interior design, working with existing natural elements like contours, trees, and stones is a common challenge. It is vital for designs to harmonize with these elements, minimizing ego and maximizing nature's gifts. In 2020, I had the chance to design a commercial building in Bogor, Indonesia, on a 440-square-meter site with a 1-meter contour difference and 12 fruit-bearing trees. Preserving these trees posed a challenge; being in the 'City of Rain,' the design had to account for Bogor's high rainfall. Initially, the floor plan incorporated a single tree, but unforeseen variables emerged during construction. Both the design and contractor teams engaged in research and development to optimize the design, ensuring tree preservation and avoiding leaks. Physical streamlining of water around the trees, roof wrapping, and an auxin process to support tree growth were applied. These approaches successfully resolved issues and ensured Tanmu Coffee's interior design operated optimally. As we approach the second year post-implementation, the design seamlessly continues to serve its purpose.

1. INTRODUCTION

The city of Bogor is nicknamed the City of Rain, based on geographical data which is located between 106° 48' East Longitude and 6° 26' South Latitude which has a minimum altitude of 190m and a maximum of 330m above sea level. Climatic conditions in Bogor City with an average monthly temperature of 26° C with the lowest temperature of 21.8° C. The air humidity is 70%, the average annual rainfall is around 3,500 - 4,000 mm with the heaviest rainfall in December and January [1]. The intensity of rain in the western part of Indonesia has increased due to the Madden Julian Oscillation flow. Rain in Bogor was recorded as very heavy with the highest intensity in Indonesia with an accumulation of 144 mm per day [2]. This has resulted in spatial designers having to pay extra attention to rain in every design that will be designed in the city of Bogor.

1.1 Site of Tanmu Coffee

Located on Jl. Pajajaran Indah V Bogor City, the author had the opportunity to design a 440m2 coffee shop. The existing condition of the arable land itself is an unused yard of the landowner, where several fruit trees have been planted in the area with an average height of more than 6m and a land contour that drops one meter from the edge of the main road. Seeing these conditions is a challenge for the designer to maintain the contours and trees so that they can be responded to in such a way as to produce an attractive, cool, and shady design. Especially in the commercial area around here which is dominated by restaurants and coffee shops which have the user experience of enjoying their dishes indoors, making the Tanmu Coffee design have its charm with its green open spaces.

The plot of land for Tanmu Coffee consists of 10 large fruit trees and 2 small fruit trees, with the large trees surrounding the roadside, making it easy for the designer to plan the building's mass. The plot's unique shape inspired the designer to create a building mass with a 45-degree angle, producing an attractive form for road users. This angle also allowed for flexibility in responding to the land contours and existing trees. After experimenting with various building shapes, the designer decided to incorporate a tree larger than 8 meters inside the bar as an aesthetic element and the main focal point of the design.
1.2 Growing Trees

The tree located inside the bar at Tanmu Coffee is treated differently from the outdoor trees, as it is considered the main star of the interior design. Despite its height of over 8 meters, the designer wants the tree to continue to grow and develop even after being incorporated into the building. Growth and development are two interrelated processes that occur in plants.

- Growth refers to the process of increasing size, volume, mass, number of cells, or protoplasm in an organism, which is irreversible.
- In plants, growth can be measured quantitatively by observing changes in the number and size of plant structures. Development, on the other hand, is the process of a plant reaching functional maturity or adulthood, accompanied by changes in the structure and function of its organs. This process can only be observed qualitatively, as functional changes occur within the plant's body [3].

The tree located inside the bar area has already reached secondary growth, which is a result of the activity of the secondary meristem tissue. The cambium tissue cells constantly divide, and the new cells produced differentiate into either xylem or phloem. This results in an increase in the diameter of the stem and roots over time. In addition, the growth and development of a plant are influenced by both internal and external factors. Internal factors include genes and hormones, which control various aspects of the plant's growth and development. External factors, such as nutrition, sunlight, water and moisture, temperature, and soil, also play a crucial role in determining the growth and development of a plant[3]. Understanding these factors is important when designing an environment for a plant to thrive, such as in the case of the tree in the bar area of Tanmu Coffee.

1.3 Tropical Architecture

The notion of tropical (humid) architecture refers to an architectural design approach that addresses the challenges posed by humid tropical climates. Such climates are characterized by several factors [4]:
- High rainfall of approximately 2000-3000 mm/year (Jakarta + 2000 mm/year or an average of + 160 mm/month). There are parts of Indonesia with low rainfall such as East Nusa Tenggara.
Solar radiation is relatively high, ranging from 1500 to 2500 kWh/m²/year (Jakarta + 1800 kWh/m²/year).

The air temperature is relatively high for cities and coastal or low-lying areas (Jakarta is between 23°C to 33°C). For cities and areas in the highlands (Bandung, Lembang, Malang, Bukit Tinggi, and others) the air temperature is quite low, around 18°C to 28°C or lower.

High humidity (Jakarta ranging from 60 to 95%)

The wind speed is relatively low (within the city of Jakarta the average is below 5 m/s).

Tropical architecture is an architectural design that aims to solve the challenges posed by humid tropical climates. The humid tropical climate is characterized by high rainfall, relatively high solar radiation, high humidity, and relatively high temperatures. To address these conditions, tropical architecture employs a range of design elements and strategies that can improve comfort and sustainability in tropical buildings. Tropical architecture is characterized by several key features that are relevant to this paper.

The sloping roof shape is most suitable for tropical architecture in areas with high rainfall. The more inclined the roof plane, the faster the rainwater will fall through the roof surface. Generally, the slope of the roof on a tropical building is more than 30 degrees. This allows rainwater to quickly fall onto the eaves of the roof and be directed to the ground, avoiding leaks and water damage inside the building [5].

Planting protective trees around buildings can help reduce environmental temperatures by blocking direct solar radiation on hard materials such as roofs, walls, parking lots or yards that are covered with hard materials. Studies have shown that a decrease in temperature of up to 3 degrees Celsius is achievable by planting protected trees around buildings [6].

![Fig. 4. Roof Pitch and Slope Requirements (Source: InterNACHI, 2009)](image)

The positioning of trees inside the bar of Tanmu Coffee plays a crucial role in creating aesthetic elements in the building design. It holds high value as the focal point of the design but also poses a challenge for the designer to respond to it. Initially, the designer and contractor conducted mitigation measures, but during the construction process, several crucial points that disrupted the bar’s operation arose. During the construction process from April to August, there were no issues as it was during the dry season and low rainfall intensity. However, in the last two months of construction, from September to October, the rainfall intensity increased, causing leaks in the tree's interior part inside the bar. This became the main issue in this paper where the designer, who is also the author, tries to elaborate on several field experiment results so that the tree can continue to grow, develop, and breathe without damaging or causing problems in the interior of the Tanmu Coffee bar.

2. METHODOLOGY

This writing employs a qualitative method with an experimental research technique conducted in the field for two weeks during the building construction process. The discussion of this method will be elaborated using the design thinking approach as a framework for the discussion in this paper.

Design thinking is a methodology which provides a solution-based approach to solving problems. It’s extremely useful when used to tackle complex problems that are ill-defined or unknown—because it serves to understand the human needs involved, reframe the problem in human-centric ways, create numerous ideas in brainstorming sessions and adopt a hands-on approach to prototyping and testing. Learning about the five stages of design thinking will empower you and allow you to apply the methodology to your work and solve complex problems that occur in our companies, our countries, and across the world.

Design thinking is a non-linear, iterative process that can have anywhere from three to seven phases, depending on whom you talk to. We focus on the five-stage design thinking model proposed by the Hasso Plattner Institute of Design at Stanford (the d.school) because they are world-renowned for the way they teach and apply design thinking [7].

The five stages of design thinking, according to the d.school, are:

- **Empathize** : Observing the problems.
- **Define** : state your users’ needs and problems.
- **Ideate** : challenge assumptions and create ideas.
- **Prototype** : start to create solutions.
- **Test** : try your solutions out.

3. RESULT AND DISCUSSION

The results of an experimental field research conducted for 2 weeks after the leakage was discovered in the ceiling of the Tanmu Coffee bar caused by the tree penetration. This will be discussed using the design thinking approach, where in the Empathize phase, the author conducted macro, mezzo, and micro-observations on the built site plan. In the Define phase, the topic was focused on specific plans, sections, and elevation areas of the bar. This was followed by the Ideate phase, where the designer, along with several
contractors and landscaping experts, broke down several factors to address the problem. In the Prototype phase, the author and team conducted 3 technical feasibility tests on several possible solutions. Finally, in the Test phase, after going through the 3 feasibility tests, a special design method was developed to address the issues in this paper. The process was carried out for one week with moderate to high intensity rainfall, resulting in the final observation of no leakage in the tree inside the bar.

### 3.1 Empathize

In the observation phase, the designer collected data on the Site plan, Floor Plan, and Specific Bar Floor Plan to identify the problems caused by high rainfall in Bogor city. In the Site Plan section, the bar building was not affected by high rainfall intensity due to its position next to a neighboring building with a height of more than 2 floors, while the bar building is only one floor, so there is no significant impact of wind and rain due to the neighboring building barrier. In the Site Plan section, the flow of rainwater distribution towards the gutter has been divided into segments so that the rainfall is not concentrated on one point of the gutter, which can cause overflow. In the Specific Bar Floor Plan, an issue was found in the roof design between the kitchen and the bar area, which was made with a gable roof to ensure that the rain falls on the front side of the bar and the back side of the kitchen. However, this caused movement in the middle part of the roof truss, resulting in looseness at several points.

![Fig. 5. General Site Plan Tanmu Coffee](Source: Personal Data, 2021)

![Fig. 6. Specific Bar Floor Plan Tanmu Coffee](Source: Personal Data, 2021)

After knowing this, the designer and contractor changed the gable roof plan into a flat roof with a 10-degree slope stretching from the top of the bar towards the kitchen with iron support structures. The use of a 10-degree slope was also designed to slow down the flow of rainfall on the roof so as not to damage the retaining wall around the tree trunk.

### 3.2 Define

After identifying several issues in the building design, the team conducted a detailed study by breaking down several detailed working drawings in the design of Tanmu Coffee. During the process of dissecting the drawings, there were several points that were focused on mitigating leaks, namely:

1. The first point is the construction of the roof shape that intersects directly with the tree, which is only limited by sheet metal barriers pulled up like a dam. Therefore, during high rainfall, there will be movement and shifting that causes water to fall into the ceiling frame that contains glass wool as a damper. The glasswool has a material that absorbs water, so when heavy rainfall occurs, the water that is collected on the glasswool will be evenly distributed and cause seepage into the open bar ceiling, as evidenced by the growth of mold on the ceiling.

2. The second point is the water flow that escapes from the branches on the roof, which will enter randomly through the stem of the tree, so the point where rainwater falls cannot be controlled at one specific point, resulting in many dripping gaps from the tree stem.

3. The third point is the tight gap between the tree stem and the ceiling and roof frame, which creates a sway when the top of the tree is hit by rain and wind, causing a shift in the roof.
From these issues, the designer and team tried to anticipate and find solutions to ensure the continuity of the building and the tree's growth and development without any leakage problems.

### 3.3 Ideate

After focusing on several aspects to solve the problems that occurred in this case, the design team did not work alone, but various parties were involved in providing solutions during the ideation process. The construction team accompanied the process to see the visibility of the appropriate technique to prevent leakage, and the garden team provided input on how to keep the tree growing and developing.

The first stage that was attempted to be solved was how to prevent water from entering the building. After seeing the problem in the roof area that only used water-resistant tires was not enough because essentially water would still enter through the tree branches that continuously flowed from leaves into the room. Thus, at this stage, the team had the idea to wrap the tree branches onto the surface of the roof with waterproof material. Then, the team provided a waterproof layer on the outer circle of the roof to prevent leaks into the space that contained glasswool.

The second stage was to anticipate the presence of rainwater droplets that penetrated through the tree branches. The team came up with an idea to install rings on the tree branches located under the edge of the ceiling. This is expected to accommodate the flow of water into the ring, which will then be directed into a plastic pipe that ends in the lower bar area. Then, because the appearance of the pipe is less attractive, it will be covered with climbing plants that surround the tree branches.

The third stage, the team had the idea to increase the distance between the ceiling ring and the tree trunk by 2 cm. This is expected that if there is a tree shift due to rain and wind, it will not directly touch the building roof, which can cause a shift in the roof frame and structure.

### 3.4 Prototyping

After obtaining several ideas, the prototyping process was carried out in the field for two weeks, based on the heaviest rainfall intensity recorded during the last two weeks of June. During the prototyping process, several new findings were discovered in the field, requiring the ideation phase to be adjusted accordingly. The following are the processes carried out by the team during the prototyping stage:

1. To prevent leakage from the upper tree trunk part of the ceiling, the team first used cast plastic wrapping to cover the top of the roof. However, the sloping tree trunk span made the cast plastic unable to cover the tree trunk sections perfectly, resulting in leaks. The second system was implemented by using a tarpaulin material, cut lengthwise to a width of 20 cm, with a 10 cm overlap on each section of the wrap. This method was applied like a bandage until it covered the entire roof area. The bandage method also created a water circulation path that flowed down from the roof and easily passed through the bandage, creating its own organic shape following the tree trunk. This method was considered effective because there were no leaks or fungi found in the two-week testing phase, indicating that water did not enter the roof cavity.

2. The process using a ring system on the tree branches connected to plastic pipes yielded unsatisfactory results due to ineffective placement of the ring holes, resulting in water droplets spreading evenly on each side of the tree trunk. The designer then modified the scheme by installing a water rope on the tree trunk with a width of 0.5 cm and a depth of 0.5 cm at each water droplet point,
which was redirected to a larger water rope. This system created cuts in the tree trunk like a river that flowed into a larger rope and at certain safe points, the water droplets were allowed to drip into the soil under the tree.

3. There was a dilemma between function and aesthetics when determining the gap width between the ceiling and the tree trunk. When the gap was widened by 2 cm, the team felt doubtful whether the tree would continue to damage the roof structure. However, if the gap has widened further, it would affect the visual appearance of the bar. The landscape team provided guidance by controlling the tree's growth with hormones. Maintenance was carried out by trimming the branches above the roof, allowing sunlight to reach the small trunk and regulating the cytokinin hormone, while the auxin hormone of the tree was concentrated on the new leaves resulting from the trimming. Thus, the focus of tree growth was redirected to produce new leaves, ensuring the tree's health and the diameter of the tree trunk inside the bar remained under control.

3.5 Test

Based on the experiments conducted above, after 2 weeks of prototyping until the Grand Opening of Tanmu Coffee, no leaks were found from the tree inside the bar. This indicates that the above process is sufficient to overcome the problem. As of the writing of this article, it has been 23 months since the implementation of the method and according to data obtained directly from the owner of Tanmu Coffee, there have been no significant problems with leaks, which can still be handled by staff in the bar. The growth of the tree is also good, with it still growing and having lush leaves.

Fig. 9. Condition of Tanmu Bar Tree in April 2023 (Source: Personal Data, 2023)

4. CONCLUSION

The natural elements and human-made elements should ideally have synergy and coexist, regardless of their purpose and function, which can be achieved through various approaches while still maintaining the existing ecosystem. The interaction between nature and buildings is not a new concept, but it can continue to be applied in every design. For example, the placement of tall trees inside a room is usually avoided due to potential issues, but with a more careful approach to design, everything can work together. This is evident in the design of Tanmu Coffee in the Bogor region, where the tree inside the bar is the star of the interior design, serving as an aesthetic element that adds significant value to the design.

In conclusion, the design team of Tanmu Coffee successfully addressed the issue of leakage caused by high rainfall in Bogor city. Through careful observation and analysis, they implemented effective solutions to prevent water from entering the building, control the flow of water from the tree branches, and address the movement of the roof during inclement weather. The team conducted thorough prototyping and testing, leading to the implementation of measures such as wrapping the tree branches with waterproof material, creating a water circulation path, and redirecting water droplets. These solutions have proven to be successful, as no leaks have been detected from the tree inside the bar during 23-month period since implementation. The growth of the tree has remained healthy, with lush leaves enhancing the aesthetic value of the space. The project demonstrates the possibility achieving synergy between nature and the build environment while effectively mitigating challenges related to weather conditions.

Challenges will inevitably arise in every design, and how we approach and try to solve them is another matter. Although the initial design was deemed optimal, the reality on the ground required research and development to address the issues that arose. The results of the above experiments were deemed sufficient, but the author acknowledges that this experiment is limited due to the need for quick critical thinking to address
problems and prevent their impact from expanding during the construction process. This limitation is also due to constraints in time, manpower, and budget to produce a better, more solid, and rigid system to address the issues. This experiment is an initial idea that is expected to be continuously developed by readers to create synergy between space and nature.

Reference