buildings

Review

Enhancing Sustainable Railway Station Design in Tropical Climates: Insights from Thailand's Architectural Theses and Case Studies

Suppapon Tetiranont [1], Wannapol Sadakorn [1], Napong Tao Rugkhapan [2] and Lapyote Prasittisopin [1,*]

[1] Architectural Technology Research Unit, Department of Architecture, Faculty of Architecture, Chulalongkorn University, Bangkok 10330, Thailand; 6430112225@student.chula.ac.th (S.T.); 6571006225@student.chula.ac.th (W.S.)
[2] Department of Urban and Regional Planning, Faculty of Architecture, Chulalongkorn University, Bangkok 10330, Thailand; napong.r@chula.ac.th
* Correspondence: lapyote.p@chula.ac.th

Abstract: An environmentally conscious architectural design of a railway station can have a substantial influence on government spending. Nevertheless, an extensive collection of guidelines for using sustainable design principles in the construction of a railway station can provide several advantages. The goal is to review design visions for railway stations in Thailand, as reflected in student theses and government proposals, from 1983 to 2022 for sustainable design aspects in tropical climates. We perform an analysis of architectural design aspects including service areas, shape, entrances, roofing, style, and development in order to uncover design trends and possible areas that may be enhanced. Station designs are mostly characterized by curved and gable roofs, with 3D curved buildings being the next most common feature. High speed rail (HSR) stations stress local cultural elements in their major entrances while also improving passenger flow. Public buildings frequently employ curved or gabled porticos to achieve a majestic look. Although university theses place a high importance on conceptual design and functionality, it is essential to also consider cost-effectiveness. Key design considerations for future railway stations are transparency, connection, efficient mobility, and cost–time efficiency. The research uncovers deficiencies in user-centered design for thermal comfort and inclusiveness (design-for-all) in Thailand's tropical environment. Addressing these aspects is critical for future sustainable railway station design evaluations.

Keywords: railway station; architecture; design; tropical climate; structure; sustainability

check for updates

Citation: Tetiranont, S.; Sadakorn, W.; Rugkhapan, N.T.; Prasittisopin, L. Enhancing Sustainable Railway Station Design in Tropical Climates: Insights from Thailand's Architectural Theses and Case Studies. *Buildings* **2024**, *14*, 829. https://doi.org/10.3390/buildings14030829

Academic Editor: Ewa Janina Grabska

Received: 27 February 2024
Revised: 11 March 2024
Accepted: 14 March 2024
Published: 19 March 2024

1. Introduction

In the present, a good infrastructure system is increasingly necessary. In most countries, especially developing countries, their railway systems, which are currently low in efficiency, need improvement to meet the growing demand for the transportation of goods and people. Most of Thailand's railway system still consists of single tracks, which slow down the movement of trains due to the need to wait for other trains to pass. In addition, long-distance (LD) train tickets are expensive, and the speed of the trains is not worth the cost when compared to airplanes or tour buses. Governments in any nation invest a large budget on public transportation infrastructure. For example, the federal infrastructure bill in the United States plans to budget USD 44 billion for rail transportation (approximately USD 140 per person in the United States) [1]. The International Energy Agency (IEA) published in 2021 that global investment in electric railways was estimated to be around USD 450 billion (about USD 1400 per person in the US) per year [2]. Moreover, it was reported that over 1600 buildings have been used for over 200 years (RHT). Maintenance and renovation are tremendously important in this area. In addition, many countries such as those in Europe have focused on developing universal designs or "design-for-all" guidelines for safe and sustainable mobility since 1997 [3]. The Italian Railway authorities, for example, planned to build additional conveniences for accessibility at 2150 medium- and small-sized Italian railway stations, with a budget of EUR 15 million per year [4].

1.1. Literature Review

Currently, developing countries are now focusing on improving and investing in both new and existing rail infrastructures, including in Thailand. Several studies on the architectural design of modern railway stations can offer several benefits [5]. The studied benefits include sustainable design [6,7], smarter system design [8–11], acoustic design [12,13], designs for reduced crime and accidents [14–18], designs for people with reduced mobility [19–22], reduced waiting-time design [23], universal or design-for-all design [24], aesthetic design [25], and reduced PM2.5 pollution [26]. Several design aspects can deliver important integrated facets by eventually bringing down the overall investment and life cycle cost.

While the construction of railway stations was underway, the transportation network emerged as a representation of authority [27]. Railway stations serve as political and diplomatic instruments for China, Europe, and Japan to demonstrate their technology and maintain a balance of power with other nations. Pavlićević and Kratz [28] discovered that overseas diplomatic endeavors have frequently been portrayed within the framework of the China Threat narrative. This narrative suggests that Beijing aims to change the power dynamics in Thailand, Indonesia, Myanmar, Vietnam, Laos, Thailand, Malaysia, and Singapore, thereby negatively impacting the economic, political, and security interests of the countries in the region. This study disputes these interpretations and indicates that these programs lack both the aim and capability to promote such a hostile and extensive agenda towards the area. Hong [29] also stated that there is a connection between China's ambitious foreign policy towards the ASEAN, its national pride, and its financial interests in building modern rail in the area. This analysis examined the underlying reasons behind China's intentions to expand modern rail in the ASEAN region, taking into account China's growing influence and the competition between China and Japan. However, China was likely encountering significant obstacles in achieving its goals. Furthermore, Kitkuakul [30] advocated that the establishment of a railway station might be facilitated by the implementation of a sister city relationship strategy, whereby the funding, which can be limited, was likely to be sourced from economically stronger nations. Akin to Shrivastva [31], the provision of financial grants and technology transfer can achieve success by means of collaborations between public and private entities. Nevertheless, various studies have also argued that implementing such policies across adjacent borders, such as India–China, Pakistan–China, China–Vietnam, might generate geo-psychological pressures on both nations, impacting their diverse geopolitical relationship [32,33]. Moreover, Lim et al. [34] pointed out that the progress made in this regard was diminished by the sluggish implementation of the modern railway project, which was further hindered by the fragmented institutional structure in Indonesia and Malaysia.

Because building performance can be greatly impacted by climate, guidelines for designing railway station architecture in tropical climate conditions are needed [35]. About 25% of the world's energy is consumed by buildings. To reduce society's dependence on fossil fuels, we need to design a building environment with energy balance. Every year, millions of new buildings are needed to accommodate the world's growing population, which will require a lot of raw materials and energy. Climate adaptation is a way to create the sustainable development of buildings [36]. For example, Khan [37] conducted a comprehensive analysis of the energy efficiency of Pakistan's railway stations from 1980 to 2018. These data indicated that rail transit achieved a mere 36% efficiency in 1980, in contrast to its optimal efficiency of 100% in 2018. However, few pieces of literature for designing these in a tropical climate are available. Whereas Theerathitichaipa et al. [38] studied railway service accessibility and unveiled a disparity, indicating that regions with higher population density had better access to railway stations in comparison to districts with lower population density. Designing a railway station's architecture in tropical climate conditions requires careful consideration of several factors to ensure the station provides comfortable and functional spaces for passengers and staff. A tropical climate is characterized by elevated temperatures, humidity, and rainfall throughout the year, making it challenging to maintain thermal comfort and protect the station from moisture and fungal growth. Several factors are taken into consideration in tropical contexts such as climate-responsive design [39], material selection [40], indoor air quality [41], and landscape design [42]. Incorporating passive design strategies, selecting appropriate materials, improving indoor air quality, and incorporating landscape design can help create a comfortable and sustainable railway station for passengers and staff. Riza et al. [43] reported that the small railway station architecture in Indonesia has distinguished architectural designs such as a simple rectangular layout, a pyramid roof structure, and a closed frame building structure. Sulistyani [44] also advocated for rail station architecture in Java, Indonesia, that incorporated local architectural knowledge and colonial context, striking a balance between neoclassical and eclectic architectural styles to address the island's unique conditions. However, no work was evaluated for large-scale public buildings.

This work determined four diverse types of railway stations including:

- High-speed railway (HSR) stations, which are places where high-speed trains can travel long distances, often with a long distance between stations, and transport passengers between provinces or regions;
- LD railway stations, where trains can travel long distances often with shorter distances between stations than high-speed trains, and they transport passengers between provinces or regions;
- Commuter rail transit (CRT) stations, where the station may connect with a light rail transit station and link further regional areas to local transit [45];
- Light Rail Transit (LRT) stations, where the station is generally located in urban and suburban areas. The LRT train typically entails two or three coaches that typically operate at an average speed of 55 to 60 km/h on lines with extensive stops/stations and around 65 to 70 km/h on lines with fewer stops/stations [46,47].

Unlike the above literature, this review offers sustainable designs from architectural students and government documents, and the focus of the analysis is based on architectural design concepts in tropical climates. Our literature survey did not find any earlier studies on the categorization and analysis of architectural design for railway stations in tropical regions. This work aims to review 48 pieces of railway station design literature from 1983 to 2022, based on public drafts and student theses, with a focus on LD and HSR stations. The classification and analysis of the reviewed railway station architecture entails area, form, entrance structure, roof structure, architectural style, and design development. This review provides a systematic guideline for designers, architects, and students to comprehend the basic architectural design concepts of railway stations in tropical climates, enabling them to provide proper designs that minimize costs and enable effective usage.

1.2. Significance of the Review

As previously indicated, each nation has a substantial budget allocated for the construction of infrastructure such as railway stations. Gaining a more comprehensive comprehension of the design in the first phase might yield significant advantages in terms of aesthetics, symbolism, cost, construction duration, mobility, and sustainability. The study offers a helpful synopsis of the architectural factors involved in railway station design. The goal of this work is to review architectural design concepts for railway stations in Thailand, as reflected in 48 student theses and government proposals for sustainable design concepts in tropical climates. The issues and future recommendations were also discussed. Our findings indicate a range of factors that need to be taken into consideration, such as structural complexity, cost, aesthetics, and local contexts. However, it would be advantageous to look more specifically into the issues and solutions that are unique to tropical climates. The evaluation establishes a basis for further investigation and advancement in the realm of tropical railway station architecture.

2. Review Methodology

The research was conducted by collecting research papers and theses in the Faculty of Architecture from five university databases and train station proposal blueprints from library databases and electronic media, "Basic Structure of Thailand." The search was conducted from January to November 2022. The first architecturally designed and constructed railroad station buildings in Thailand were found in 1983. In total, 60 designs were found but four of them focused mainly on transit-oriented development or landscape study, rather than the building part, and were excluded from this work. After excluding the irrelevant designs, there were 48 items left relating to railway structure design. It should be noted that the limitation of some information from the universities outside Bangkok was excluded.

The 48 items, as tabulated in Appendix A, left relating to railway structure design were analyzed and summarized according to several criteria: the type of station by year, the number of stations by service line, the relationship between area usage, the number of floors, the number of platforms, the form, the type of roof, the entrance characteristics, the architectural style, and the design development, respectively. The PICO (population, intervention, comparison, and outcome) process was adapted and depicted in Table 1. Some qualitative analyses were performed to determine the forms and architectural styles of the structures and designs, based on group discussions of five academic and practitioner experts. This may be the limitation of the qualitative research in this work since the analysis is based on the background and experience of each individual. It should be noted that some literature did not provide exact length or area values; therefore, the researchers used AutoCAD software to measure them. Hence, there may be a risk of bias from the five experts, which should be acknowledged as a limitation of this analysis work. The research flow diagram is illustrated in Figure 1. The direct and indirect factors influencing the architectural design for railway stations in tropical climates are also given in this figure.

Table 1. PICO method of study.

PICO Component	Explanation
Problem—P	The architectural design of railway stations in tropical design is lacking.
Intervention—I	Examine railway station designs of theses in Thai universities and draft proposals of Thai government.
Comparison—C	Compare railway station designs in tropical climates (Thai context) with the general design.
Outcome—O	Architects and designers make structures more appealing and functional. Thesis-designed stations emphasize concept and function over cost. Railway station design should prioritize transparency, connectivity, movement, cost- and time-efficiency.

Guidelines for designing modern railway stations exist in developed countries such as the UK, USA, Europe, and China, leaving behind the railway stations in developing countries globally. However, many of these design guideline suggestions cannot be adopted in many nations such as when designing for tropical climates. With the growing construction of railway stations around the world, especially in developing countries, the novelty of this work presents, for the first time, reviewed design principles of railway stations in tropical climates. The benefits of this review work are that it can offer designers, educators, and students an in-depth comprehension of the general design concept for designing railway stations. This review forms part of establishing the design guidelines for railway stations in tropical climates.

The main focus of the summary is to provide guidelines for designing the important components of the station and the differentiation between the thesis works and the practical building designs.

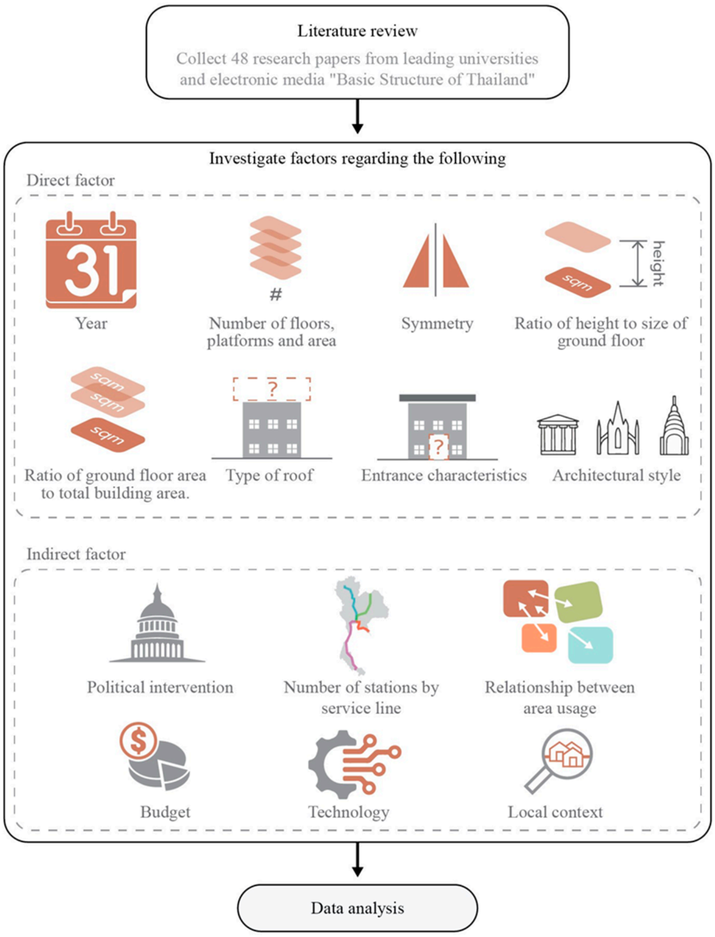


Figure 1. Research flow diagram.

3. Results

3.1. Size of Station and Service Area

From data analysis, it is clear from the bar chart that there has been a significant increase in the number of railway station blueprints and theses since 2014–2016, as shown in Figure 2. A substantial portion of the literature focuses on HSR and LD stations (greater than 90%). This is because the primary factors that determine the economic viability of HSR stations are construction costs, the value of time savings per commuter, traffic volume, and the level of congestion in the current global transport networks [48].

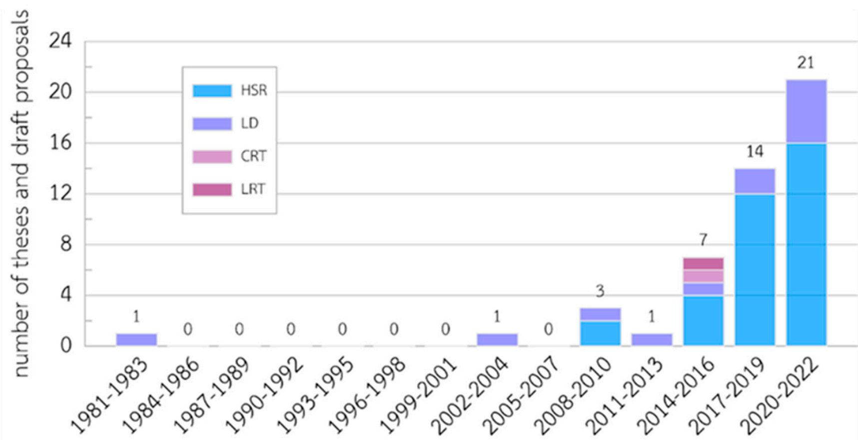


Figure 2. Classification of railway station categories by year range.

In Thailand, four main routes connect Bangkok with the northern, southern, eastern, and northeastern regions. Thonburi, BTS, and node lines are the routes located in Bangkok. The railway station was built significantly on the Northeastern line, which has a large and populated area. When considering only the train stations on the Northeastern line, as shown in Figure 3, there are 14 stations. It was found that HSR stations have a larger functional area (ranging from 31,450 to 91,000 sq. m.) than LD stations, up to 31–91 times larger. The HSR stations were designed with other usable areas such as waiting rooms, commercial sections, intersections, and more platforms. In addition, HSR stations have more floors (ranging from three to five floors) than LD stations (two floors). The LD stations are designed for rural and distant areas; therefore, many trains pass and do not stop at these stations. The number of platforms in HSR stations is the highest at 14 platforms. This is because these stations are main intersection stations and a hub for international lines like those from Laos and China. Therefore, when designing a train station, the location should be considered to ensure it can accommodate commuters' needs appropriately. It should be noted here that the service area in each station is not related to the number of passengers. As discussed, the station types are generally classified as national, hub, international, and general stations. Therefore, the benefits of designing the service area are dependent on the commute type.

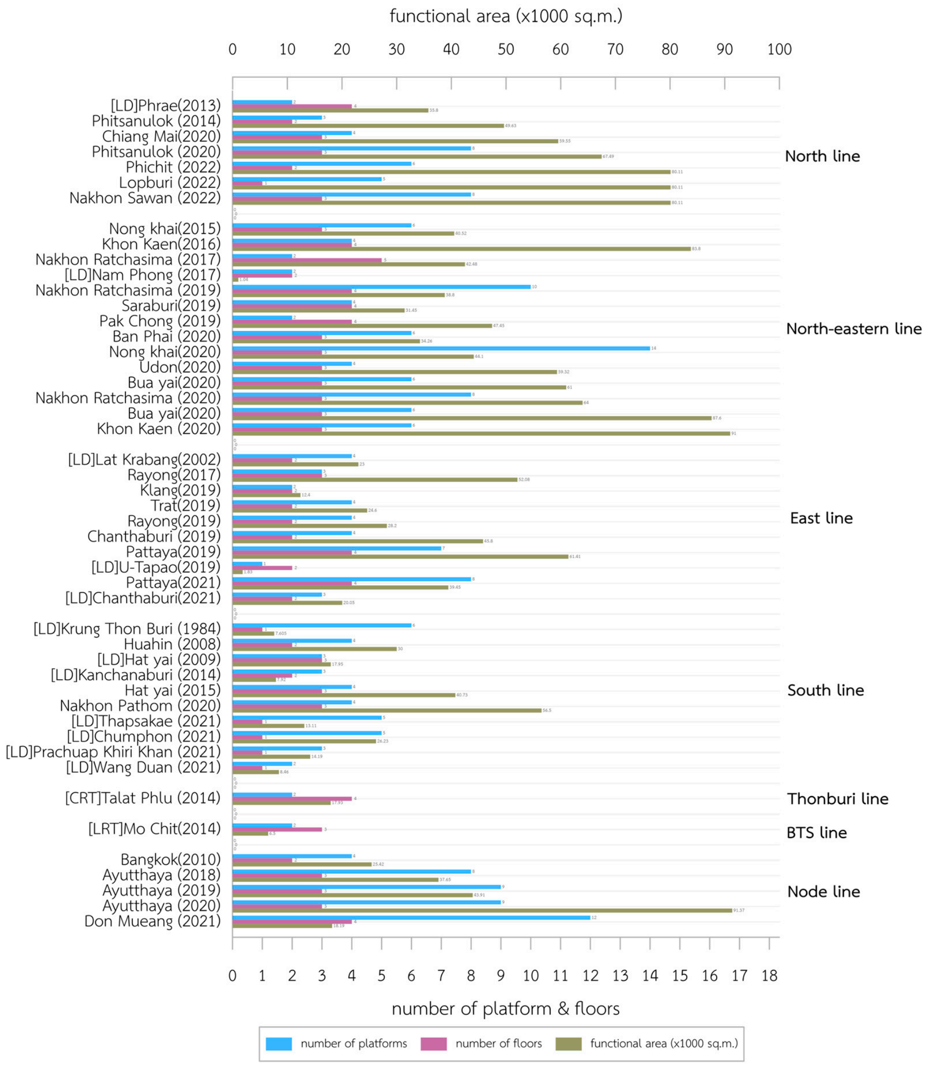


Figure 3. The functional area used, the number of platforms, and the number of floors of all railway stations.

3.2. Form of Station

The form of the station is analyzed with three considerations: (1) symmetry, (2) ratio between height and area of the first floor, and (3) ratio between area of the first floor and the total floor area.

The symmetrical design is defined herein as the building structure of the main entrance views where both sides have area ratios of not greater than 10% differences. In general, most government buildings have symmetrical designs to create a sense of trust, reliability, and stability. The symmetry projects a positive image while also enhancing the building's ornamentation perception for users. Figure 4 shows the analysis of the ratio between symmetry and asymmetry of 29 HSR stations. The results reveal that 26 or 90% of the HSR stations have symmetrical designs, in both architectural design proposals and student theses. The remaining three non-symmetrical designs appear in theses only. All the HSR design proposals are in a symmetrical form. It is also worth noting that symmetrical forms facilitate easier design and construction due to their unified structure, leading to enhanced stability against external forces like seismic and wind loads. As a result, this form is commonly employed in public buildings. The predominant preference for symmetrical design strongly highlights symmetry as a key formal aesthetic consideration for public buildings in Thailand.

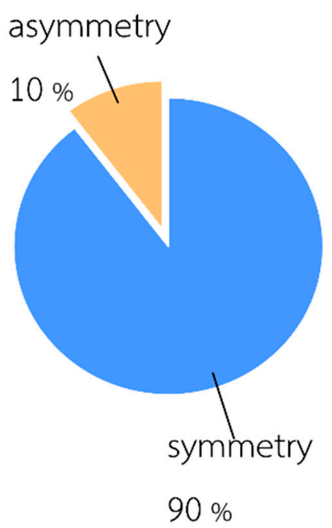


Figure 4. Ratio between symmetry and asymmetry forms of HSR stations.

Figure 5 shows the ratio between the height and the first-floor area of HSR and LD stations. The height was measured from the ground to the top of the roof structure using AutoCAD software. When determining the height-to-first-floor area ratio of the LD stations, the results indicate that the LD stations have an average ratio value of 2175, with a range of ratio values from 1760 to 2840. Meanwhile, the HSR stations have a lower average ratio of 1360, with a range of ratios from 640 to 3350. The average ratio value of the height-to-first-floor area of the HSR station is approximately 36% lower than the average ratio value of the LD station. These findings indicate that the HSR station design has a flatter exterior proportion than the LD stations, as the HSR stations are mostly interconnected to adjacent LD stations. As far as station functions are concerned, this consideration led to a horizontal rather than a vertical layout. Other reasons for the flatter exterior of HSR stations include designing for more passengers, more facility requirements, a design concept as the main regional hub, and universal design for loading, train service information, seat booking, wheelchairs, and escorts from and to the station entrances and exits to the train [49]. These considerations reflect the designer's acute understanding of the role of a railway station, not only as a transport conduit but also as a place in itself.

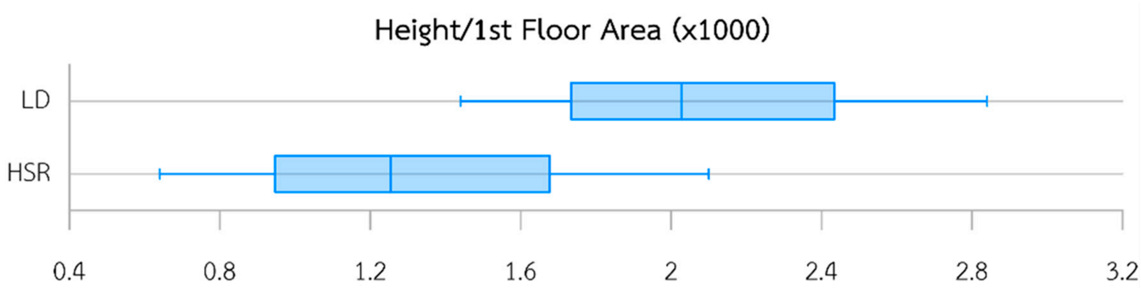


Figure 5. Ratio between height and first-floor area.

The values calculated from the area ratios between the first floor and the total floor are shown in Figure 6. The results reveal that when considering the area ratio of the first floor and the total area of the LD station, the average value is 55.0%, with a range of 28% to 65%. Meanwhile, the HSR has a lower value of 52.3%, with a wider range of 39% to 93%. This means that HSR stations have a higher proportion of first-floor area because they are generally transfer stations for LD stations or other transport, which are located on the first floor. As a result, an LD station has a higher proportion of non-first-floor area than an HSR station.

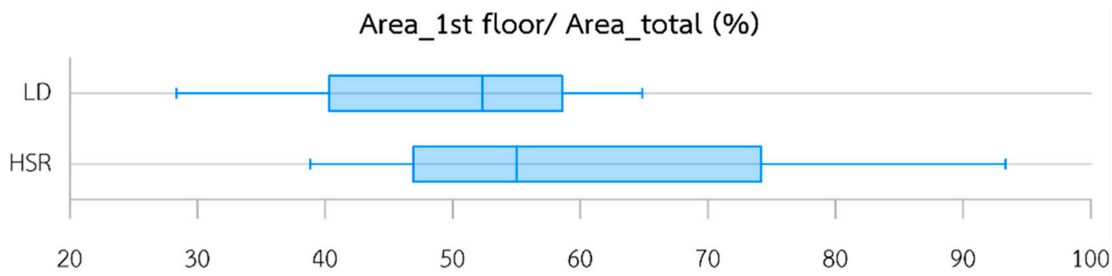


Figure 6. Ratio between first-floor area and total floor area.

3.3. Roof Characteristics

Given the variety of roof designs, the authors created a classification of roof characteristics based on the architectural design concept. Figure 7 illustrates eight different roof typologies, including geometric, gabled, lean-to, overlapping gable, curved, sawtooth, curved gabled, and 3D curved roofs.

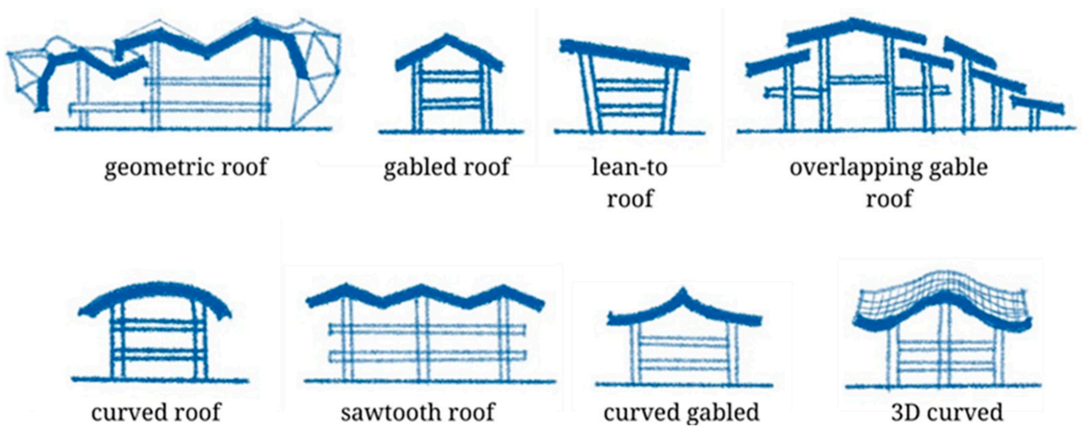


Figure 7. Roof typology.

When designing roofs for railway stations in hot and humid climates, it is essential to consider the slope of the roof to reduce solar energy entering the building and prevent rainwater from accumulating [50,51]. According to De Wall [50], roof systems with small slopes do not effectively reduce solar energy as they can receive equal solar heat. Therefore, railway station roofs require a sufficient slope to achieve optimal design.

The analysis of HSR station roof design from 2014 to 2022 is presented in Figure 8, based on draft proposals. The analysis indicates that all of the proposals feature sloping roofs, and no flat roofs were proposed. This is because a sloping roof can reduce the amount of solar energy entering the building and prevent rainwater ponding.

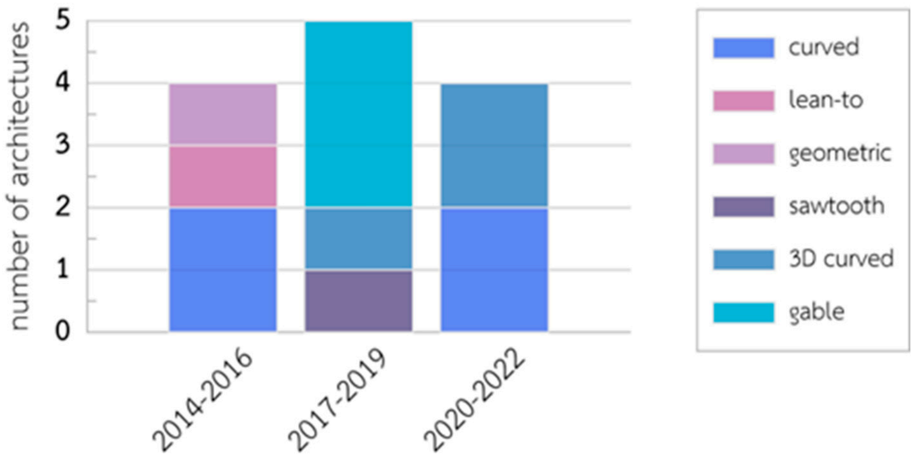


Figure 8. Compilation of characteristics of high-speed railway station roofs since 2014.

In terms of roof form, the station's design aims to reflect local identity and does not feature complex, costly roof structures. The most common roof types are curved and gable roofs, followed by 3D curved roofs. A few designs feature lean-to, geometric, and sawtooth structures. In addition, it was found that the 3D curved roof was introduced in the railway station design after 2017. Recently, only two roof design types were conducted, which were 3D curved roof designs and curved designs. The curved roof design can add interest to the entrance without significantly increasing the complexity of the structure and construction process. The gabled roof design is popular in construction due to its simplicity, which can still highlight the identity of the region in the station's design.

It is worth noting that roof designs are often deliberately designed to reflect regional identity and Thai traditional architecture. Specifically, HSR stations, being nationally prominent projects, tend to showcase roof designs that blend regional and national identities. For example, the Kamakhya Station in India emphasizes the importance of maintaining the city's identity in the station's visual and experience design, which can be an investment in tourism and benefit the local economy [52]. These showcases can be for government investment in tourism activity and cause local economies to benefit from tourists as well [53].

In this study, many of the roof characteristics are designed to represent local identity. Located in the Northeast, the Udon Thani HSR station, for instance, is a multi-story HSR station with design motifs inspired by the ancient pottery of Ban Chiang, the province's prehistoric archaeological site. The historical elements are reinterpreted and recreated in modern decorations, patterns, forms, and color schemes, as illustrated in Figure 9.

Our analysis also notes that the designs derived from the student theses tend to feature complex roof characteristics. Figure 10 shows student design theses from 2016 to 2022. The findings point to an increasing trend in roof design with greater complexity since around 2016. From around 2017 onwards, there has been a development from roofs with geometric shapes to 3D curved roofs. We speculate that complex roof structures were achieved in the later years because of the availability of commercial parametric modeling software and were thus adopted for educational purposes [54]. Many parametric design concepts can be created using CAD packages such as Autodesk Revit, Nemetschek, Soft [55].

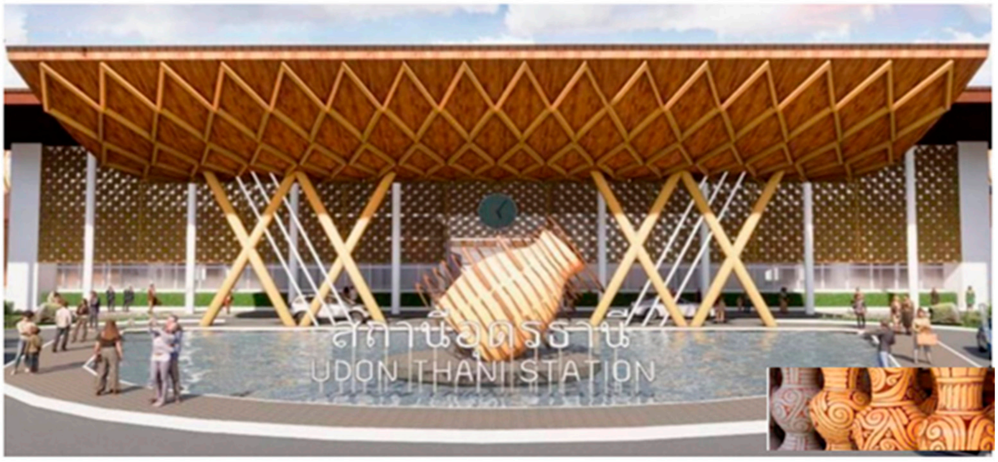


Figure 9. Draft proposal of Udon Thani railway station and ancient Ban Chiang pottery.

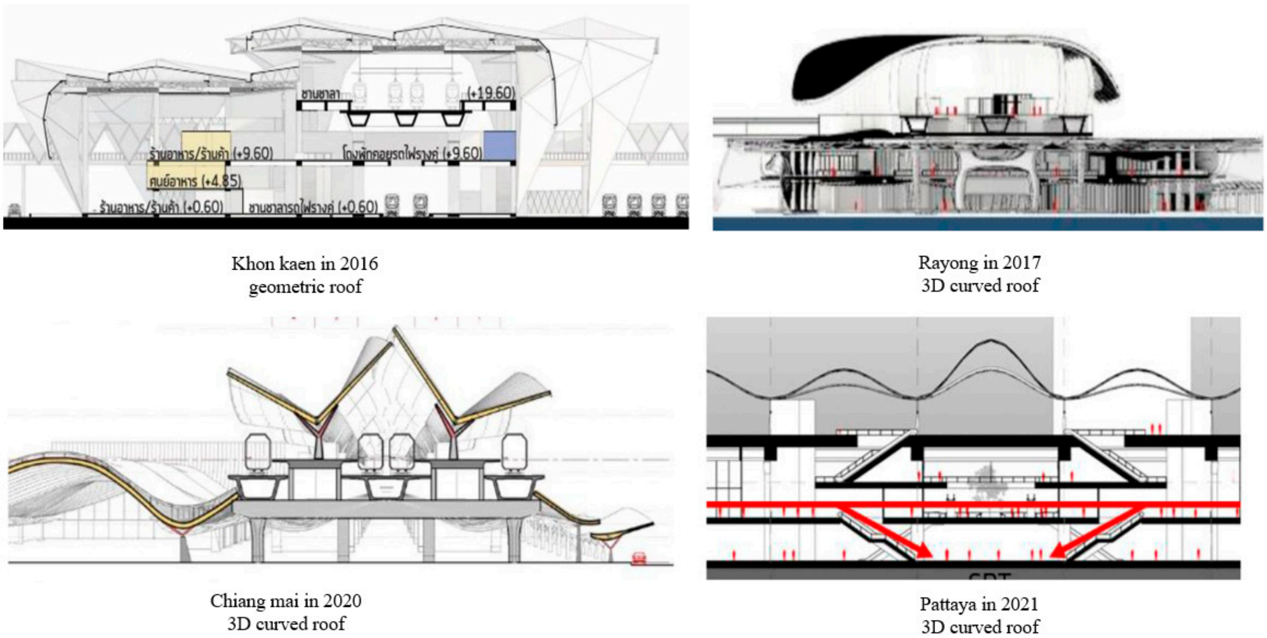
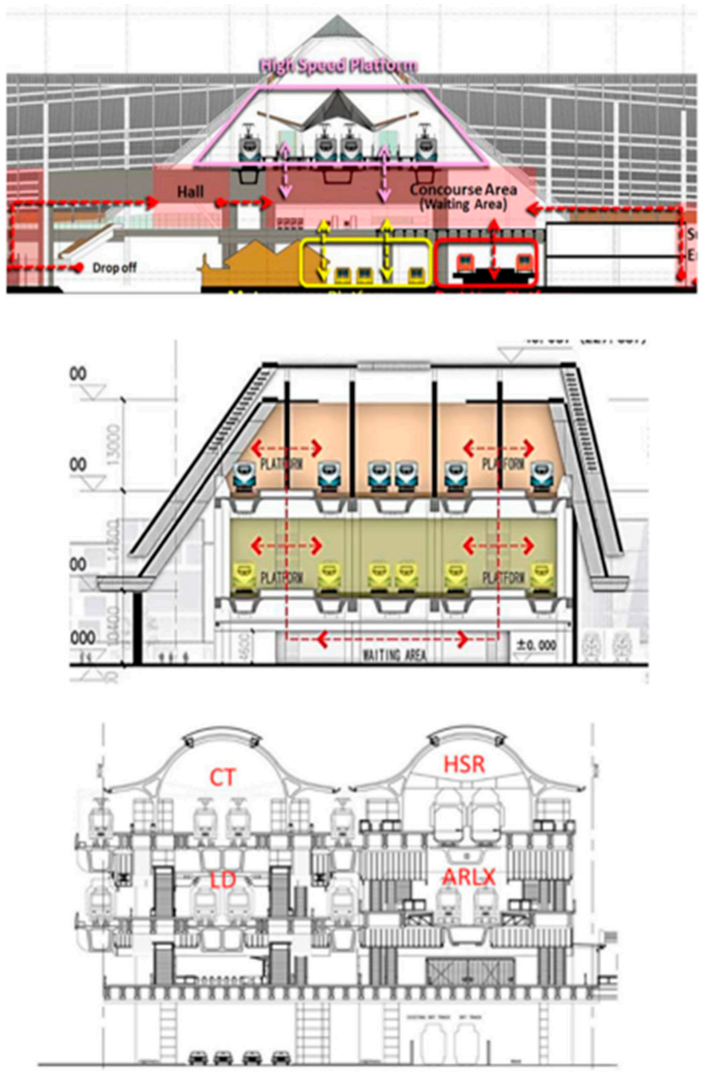


Figure 10. Development of HSR stations from theses.

However, complex roof designs are not always tenable. Upon performing numerical structural safety analysis like finite element analysis, some of the designs, for example, may not be secure. As a result, the complex roof designs were simplified. Other practical challenges include construction difficulties that lead to high construction costs. For example, joints of complex roofs are prone to leakage over time. Barrelas et al. [56], studying 15 pavilion schools in Portugal, found that most severe defects primarily affect the building's exterior envelope like the roof. In our research, for example, popular 3D curved roofs have been proposed in the student theses since 2017, as shown in Figure 11. In the design proposals for constructing the roof, reducing the structure's complexity and curvature to align with the local identity is a valid consideration. However, it is crucial to take into account not only the design's aesthetics and complexity but also practical factors such as structural safety, construction feasibility, and maintenance costs.



Ayutthaya in 2019
gabled roof

Nakhon Ratchasima in 2020
lean-to roof

Don Mueng in 2021
curved roof

Figure 11. Development of HSR stations from draft proposals.

In sum, it is crucial to consider the local context and identity of the site in which the building is located. Despite the prevailing preference for complex and parametric-shaped roofs in university design theses, it is important to balance that with practical factors and the local context. Thus, while contemporary design trends often lean towards parametric shapes, designers must carefully weigh various constraints, including structural safety, cost, maintenance, feasibility, and material availability. Consequently, designers may reduce the complexity of the structure and prioritize the incorporation of the site's local context and identity.

When considering the draft for the actual construction of the HSR stations shown in Figure 11, it is evident that the roof design exhibits large patchwork characteristics, creating significant surface areas under the roof with different qualities such as gabled, gabled on the top, and curved roof. Therefore, it can be seen that roofs have different features depending on the location's region. The Ayutthaya HSR station in 2019 has a gabled roof to emphasize the province's identity, which has historical significance as the old capital of Thailand. The Nakhon Ratchasima HSR station in 2020 also features a gabled roof with a flat top, highlighting its gable-like appearance from the side view, while the interior space is unique, creating a difference between the interior and exterior areas. Lastly, the Don Mueang HSR Station in 2021, located next to the international airport, features a curved roof design reflecting the wind-lifting shape of an airplane wing. The roof design is modern in shape, avoiding complex and expensive structures to maintain cost-effectiveness, as well as increasing structural efficiency from horizontal loading like wind.

3.4. Main Entrance Characteristics

The main entrance is a prominent feature of a public building, and, therefore, is often designed to accommodate key functions and reflect the beauty of its architectural identity, such as high and popular styles [57]. In terms of functionality, the main entrance offers practical advantages by reducing the distance one must walk from their starting point or destination during a trip. The main entrance serves as an important junction that allows pedestrians to move between the street network and facilities for boarding or alighting. This accessibility can contribute to increased ridership and success for passenger railway systems by exposing more people to the existing network [58]. The types of main entrances to HSR stations are shown in Figure 12. They can be classified into nine types, including lean-to, curved portico, curved gable portico, gabled portico, underground entrance, 3D curved portico, double overlapping gable portico, overlapping portico, and side entrance.

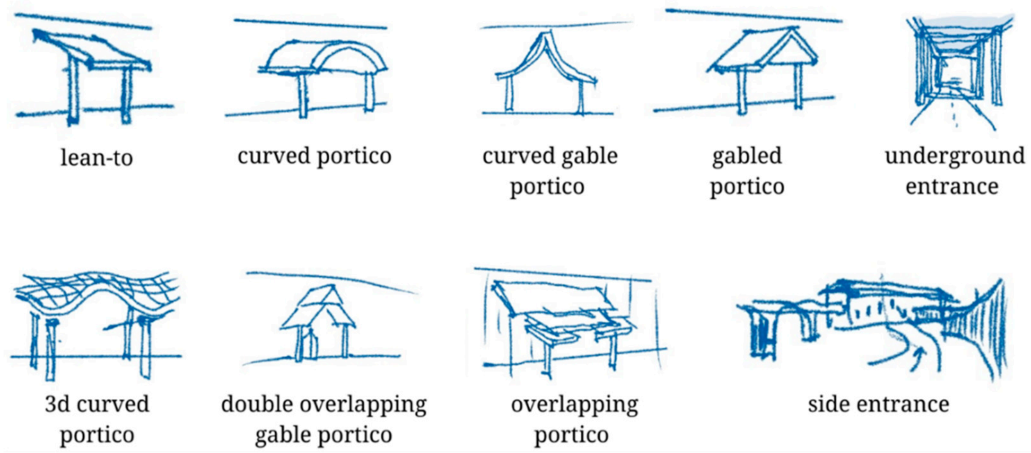


Figure 12. Main entrance characteristics.

Regarding the characteristics of main entrances to HSR stations from the student theses submitted between 2014 and 2022, they can be classified as depicted in Figure 13. The main entrance designs can reflect the cultural, political, and religious context of the area [59]. The most elaborately designed main entrances feature curved porticos and gabled porticos, followed by lean-to porticos, side entrances, overlapping porticos, curved gabled porticos, basement entrances, 3D curved porticos, and double overlapping gable porticos, respectively. A curved portico is an architectural feature that creates a sense of grandeur and elegance to the building's façade. A portico is a covered entranceway typically supported by columns or pillars and can be an integral part of a building's overall design. A curved portico is a type of entranceway that features a curved or arched roofline. This design evokes a sense of movement and flow and can be particularly effective in buildings with curved or rounded façades. The curved roofline also provides a visual contrast to the straight lines of the building's walls, creating a more dynamic and interesting appearance. A gabled portico is a type of entranceway that features a triangular or peaked roofline, known as a gable. This design accentuates a sense of height and grandeur and can be particularly effective in buildings with tall or imposing façades. The gable can also provide a visual focal point for the entranceway, drawing the eye upward and creating a sense of verticality.

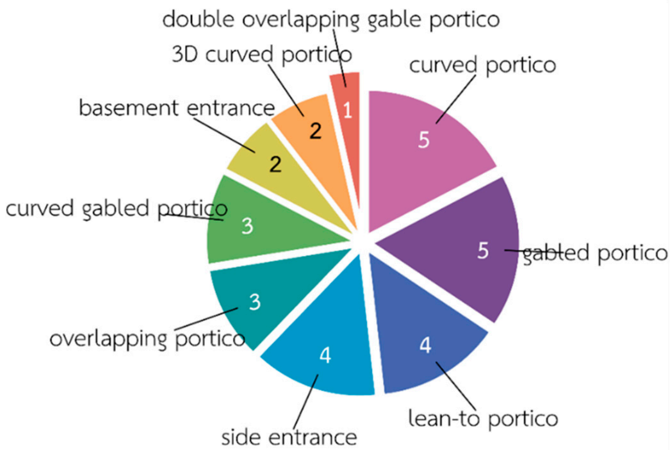


Figure 13. Number of HSR stations for different main entrance characteristics after 2014.

A lean-to portico is an architectural feature of a slanted roof attached to the side of a building, supported by columns or pillars. This type of portico serves both functional and stylistic purposes, providing protection from the elements and adding visual interest to the façade. The lean-to portico is often used in residential architecture, where it can shelter outdoor space and create a welcoming entranceway. It can also be used in commercial and public buildings, such as schools or government offices, where it can provide covered outdoor spaces for waiting or congregating. One advantage of lean-to porticos is that they provide a simple, cost-effective way to add outdoor space to a building. They can be built using a variety of materials, including wood, brick, or stone, and are designed to blend seamlessly with the building's existing architecture. Another criterion for designing a sustainable railway station is to incorporate buffer zones or outdoor space, which may significantly improve the living circumstances of the residents in terms of both thermal comfort and indoor air quality. This redesign is very common for buildings in tropical climates to save energy from air conditioning systems. Tantasavasdi and Inprom [60] reported that using the buffer spaces and open area can provide thermal comfort for 24 h compared to 0 h in the comfort zone per day and indoor air quality from 24 h compared to 8–17 h, passing the minimum ventilation requirement per day. Additionally, in order to examine the impact of atrium components on indoor natural environmental conditions, Atthakorn et al. [61] evaluated four specific case studies in Bangkok. Their objective was to identify the relationship between atrium elements and the characteristics of the indoor environment. Based on the findings, the researchers proposed guidelines for designing semi-open atriums and proportion of roof openings (skylights) and the level of openness of the atrium on the ground floor might significantly influence the design in order to improve sustainability.

An overlapping portico in a public building refers to a type of architectural design in which a building has a series of covered walkways or porches arranged to create a layered effect. This design can be seen in various public buildings, such as government offices, museums, libraries, and other public institutions. This design is often used to create a sense of grandeur and importance, as the layered effect gives the building a more imposing and impressive appearance. Additionally, overlapping porticos serve functional purposes. They provide shelter from the elements, allowing people to move around the building without getting wet or exposed to the sun; furthermore, the shaded areas created by overlapping porticos can be used as outdoor seating areas and walkways.

A curved gabled portico is an architectural feature characterized by a curved or rounded roof covering a porch or entranceway. These types of porticos appear in various architectural styles, including Gothic, Renaissance, and Baroque. Curved and gabled porticos are architectural features that can add a sense of grandeur and elegance to a building's façade. A portico is a covered entranceway that is typically supported by columns or pillars and can be an integral part of a building's overall design. A curved portico is a type of entranceway that features a curved or arched roofline. This design can create a sense of movement and flow and can be particularly effective in buildings with curved or rounded façades. The curved roofline can also provide a visual contrast to the straight lines of the building's walls, creating a more dynamic and interesting overall design. A gabled portico is a type of entranceway that features a triangular or peaked roofline, known as a gable. This design can create a sense of height and grandeur and can be particularly effective in buildings with tall or imposing façades. The gable can also provide a visual focal point for the entranceway, drawing the eye upward and creating a sense of verticality.

The least popular main entrance features include basement entrances, 3D curved roof entrances, and double overlapping gable portico main entrances. Railway stations with basement entrances may be less popular because they are larger stations that can accommodate multiple types of trains, such as Don Mueang Station in 2021 and Ayutthaya Station in 2019, and therefore there are fewer stations with this feature. In addition, the construction and material used for basement entrances, 3D curved roof entrances, and double overlapping gable portico main entrances generally require larger budgets, which can lead to cost constraints. Basement entrance architecture refers to the design concept in which the main entrance of a building is located at the basement level rather than at the ground level. This approach can provide several territorial advantages. Firstly, it allows for greater privacy and security by restricting access to unauthorized individuals. Additionally, the basement entrance can be designed with security features such as cameras or access control systems to further enhance security. Furthermore, this design approach can provide a solution for sites with limited space by freeing up valuable above-ground space for other uses, such as landscaping or parking. In urban environments where space is at a premium, this design concept can be especially beneficial.

A 3D curved roof entrance features a roof with a 3D curve that covers an entranceway. These entrances are often designed to create a dramatic effect and can be found in a variety of building types, including commercial buildings, public buildings, and private residences. The use of 3D curved roof entrances to create impressive entrances dates back centuries. However, these entrances are less common in railway stations due to the complexity of their shape, which makes construction difficult and often not cost-effective. In contemporary urban architecture, various considerations, including accessibility for disabled individuals [62] and wheelchair users, evacuation plans [63], and smoking areas [64,65] are considered alongside architectural styles.

3.5. Architectural Style

After classifying railway station designs' architectural style since 2014, the classification of HSR station designs based on architectural design concepts is shown in Figure 14. The results reveal a significant increase in the number of HSR station designs since 2014. The highest proportion of HSR station designs is the Thai contemporary style (32%), followed by parametric (30%), post-modern (27%), modern (7%), and colonial (4%) styles.

The Thai contemporary architecture style is a modern interpretation of traditional Thai architecture, blending past elements with modern design and construction techniques suitable for tropical climates. One of the key features of Thai contemporary architecture is the use of natural materials such as wood, bamboo, and stone, which are often combined with modern materials like concrete and steel. This creates a unique blend of traditional and modern elements that are both functional and visually appealing. Another important aspect of this style is the incorporation of traditional Thai design motifs such as intricate carvings, patterns, and colors. These motifs are often used in a subtle way to a sense of continuity with the past while allowing for contemporary interpretations. Therefore, this style is a preferred choice adopted to reflect local identity aligning with the building adoption of tropical climate conditions [66].

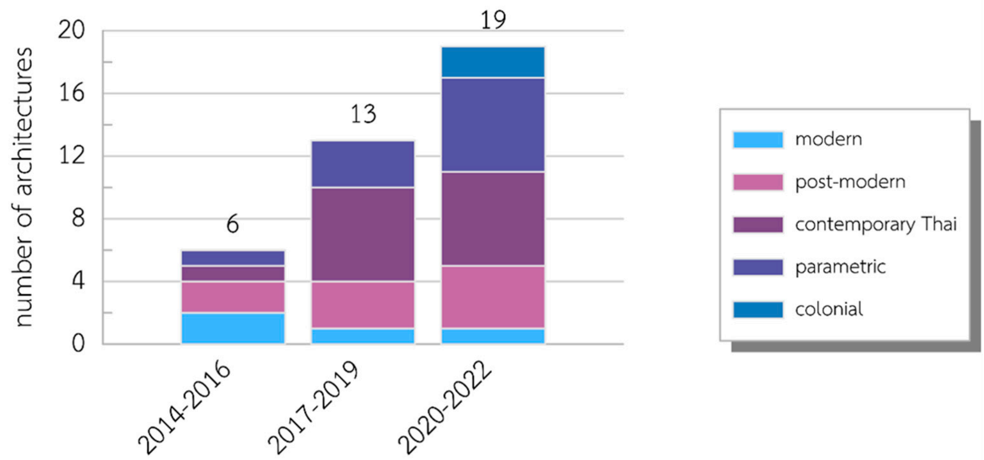


Figure 14. Classification of HSR stations since 2014 based on architectural styles.

The post-modern style of train station design can be adapted to a tropical climate in several ways. One of the key design considerations for a train station in a tropical environment is how to provide shade and ventilation while also maintaining a sense of visual interest. This style can be incorporated with domain features such as open-air atriums, greenery, and sustainable materials to create a visually stunning and environmentally friendly space that is well-suited to the local climate and culture [67,68]. The demand for modern architecture is decreasing over time, while the demand for contemporary Thai and colonial styles remains the same. In addition, there is an increasing demand for parametric colonial architecture.

The declining interest in modern architecture may be attributed to the rising popularity of design innovations such as parametric and non-orthogonal architecture. Designers are seeking alternatives to traditional station designs, aiming to craft dynamic spaces, which are crucial considerations in the context of railway station design [69,70]. There are various options available for designing stylistically unique buildings, particularly through the use of parametric and non-orthogonal architecture. These approaches allow for the creation of free-form designs that can differ significantly from traditional, symmetrical forms. Design software such as Rhino with Grasshopper and Solidworks can be adopted when using parametric design.

However, the situation presents Thai designers with a tension between the desire for unique, innovative architecture and the goal of creating grand and elegant infrastructure that adheres to symmetrical forms. Often, the government may prioritize the latter, which limits the extent to which designers can explore experimental approaches to building design. In practice, this tension between innovation and tradition can be seen in many modern building designs in Thailand and elsewhere. Architects and designers seek to push the boundaries of what is possible with unconventional forms, while more pragmatic designers prefer the creation of buildings that fit into existing architectural frameworks and cultural expectations. Ultimately, the choice between these approaches depends on a variety of factors, including the purpose of the building, its intended audience, and the broader social and cultural context in which it will be situated [71]. A critical balance between these two concepts is required, one that balances the benefits and limitations of both innovation and tradition.

3.6. Development of Railway Station Design

This section discussed the development of railway station designs for the same buildings based on four sections entailing (1) thesis-to-thesis over time, (2) thesis-to-draft proposal, (3) draft proposal-to-draft proposal over time, and (4) the existing design evolution of the railway station. The development of eight railway station designs at the same stations is exhibited in Figure 15.

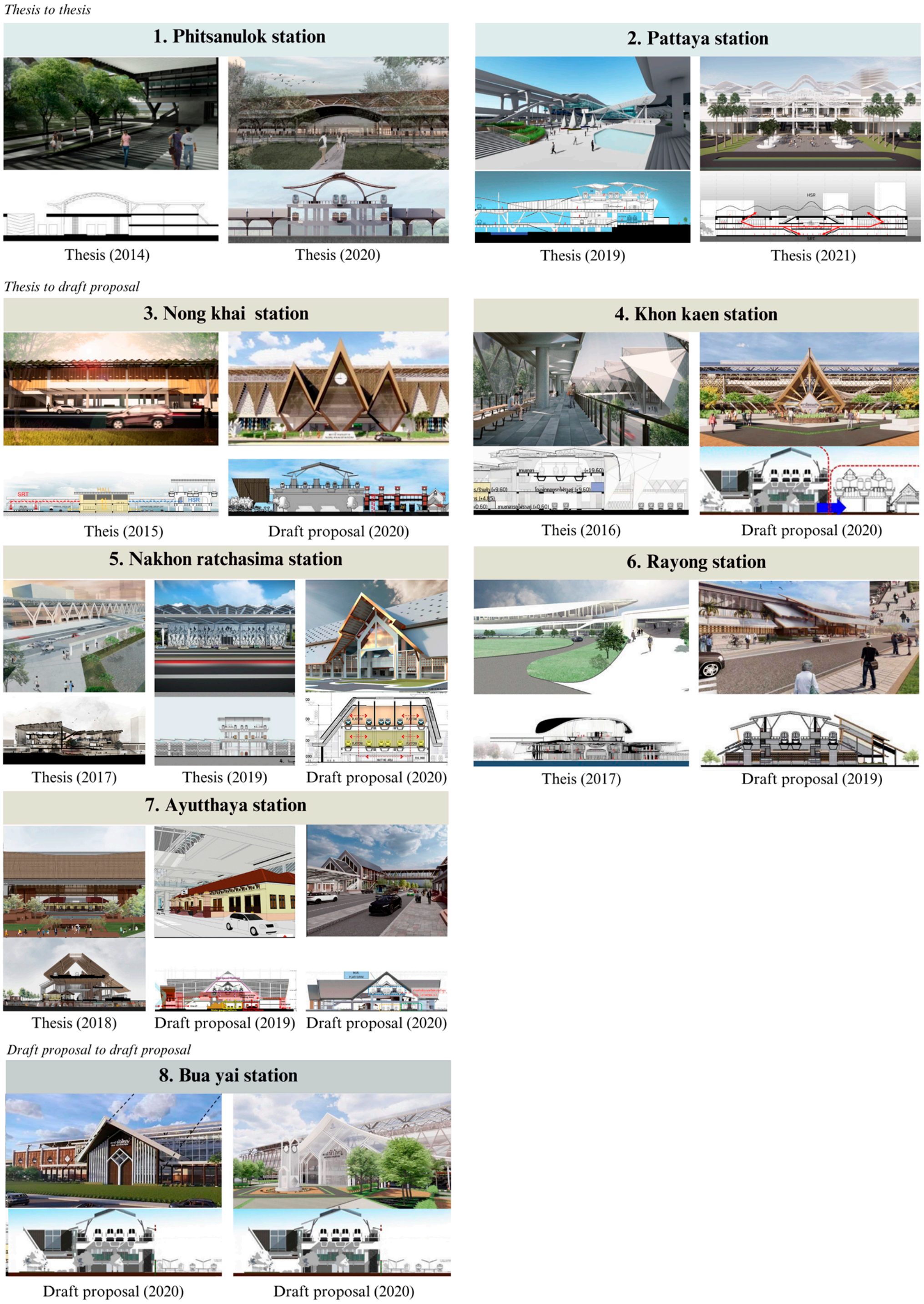


Figure 15. Development of railway station designs at the same locations.

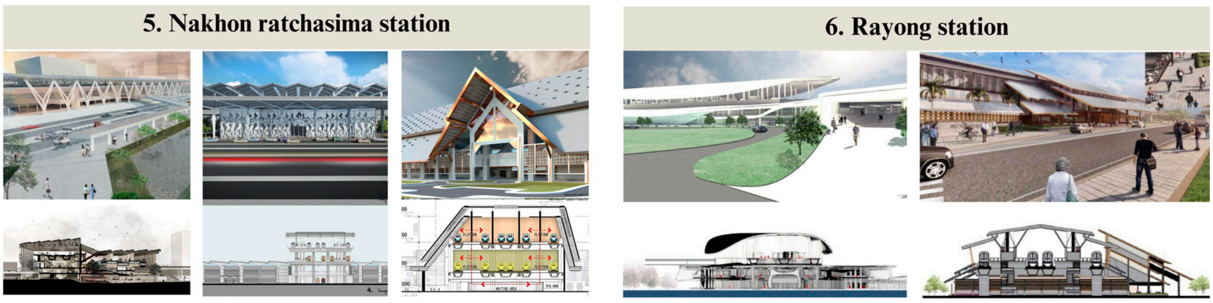
The design of buildings and structures has evolved over the years, with architects and designers striving to create more visually appealing and functional structures. In this context, the structural differences between the two versions of a station start and end with a thesis of Phitsanulok and Pattaya railway stations. Specifically, the Phitsanulok station designed in 2014 was compared with the station designed in 2020, and the Pattaya station designed in 2019 was compared with the station designed in 2021. The railway stations designed in 2014 have a simpler design and a smaller footprint compared to the 2019 versions. Their architecture appears straightforward, with minimal embellishments and a focus on practicality. The stations are designed to serve their primary purpose of transporting passengers efficiently. However, the stations designed recently have a much more complex structure, as seen in the use of a 3D curved roof to create a nature-inspired dynamic perception. This design element gives the station a unique and striking appearance, making it a landmark in the area.

The 3D curved roof of the Phitsanulok railway station, designed in 2020, draws inspiration from nature, particularly the organic curves observed in natural elements like seashells and flower petals. This design feature creates a dynamic perception, with the roof appearing to be in motion, even when the structure is stationary. The curved roof also allows natural light to enter the station, creating a warm and inviting atmosphere for passengers. In addition to the curved roof, the 2020 design has other structural design elements that are not present in the 2014 version. For example, the station's interior layout is reconfigured to provide better flow and functionality. The station now has separate areas for ticketing, waiting, and boarding, making it easier for passengers to navigate the station. The station also has a more extensive platform and improved lighting, enhancing passenger safety and comfort. The Phitsanulok railway station that was designed in 2020 is a significant improvement over the 2014 version, both in terms of its structural design and functionality. The use of a 3D curved roof, inspired by nature, gives the station a unique and striking appearance, making it a landmark in the area. The reconfigured interior layout and improved lighting also enhance passenger safety and comfort. Overall, the railway stations designed in the latest version demonstrate how structural design can improve functionality while creating visually appealing structures.

The process of designing a railway station involves several stages, starting with the development of a thesis and culminating in the creation of a draft for actual construction. This process typically involves the incorporation of various elements, such as site constraints, user needs, and aesthetic considerations. As such, the resulting station design can depart from the original vision, depending on the specific requirements of the project. In comparing two different railway station designs at the same place, specifically one designed previously and another designed later, it can be observed that there are differences in their structural design. The former design is characterized by a simpler and smaller footprint, whereas the latter design incorporates a more complex structure. The latter can be seen in the increased use of 3D curved roofs, which serve to create a dynamic perception and draw inspiration from nature. The use of 3D curved roofs is a common design element in modern architecture, and it is often employed to create a sense of fluidity and movement. This approach is particularly effective in station design, where the goal is to provide a seamless transition for commuters moving through space. The incorporation of curved roofs can also serve as a way to integrate the station with its surrounding environment, as it can create a visual link between the built environment and the natural landscape. Furthermore, the latter design of a railway station appears to prioritize the creation of a unique visual identity. The use of dynamic curves and organic forms creates formal uniqueness, which can help to differentiate the station from other similar structures. This approach is in contrast to the former station design, which appears to prioritize functional considerations over aesthetic ones. In summary, the process of station design involves several stages, and the resulting structure can vary significantly depending on the specific requirements of the project. In comparing the two different station designs for similar projects, it is evident that the later design of a railway station incorporates a more complex and visually distinct structure, as evidenced by its increased use of 3D curved roofs. With the development of parametric design, this design approach serves to create a sense of fluidity and movement, as well as to integrate the station with its surrounding environment. It should be noted that although this design type can provide complex and distinct structure, the maintenance of this structure can be its limitation practically because in tropical climates, sunlight and water can severely deteriorate the structure and jointing between each roof panel. Once the jointing was degraded, the water can leak into the structure. Hence, either inspection and maintenance more often or designing the complex system of using hindered joints where the sunlight does not reach can be promising solutions.

The design process for stations involves several stages, including the development of a thesis and culminating in the creation of a draft for actual construction. In the case of the university design theses, where the focus is on conceptual design and functional space rather than cost, the resulting structures are typically more complex. One notable example of this complexity is the use of geometric or 3D curved roofs to create dynamic space or attract users with new shapes. While these design features can create a unique and visually striking station, they are also costly to implement. Materials must often be ordered directly from the manufacturer, increasing both the time and expense of the construction process. However, when designing stations with an emphasis on cost-efficiency and economic considerations, designers are advised to prioritize designing structures that resonate with the local identity, mirroring the building's context. This approach can help reduce costs by utilizing locally sourced materials and pre-existing elements from the surrounding environment. Furthermore, incorporating local materials and design elements can also serve to create a sense of place and community identity. By reflecting the surrounding area, the station can become an integral part of the local community and a source of pride for residents. In conclusion, the design process for stations can vary significantly depending on the project's specific requirements, with university-designed stations often prioritizing conceptual design and functional space over cost. However, if the focus is on the economy and economics, designers may prioritize creating stations with a local identity that reflects the building's composition. This approach can help lower total construction costs, create a sense of place, and foster a connection to the surrounding community.

In Figure 16, two stations emerge as a proper prospect for studying train design evolution, as each station consists of three consecutive stations ranging from a thesis to a draft proposal in 2020. When considering the Nakhon Ratchasima station, several key changes can be acknowledged. In terms of the building area, an overall rise in building area could be seen from 42,483 to 64,000 square meters. Sources for the station range from a thesis in 2017 to a draft proposal in 2020. Moreover, the architectural style starts with a newer approach, such as parametric with a lean-to main entrance and sawtooth roof in 2017, followed by a post-modern style with a similar approach, and ends in 2020 by combining the gabled portico main entrance with a lean-to roof to embody Thai elements with a contemporary approach.



Type (year)	Thesis (2017)	Thesis (2019)	Draft proposal (2020)	Thesis (2017)	Draft proposal (2019)
Platforms	2	10	8	3	4
# Floors	5	4	3	3	2
Area	42483	38795	64000	52083	28200
Height/1st floor area	1.13	2.1	2.14	1.18	3.28
1st floor area/area	63.12	52.26	31.43	55.2	16.24
Roof	Sawtooth	Sawtooth	Lean-to	3D curved	Overlapping gable
Main entrance	Lean-to	Lean-to	Gabled portico	3D curved portico	Overlapping portico
Architecture style	Post modern + parametric	Post modern	Thai contemporary	Parametric	Thai contemporary

Figure 16. Evolution of railway station design.

When considering the Ayutthaya station, in terms of architectural style, the thesis, unlike the other counterparts, starts with Thai contemporary design, followed by a modern style station as a draft proposal in 2019, and finally results in Thai contemporary style as a way to reflect Ayutthaya's old temple. In terms of architectural elements, the roofs undergo no significant changes, as all prospects feature a type of gabled roof. It is interesting to note that the final proposal in 2020 had significantly more building area and platforms than the first draft proposal in 2019 to facilitate more logistical demands. Finally, both station platforms were added to nine platforms in order to facilitate more traffic demands.

4. Discussion

The absence of a thesis before the design process of a station may be attributed to its unexpected location, particularly if it is not a provincial or major city station. In such cases, the design process may focus more on the unique site constraints and promoting design opportunities, rather than on pre-existing concepts. One important aspect of station design is the development of the entrance, which serves as a gateway for commuters and visitors. In some cases, the design of the entrance may be informed by specific architectural elements, patterns, and shapes that emphasize transparency and connection. For example, the use of light and white colors can create a sense of openness and spaciousness, which can help to reduce feelings of congestion or claustrophobia. Additionally, the incorporation of transparent materials such as glass can help to create a visual connection between the inside and outside of the station, as well as between different parts of the station itself. Physical connection is also an important consideration in station design, as it can impact the flow of commuters and visitors. By incorporating design elements that facilitate movement and navigation, such as clear signage and well-lit pathways, designers can help to improve the overall user experience.

Another important issue for the architectural design of railway stations in tropical areas is how to connect extreme events representing several characteristics that are different from those observed in isolated or univariate extreme events due to their complex and dependent nature [72]. These factors encompass a significant, inadequately understood susceptibility to minor alterations in average climatic conditions and natural seismic phenomena, as well as limited access to data on crucial physical and sociological attributes [73–75]. The relationship between extreme events is strongly influenced by situational factors such as season, location, structural typology of the building, and population density [76]. To make progress in addressing these events, it is crucial to conduct a thorough analysis focused on their impacts, utilize advanced metrics, and gather high-quality, detailed impact data. This is a domain where the influence of advancing computing and communication technology is expected to be strongly experienced. In essence, we advocate for the implementation of systems that can identify and acknowledge the many elements of a connected severe event responding to the building and communities, and effectively collect and exchange crucial information about these elements [77]. This would greatly aid in the management of risks at all levels of decision-making for architects, clients, landlords, structural engineers, and contractors in AEC industries.

It is found today that climate change poses a significant peril to human health, both in outside environments and within structures. It is imperative to acknowledge that the consideration of health in buildings should not be limited to routine operations alone. Furthermore, these flames are progressively transpiring in close proximity to densely inhabited regions [78]. With the increasing severity and frequency of extreme climate events, structures are subjected to heightened levels of stress throughout the operation as well as thermal discomfort. Sadakorn et al. [79] noted that the semi-outdoor condition in tropical climates over the summer was unacceptable in terms of a thermal comfort survey around the railway station. In addition, extreme heat waves can lead to possible rolling blackouts, while wildfires can potentially generate potential power disruptions. Because of a lack of energy-efficiency policies, establishing a formal policy and increasing environmental awareness among building stakeholders should be emphasized [80,81]. A study was conducted to analyze the effects of summer overheating and harsh climatic conditions on dwelling features and quality, health comfort, interior environmental conditions, and the energy penalty faced by low-income people in South Asia for sustainable residential design section [82].

Natural calamities such as typhoons, tornadoes, and floods were reported to cause failure mechanisms to effectively limit the loss of functionality in residential and public buildings [83]. This requires building codes and guidelines locally. Moreover, such calamities can be caused by excessive moisture, providing optimal circumstances for the proliferation of molds in structures [84,85]. Individuals with respiratory conditions and compromised immune systems are the most susceptible in this situation. Mold is commonly associated with ocular and dermal irritation, respiratory distress, and dyspnea [86]. Kembel et al. [87] examined that the ecology of bacterial communities was significantly influenced by architectural design factors such as space type, building arrangement, human usage and mobility, and ventilation source. The restrooms harbored bacterial communities that were significantly different from those found in all other rooms. Additionally, spaces with a high level of human occupant diversity and strong connections to other spaces through ventilation or human movement exhibited a unique group of bacterial species compared to spaces with low occupant diversity and limited connections. The bacterial community structure within workplaces was mostly influenced by the source of ventilation air. It should be noted that these calamities including typhoons with heavy rainfall and very strong winds, reaching speeds of up to 270 km/h, and earthquakes can also be commonly found in Southeast Asia region. These lead to the design perspectives of emergency shelters and evacuation areas for travelers and the surrounding population inside and around the railway station. Bakhshi Lomer et al. [88] revealed that the criteria for selecting the optimal emergency shelters were proximity to the fault line, building topology and design concept, population density, availability of open and green areas, and the condition of the buildings. A refugee shelter can be designed in the area of the railway station building that encompasses both architectural and non-architectural elements, meeting international eligibility standards in terms of features, basic necessities, and evacuation actions [89,90].

Regarding the Integrated Design Process (IDP) framework, advocating for the adoption of an IDP for railway station design can provide a greater likelihood of successful project delivery and offer a higher level of control over building performance targets [91]. Nevertheless, the feasibility index and theoretical model of an IDP remain imperfect. Implementing an IDP necessitates substantial cultural and technological transformations, primarily because of the conventional contracting patterns and the resistance to change among contractors, engineering consultants, and architects in specific regions like Asia [92]. Efforts must be made by project stakeholders and academia to actualize the integrated design process and to make the required modifications to contracts, timelines, and costs. As sustainable design and practice progress, the demand for IDP as a standard workflow increases for railway station design. Hence, it is imperative for stakeholders during the designing of the architectural element to establish suitable IDP procedures for each region and building typology to cater to the requirements of sustainable construction projects [93,94].

Additionally, thanks to advances in current design approaches and construction techniques, these practical innovations can offer increased cost efficiency, structural efficiency, and time efficiency. Digital design and construction have made it possible to design, visualize, and simulate a project before construction, minimizing the need for costly on-site changes. Robotic manufacturing techniques can also reduce the cost of construction by automating some of the labor-intensive tasks. Digital design and construction tools allow for faster and more accurate design processes, reducing the time taken to complete a project. Robotic manufacturing techniques have also led to faster construction processes by automating labor-intensive tasks, reducing the time required to complete a project. This allows for complex designs to be easily attained, reducing the total construction cost in the process. Future works, including the integration of digital design and construction, robotic manufacturing, as well as sustainable construction like BIM [95,96] 3D printing [97,98], prefabrication [99,100], digital fabrication [101–103], innovative material [103–105] design for manufacturing and assembly (DfMA) [106–108], AI [109,110], sustainable design and materials [111–114], and machine learning [115–117] are valuable tools to predict the design and construction activities accurately and offer sustainable solutions and outcomes. The integration of these tools in the design and construction processes of railway stations is essential to enhance the efficiency and productivity of construction projects while reducing costs and improving the overall quality of the construction projects.

5. Conclusions

This review was conducted by collecting research papers and theses in the Faculty of Architecture from five leading university databases and railway station proposal blueprints in tropical climates from library databases and electronic media. In total, 48 railway station designs were collected and analyzed. The results revealed:

- An increase in high-speed railway station blueprints and theses since 2014–2016 due to the long-term development plan of the nation;
- The primary factors that determine the economic viability of HSR stations are construction costs, time savings per commuter, traffic volume, and the level of congestion in current global transport networks;
- HSR stations have a flatter exterior proportion than LD stations due to having more passengers, increased facility requirements, their design concept as the main regional hub, and their universal design for loading and train service information;
- The most common roof types are curved and gable roofs, followed by 3D curved roofs;
- The main entrance of HSR stations can reflect the local identity of the area and provide practical advantages by reducing the distance one must walk from their starting point or destination;
- The most elaborately designed main entrances feature curved porticos and gabled porticos, which can add a sense of grandeur and elegance to a building's façade. An overlapping portico in a public building creates a sense of grandeur and importance, while a curved gabled portico is an architectural feature that adds grandeur and elegance to a building's façade;
- The design of buildings and structures has evolved over time, with architects and designers now striving to create more visually appealing and functional structures;
- Station design involves several stages, with university-designed stations prioritizing conceptual design and functional space over cost;
- Station design should emphasize transparency and connection, facilitate movement and navigation, and offer increased cost-efficiency and time-efficiency;
- The current global issue of climate change has a widespread impact on the entire planet. Hence, these concerns are crucial in the field of creating environmentally friendly structures for public railway stations.

This review is an initial part of designing user-friendly, thermally comfortable and design-for-all railway stations in tropical climates. The field study and sentimental analysis for the railway station design guidelines are under investigation.

Author Contributions: Conceptualization, L.P. methodology, S.T. and W.S.; software, S.T.; validation, L.P., N.T.R. and S.T.; formal analysis, S.T. and N.T.R.; investigation, S.T. and W.S.; resources, L.P.; data curation, S.T. and W.S.; writing—original draft preparation, S.T.; writing—review and editing, L.P. and N.T.R.; visualization, S.T.; supervision, L.P.; project administration, L.P.; funding acquisition, L.P. All authors have read and agreed to the published version of the manuscript.

Funding: This project was funded by the National Research Council of Thailand (NRCT) and Chulalongkorn University (N42A660629), and by the Thailand Science Research and Innovation Fund Chulalongkorn University (SOCF67250015). The study was (partially) supported by the Ratchadapisek Sompoch Endowment Fund (2023), Chulalongkorn University (Review_66_012_2500_001).

Data Availability Statement: Some or all data, models, or codes generated or used during the study are available in a repository online in accordance with funder data retention policies. (https://drive.google.com/file/d/1OrVZ6POCc1GqCfp_LJe5F1n-TvxgY7Ci/view?usp=sharing (accessed on 20 November 2023)).

Conflicts of Interest: The authors declare no conflicts of interest.

Appendix A

Table A1. Compilation of railway stations from a thesis and design plans.

Station's Name (Year)	Construction Typology	Number of Platforms	Number of Floors	Floor Area (sq.m.)	Connections	Reference
North Line						
High-speed railway (HSR) station						
Phitsanulok (2014)	New construction	3	2	49,632	LSR + car park, bus	Thesis
Chiang mai (2020)	New construction	4	3	59,548	Taxi, minibus	Thesis
Phitsanulok (2020)	Renovation	8	3	67,491	LD + Taxi, minibus, motorbike, bike, bus	Thesis
Phichit (2022)	Renovation + Addition	6	2	80,105	node (private car) + LD + CRT	Draft proposal
Lopburi (2022)	Renovation + Addition	5	1	80,105	node (private car) + LD + CRT	Draft proposal
Nakhon Sawan (2022)	Renovation + Addition	8	3	80,105	node (private car) + LD + CRT	Draft proposal
Long-distance railway (LD) station						
Phrae (2013)	Renovation	2	4	35,800	node (bus, private car)	Thesis
Station's Name (Year)	Construction Typology	Number of Platforms	Number of Floors	Floor Area (sq.m.)	Connections	Reference
North—eastern Line						
High-speed railway (HSR) station						
Nong Khai (2015)	Addition	6	3	40,518	node (bus, private car) + LD	Thesis
Khon Kaen (2016)	Renovation	4	4	83,800	node (bus, private car, taxi) + LD	Thesis
Nakhon Ratchasima (2017)	Renovation + Addition	2	5	42,483	node (car + bus + taxi + motorcycle) + HSR	Thesis
Nakhon Ratchasima (2019)	Renovation	10	4	38,795	node (bus, private car, taxi) + LD + CRT	Thesis
Saraburi (2019)	New construction	4	4	31,448	node (private car, bus, taxi, rental car) + LD	Draft proposal
Pak Chong (2019)	New construction	2	4	47,452	node (private car)	Draft proposal
Ban phai (2020)	Renovation + Addition	6	3	34,257	node (private car, van) + LD	Draft proposal
Nong Khai (2020)	Addition	14	3	44,100	node (private car) + LD	Draft proposal
Udon (2020)	Renovation + Addition	4	3	59,323	node (private car) + LD	Draft proposal
Bua yai (2020)	Addition	6	3	61,000	node (private car) + LD	Draft proposal

Table A1. *Cont.*

Station's Name (Year)	Construction Typology	Number of Platforms	Number of Floors	Floor Area (sq.m.)	Connections	Reference
Nakhon Ratchasima (2020)	Addition	8	3	64,000	node (private car)	Draft proposal
Bua yai (2020)	Addition	6	3	87,600	node (private car) + LD	Draft proposal
Khon Kaen (2020)	Addition	6	3	91,000	node (private car) + LD	Draft proposal
Long-distance railway (LD) station						
Nam Phong (2017)	Renovation	2	2	1040	node (private car)	Draft proposal
Station's Name (Year)	Construction Typology	Number of Platforms	Number of Floors	Floor Area (sq.m.)	Connections	Reference
Eastern Line						
High-speed railway (HSR) station						
Rayong (2017)	New construction	3	3	52,083	node (private car)	Thesis
Klang (2019)	New construction	2	2	12,400	node (private car, motorbike, bus)	Draft proposal
Trat (2019)	New construction	4	2	24,600	node (private car, motorcycle, bus)	Draft proposal
Rayong (2019)	New construction	4	2	28,200	node (private car, motorcycle, bus)	Draft proposal
Chanthaburi (2019)	New construction	4	2	45,800	node (private car, motorbike, bus)	Draft proposal
Pattaya (2019)	New construction	7	4	61,412	node(car) + LRT	Thesis
Pattaya (2021)	New construction	8	4	39,447	node (bus, taxi, van) + LD + LRT	Thesis
Long-distance railway (LD) station						
Lat krabang (2002)	Renovation + Addition	4	2	23,000	node (private car)	Thesis
U-Tapao (2019)	New construction	1	2	1830	node (private car)	Thesis
Chantha-buri (2021)	New construction	3	2	20,045	node (private car)	Draft proposal

References

1. Hampton, D.J. *Amtrak CEO Outlines Plans for Spending $66 Billion from Infrastructure Funding*; U.S. News: Washington, DC, USA, 2021.
2. IEA. *Global EV Outlook*; International Energy Agency: Paris, France, 2021.
3. Goldsmith, S. *Universal Design*; Routledge: London, UK, 2007.
4. RFI. Network Statement. 2023. Available online: https://www.rfi.it/content/dam/rfi/rfi_en/railway-infrastructure/pir-2023/giugno2022/NS%202023_June%202022%20edition.pdf (accessed on 10 October 2023).
5. Cozens, P.; Neale, R.; Whitaker, J.; Hillier, D. Investigating personal safety at railway stations using "virtual reality" technology. *Facilities* **2003**, *21*, 188–194. [CrossRef]
6. Yoo, B.-J.; Park, C.-B.; Lee, J. A study on design of photovoltaic system using electrical railway stations. In Proceedings of the 2016 19th International Conference on Electrical Machines and Systems (ICEMS), Chiba, Japan, 13–16 November 2016.
7. Kaewunruen, S. Wireless sensor networks: Toward smarter railway stations. *Infrastructures* **2018**, *3*, 24.
8. Alawad, H.; Kaewunruen, S.; An, M. Learning from accidents: Machine learning for safety at railway stations. *IEEE Access* **2019**, *8*, 633–648. [CrossRef]

9. Patel, M.; Rathod, N.A.; Mehta, B. Electrical Power Distribution Design & Voltage Profile Improvement for Metro Railway Station. In Proceedings of the 2020 Fourth World Conference on Smart Trends in Systems, Security and Sustainability (WorldS4), London, UK, 27–28 July 2020.
10. Fan, Z.; Xiao, Z.; Liu, J. Energy performance assessment of semi-transparent photovoltaic integrated large-scale railway stations among various climates of China. *Energy Convers. Manag.* **2022**, *269*, 115984. [CrossRef]
11. Kazanskiy, N.; Popov, S. Integrated design technology for computer vision systems in railway transportation. *Pattern Recognit. Image Anal.* **2015**, *25*, 215–219. [CrossRef]
12. Hellström, B. Theories and methods adaptable to acoustic and architectural design of railway stations. In Proceedings of the Twelfth International Congress on Sound and Vibration, Lisbon, Portugal, 11–14 July 2005.
13. Wu, Y.; Kang, J.; Zheng, W. Acoustic environment research of railway station in China. *Energy Procedia* **2018**, *153*, 353–358. [CrossRef]
14. Kaakai, F.; Hayat, S.; El Moudni, A. A hybrid petri nets-based simulation model for evaluating the design of railway transit stations. *Simul. Model. Pract. Theory* **2007**, *15*, 935–969. [CrossRef]
15. Cozens, P.; Van der Linde, T. Perceptions of crime prevention through environmental design (CPTED) at Australian railway stations. *J. Public Transp.* **2015**, *18*, 73–92. [CrossRef]
16. Wang, N.; Satola, D.; Wiberg, A.H.; Liu, C.; Gustavsen, A. Reduction strategies for greenhouse gas emissions from high-speed railway station buildings in a cold climate zone of China. *Sustainability* **2020**, *12*, 1704. [CrossRef]
17. Jones, M. Can railway station design reduce the risk of a terrorist attack or the impact of an incident? *Proc. Inst. Mech. Eng. Part F J. Rail Rapid Transit* **2011**, *225*, 351–357. [CrossRef]
18. Ali, N.; Qi, Z. Defensible citadel: History and architectural character of the Lahore Railway Station. *Front. Archit. Res.* **2020**, *9*, 805–819. [CrossRef]
19. Hassannayebi, E.; Memarpour, M.; Mardani, S.; Shakibayifar, M.; Bakhshayeshi, I.; Espahbod, S. A hybrid simulation model of passenger emergency evacuation under disruption scenarios: A case study of a large transfer railway station. *J. Simul.* **2020**, *14*, 204–228. [CrossRef]
20. Hermant, L. Human movement behaviour in South African railway stations: Implications for design. In Proceedings of the SATC 2011, Pretoria, South Africa, 11–14 July 2011.
21. Kandee, S. Intermodal concept in railway station design. In *Transportation Facilities and the Design Railway Station*; 2004. Available online: https://tarjomefa.com/wp-content/uploads/2017/03/6336-English-TarjomeFa.pdf (accessed on 5 October 2023).
22. Swift, A.; Cheng, L.; Loo, B.P.; Cao, M.; Witlox, F. Step-free railway station access in the UK: The value of inclusive design. *Eur. Transp. Res. Rev.* **2021**, *13*, 1–12. [CrossRef]
23. Yeung, H.K.; Marinov, M. A systems design study introducing a collection point for baggage transfer services at a railway station in the UK. *Urban Rail Transit* **2019**, *5*, 80–103. [CrossRef]
24. Hoogendoorn, S.P.; Hauser, M.; Rodrigues, N. Applying microscopic pedestrian flow simulation to railway station design evaluation in Lisbon, Portugal. *Transp. Res. Rec.* **2004**, *1878*, 83–94. [CrossRef]
25. Sekiguchi, M. JR East's approach to universal design of railway stations. *Jpn. Railw. Transp. Rev.* **2006**, *45*, 9–11.
26. Kido, E.M. Aesthetic aspects of railway stations in Japan and Europe, as a part of "context sensitive design for railways". *J. East. Asia Soc. Transp. Stud.* **2005**, *6*, 4381–4396.
27. Thaithatkul, P.; Sanghatawatana, P.; Anuchitchanchai, O.; Chalermpong, S. Effectiveness of Travel Demand Management Policies in Promoting Rail Transit Use and Reducing Private Vehicle Emissions: A Stated Preference Study of Bangkok, Thailand. *Nakhara J. Environ. Des. Plan.* **2023**, *22*, 303. [CrossRef]
28. Pavlićević, D.; Kratz, A. Testing the China Threat paradigm: China's high-speed railway diplomacy in Southeast Asia. *Pac. Rev.* **2018**, *31*, 151–168. [CrossRef]
29. Hong, Y. China's eagerness to export its high-speed rail expertise to ASEAN members. *Cph. J. Asian Stud.* **2014**, *32*, 13–36. [CrossRef]
30. Kitkuakul, P. Exploring the Implementation of Sister City Relationship Policy by Thai Provincial Governments. *Int. J. Dev. Adm. Res.* **2022**, *5*, 1–14.
31. Shrivastva, C. Railway Modernisation in India: A South Asian Case Study. In *Railway Transportation in South Asia: Infrastructure Planning, Regional Development and Economic Impacts*; Mitra, S., Bandyopadhyay, S., Roy, S., Dentinho, T.P., Eds.; Springer International Publishing: Cham, Switzerland, 2021; pp. 255–268.
32. Shrivastva, C.; Roy, S.; Ashok, D. Border Region Railway Development in Sino-Indian Geopolitical Competition. *India Q.* **2023**, *79*, 209–222. [CrossRef]
33. Lal, R. *Understanding China and India: Security Implications for the United States and the World*; Praeger: Westport, CT, USA, 2006.
34. Lim, G.; Li, C.; Syailendra, E.A. Why is it so hard to push Chinese railway projects in Southeast Asia? The role of domestic politics in Malaysia and Indonesia. *World Dev.* **2021**, *138*, 105272. [CrossRef]
35. Mirrahimi, S.; Mohamed, M.F.; Haw, L.C.; Ibrahim, N.L.N.; Yusoff, W.F.M.; Aflaki, A. The effect of building envelope on the thermal comfort and energy saving for high-rise buildings in hot–humid climate. *Renew. Sustain. Energy Rev.* **2016**, *53*, 1508–1519. [CrossRef]
36. Guo, A. Research on Train Station Architecture Design Method Based on Climate Response. Ph.D. Thesis, University of Hawai'i at Manoa, Honolul, HI, USA, April 2021.

37. Khan, M.Z. Analysing Energy Efficiency of Rail and Road Transport in Pakistan Through Data Envelopment Analysis. In *Railway Transportation in South Asia: Infrastructure Planning, Regional Development and Economic Impacts*; Springer: Berlin, Germany, 2021; pp. 85–102.
38. Theerathitichaipa, K.; Wisutwattanasak, P.; Se, C.; Seefong, M.; Jomnonkwao, S.; Champahom, T.; Ratanavaraha, V.; Kasemsri, R. Assessment of Disparity in Accessing Railway Stations in Thailand: An Application Geographic Information System Network Analysis. *J. Geovisualization Spat. Anal.* **2024**, *8*, 6. [CrossRef]
39. Manandhar, R.; Kim, J.-H.; Kim, J.-T. Environmental, social and economic sustainability of bamboo and bamboo-based construction materials in buildings. *J. Asian Archit. Build. Eng.* **2019**, *18*, 49–59. [CrossRef]
40. Latha, P.; Darshana, Y.; Venugopal, V. Role of building material in thermal comfort in tropical climates–A review. *J. Build. Eng.* **2015**, *3*, 104–113. [CrossRef]
41. Sekhar, S.; Willem, H. Impact of airflow profile on indoor air quality—A tropical study. *Build. Environ.* **2004**, *39*, 255–266. [CrossRef]
42. Yang, W.; Lin, Y.; Li, C.-Q. Effects of landscape design on urban microclimate and thermal comfort in tropical climate. *Adv. Meteorol.* **2018**, *2018*, 2809649. [CrossRef]
43. Riza, M.A.A.; Darmawan, E.; Ikaputra, I.; Wihardyanto, D. Architecture of Small Type Train Station in Yogyakarta, Indonesia. *J. Archit. Des. Urban.* **2021**, *4*, 27–38. [CrossRef]
44. Sulistyani, H. The Evolution of Railway Station Architecture in Java. *J. Asian Archit. Build. Eng.* **2023**, *22*, 2613–2621. [CrossRef]
45. Chen, Y.-J.; Hsu, C.-K. Comparison of Housing Price Elasticities Resulting from Different Types of Multimodal Rail Stations in Kaohsiung, Taiwan. *Int. Real Estate Rev.* **2020**, *23*, 1043–1058.
46. Nag, D.; BS, M.; Goswami, A.; Bharule, S. *Framework for Public Transport Integration at Railway Stations and Its Implications for Quality of Life*; Asian Development Bank Institute: Tokyo, Japan, 2019.
47. Teodorović, D.; Janić, M. Chapter 11—Transportation, Environment, and Society. In *Transportation Engineering*; Teodorović, D., Janić, M., Eds.; Butterworth-Heinemann: Oxford, UK, 2017; pp. 719–858.
48. Steinfeld, A.; Maisel, J.L.; Steinfeld, E. (Eds.) *Accessible Public Transportation: Designing Service for Riders with Disabilities*, 1st ed.; Routledge: London, UK, 2017.
49. Nash, C. When to invest in high speed rail. *J. Rail Transp. Plan. Manag.* **2015**, *5*, 12–22. [CrossRef]
50. De Waal, H. New recommendations for building in tropical climates. *Build. Environ.* **1993**, *28*, 271–285. [CrossRef]
51. Zaid, S.; Zaid, L.M.; Esfandiari, M.; Hasan, Z.F.A. Green roof maintenance for non-residential buildings in tropical climate: Case study of Kuala Lumpur. *Environ. Dev. Sustain.* **2022**, *24*, 2471–2496. [CrossRef]
52. Hemani, S.; Punekar, R.M. Design education for sustainability: A case study for an inclusive approach to design in India. *World Rev. Sci. Technol. Sustain. Dev.* **2015**, *12*, 29–48. [CrossRef]
53. Tripathi, M.K.; Ali, M. Government Initiatives for Development of Rural Tourism in India: A Study. *Int. J. Econ. Perspect.* **2021**, *15*, 650–653.
54. Romaniak, K.; Filipowski, S. Parametric design in the education of architecture students. *World Trans. Eng. Technol. Educ.* **2018**, *16*, 386–391.
55. Stavric, M.; Marina, O. Parametric modeling for advanced architecture. *Int. J. Appl. Math. Inform.* **2011**, *5*, 9–16.
56. Barrelas, J.; De Brito, J.; Correia, J.R. Analysis of the degradation condition of secondary schools. Case study: Pavilions and prefabricated buildings. *J. Civ. Eng. Manag.* **2016**, *22*, 768–779. [CrossRef]
57. Alzahrani, A. Understanding the role of architectural identity in forming contemporary architecture in Saudi Arabia. *Alex. Eng. J.* **2022**, *61*, 11715–11736. [CrossRef]
58. Lahoorpoor, B.; Levinson, D.M. Catchment if you can: The effect of station entrance and exit locations on accessibility. *J. Transp. Geogr.* **2020**, *82*, 102556. [CrossRef]
59. Moore, J.D. *Architecture and Power in the Ancient Andes: The Archaeology of Public Buildings*; Cambridge University Press: Cambridge, UK, 1996.
60. Tantasavasdi, C.; Inprom, N. Residential unit design for natural ventilation in tropical multi-family high-rises with a double-loaded corridor. *Nakhara J. Environ. Des. Plan.* **2023**, *22*, 315. [CrossRef]
61. Atthakorn, S. Passive and biophilic design: Assessment of the semi-open educational atrium buildings in the tropics. *Nakhara J. Environ. Des. Plan.* **2022**, *21*, 203. [CrossRef]
62. Yılmaz, M. Public space and accessibility. *ICONARP Int. J. Archit. Plan.* **2018**, *6*, 1–14. [CrossRef]
63. Hostikka, S.; Paloposki, T.; Rinne, T.; Saari, J.-M.; Korhonen, T.; Heliövaara, S. *Evacuation Experiments in Offices and Public Buildings*; VTT Technical Research Center of Finland: Espoo, Finland, 2007.
64. Navas-Acien, A.; Çarkoğlu, A.; Ergör, G.; Hayran, M.; Ergüder, T.; Kaplan, B.; Susan, J.; Magid, H.; Pollak, J.; Cohen, J.E. Compliance with smoke-free legislation within public buildings: A cross-sectional study in Turkey. *Bull. World Health Organ.* **2016**, *94*, 92. [CrossRef] [PubMed]
65. Sureda, X.; Martínez-Sánchez, J.M.; López, M.J.; Fu, M.; Agüero, F.; Saltó, E.; Nebot, M.; Fernández, E. Secondhand smoke levels in public building main entrances: Outdoor and indoor PM2.5 assessment. *Tob. Control* **2012**, *21*, 543–548. [CrossRef] [PubMed]
66. Sthapitanond, N.; Mertens, B. *Architecture of Thailand: A Guide to Tradition and Contemporary Forms*; Editions Didier Millet: Bangkok, Thailand, 2012.

67. Knox, P.L. The restless urban landscape: Economic and sociocultural change and the transformation of metropolitan Washington, DC. *Ann. Assoc. Am. Geogr.* **1991**, *81*, 181–209. [CrossRef]
68. Sini, R.; Sini, R. The Singapore Playground: System of Themed Public Parks that Addresses Environmental, Social and Cultural Sustainability. In *Singapore's Park System Master Planning: A Nation Building Tool to Construct Narratives in Post-Colonial Countries*; Springer: Berlin/Heidelberg, Germany, 2020; pp. 253–328.
69. Yaneva, A. *Five Ways to Make Architecture Political: An Introduction to the Politics of Design Practice*; Bloomsbury Publishing: London, UK, 2017.
70. Schumacher, P. *Parametricism 2.0: Rethinking Architecture's Agenda for the 21st Century*; John Wiley & Sons: Hoboken, NJ, USA, 2016.
71. Vollers, K. *Twist & Build: Creating Non-Orthogonal Architecture*; nai010 Publishers: Rotterdam, The Netherlands, 2001.
72. Raymond, C.; Horton, R.M.; Zscheischler, J.; Martius, O.; AghaKouchak, A.; Balch, J.; Bowen, S.G.; Camargo, S.J.; Hess, J.; Kornhuber, K.; et al. Understanding and managing connected extreme events. *Nat. Clim. Chang.* **2020**, *10*, 611–621. [CrossRef]
73. Awada, M.; Becerik-Gerber, B.; Hoque, S.; O'Neill, Z.; Pedrielli, G.; Wen, J.; Wu, T. Ten questions concerning occupant health in buildings during normal operations and extreme events including the COVID-19 pandemic. *Build. Environ.* **2021**, *188*, 107480. [CrossRef]
74. Zain, M.; Prasittisopin, L.; Mehmood, T.; Ngamkhanong, C.; Keawsawasvong, S.; Thongchom, C. A novel framework for effective structural vulnerability assessment of tubular structures using machine learning algorithms (GA and ANN) for hybrid simulations. *Nonlinear Eng.* **2024**, *13*, 20220365. [CrossRef]
75. Zain, M.; Keawsawasvong, S.; Thongchom, C.; Sereewatthanawut, I.; Usman, M.; Prasittisopin, L. Establishing efficacy of machine learning techniques for vulnerability information of tubular buildings. *Eng. Sci.* **2024**, *27*, 10–30919. [CrossRef]
76. Santamouris, M.; Kolokotsa, D. On the impact of urban overheating and extreme climatic conditions on housing, energy, comfort and environmental quality of vulnerable population in Europe. *Energy Build.* **2015**, *98*, 125–133. [CrossRef]
77. Rugkhapan, N.T. Reseeing Chinatown cartographic response and neighborhood reinvention. *Urban Geogr.* **2020**, *41*, 573–606. [CrossRef]
78. Moazami, A.; Nik, V.M.; Carlucci, S.; Geving, S. Impacts of future weather data typology on building energy performance–Investigating long-term patterns of climate change and extreme weather conditions. *Appl. Energy* **2019**, *238*, 696–720. [CrossRef]
79. Sadakorn, W.; Tetiranont, S.; Chiyarit, J.; Prasittisopin, L. Field study on thermal comfort of outdoor and semi-outdoor in tropical climate: Case study of Bangkok, Thailand. In Proceedings of the 6th International Conference on Civil Engineering and Architecture (ICCEA 2023), Bali, Indonesia, 16–18 December 2023.
80. Andrić, I.; Koc, M.; Al-Ghamdi, S.G. A review of climate change implications for built environment: Impacts, mitigation measures and associated challenges in developed and developing countries. *J. Clean. Prod.* **2019**, *211*, 83–102. [CrossRef]
81. Jia, L.R.; Han, J.; Chen, X.; Li, Q.Y.; Lee, C.C.; Fung, Y.H. Interaction between thermal comfort, indoor air quality and ventilation energy consumption of educational buildings: A comprehensive review. *Buildings* **2021**, *11*, 591. [CrossRef]
82. Badhan, I.M.; Siddika, A. Evaluating the policy outcomes for urban resiliency in informal settlements since independence in Dhaka, Bangladesh: A review. *Nakhara J. Environ. Des. Plan.* **2019**, *17*, 97–110. [CrossRef]
83. Moeini, M.; Memari, A.M. Hurricane-induced failure mechanisms in low-rise residential buildings and future research directions. *Nat. Hazards Rev.* **2023**, *24*, 03123001. [CrossRef]
84. Brambilla, A.; Sangiorgio, A. *Moisture and Buildings: Durability Issues, Health Implications and Strategies to Mitigate the Risks*; Woodhead Publishing: Sawston, UK, 2021.
85. Chaudhary, M.T.; Piracha, A. Natural disasters—Origins, impacts, management. *Encyclopedia* **2021**, *1*, 1101–1131. [CrossRef]
86. Mendell, M.J.; Mirer, A.G.; Cheung, K.; Tong, M.; Douwes, J. Respiratory and allergic health effects of dampness, mold, and dampness-related agents: A review of the epidemiologic evidence. *Environ. Health Perspect.* **2011**, *119*, 748–756. [CrossRef]
87. Kembel, S.W.; Meadow, J.F.; O'Connor, T.K.; Mhuireach, G.; Northcutt, D.; Kline, J.; Moriyama, M.; Brown, G.Z.; Bohannan, B.J.; Green, J.L. Architectural design drives the biogeography of indoor bacterial communities. *PLoS ONE* **2014**, *9*, e87093. [CrossRef] [PubMed]
88. Bakhshi Lomer, A.R.; Rezaeian, M.; Rezaei, H.; Lorestani, A.; Mijani, N.; Mahdad, M.; Raeisi, A.; Arsanjani, J.J. Optimizing emergency shelter selection in earthquakes using a risk-driven large group decision-making support system. *Sustainability* **2023**, *15*, 4019. [CrossRef]
89. Apriani, A. Refugee Shelter on Selayar Island, South Sulawesi. *J. Res. Soc. Sci. Econ. Manag.* **2023**, *2*, 1222–1238.
90. Cetin, M.; Kaya, A.Y.; Elmastas, N.; Adiguzel, F.; Siyavus, A.E.; Kocan, N. Assessment of emergency gathering points and temporary shelter areas for disaster resilience in Elazıg, Turkey. *Nat. Hazards* **2023**, *120*, 1925–1949. [CrossRef]
91. Li, Z.; Tian, M.; Zhu, X.; Xie, S.; He, X. A Review of Integrated Design Process for Building Climate Responsiveness. *Energies* **2022**, *15*, 7133. [CrossRef]
92. Thakur, N.; Parashar, D.; Chidambaram, C.; Dharwal, M. Climate responsive strategy matrix for designing buildings in India. *Nat. Environ. Pollut. Technol.* **2021**, *20*, 1021–1031. [CrossRef]
93. Feng, W.; Zhang, Q.; Ji, H.; Wang, R.; Zhou, N.; Ye, Q.; Hao, B.; Li, Y.; Luo, D.; Lau, S.S.Y. A review of net zero energy buildings in hot and humid climates: Experience learned from 34 case study buildings. *Renew. Sustain. Energy Rev.* **2019**, *114*, 109303. [CrossRef]
94. Nguyen, A.T. Sustainable Housing in Vietnam: Climate Responsive Design Strategies to Optimize Thermal Comfort. Ph.D. Thesis, Université de Liège, Liège, Belgium, 2013.

95. Khosakitchalert, C.; Yabuki, N.; Fukuda, T. Improving the accuracy of BIM-based quantity takeoff for compound elements. *Autom. Constr.* **2019**, *106*, 102891. [CrossRef]
96. Kaewunruen, S.; Xu, N. Digital twin for sustainability evaluation of railway station buildings. *Front. Built Environ.* **2018**, *4*, 77. [CrossRef]
97. Prasittisopin, L.; Pongpaisanseree, K.; Jiramarootapong, P.; Snguanyat, C. Thermal and sound insulation of large-scale 3D extrusion printing wall panel. In *Second RILEM International Conference on Concrete and Digital Fabrication: Digital Concrete*; Springer: Berlin/Heidelberg, Germany, 2020.
98. Prasittisopin, L.; Sakdanaraseth, T.; Horayangkura, V. Design and construction method of a 3D concrete printing self-supporting curvilinear pavilion. *J. Archit. Eng.* **2021**, *27*, 05021006. [CrossRef]
99. Mostafa, S.; Kim, K.P.; Tam, V.W.; Rahnamayiezekavat, P. Exploring the status, benefits, barriers and opportunities of using BIM for advancing prefabrication practice. *Int. J. Constr. Manag.* **2020**, *20*, 146–156. [CrossRef]
100. Navaratnam, S.; Ngo, T.; Gunawardena, T.; Henderson, D. Performance review of prefabricated building systems and future research in Australia. *Buildings* **2019**, *9*, 38. [CrossRef]
101. Willis, K.D.; Xu, C.; Wu, K.-J.; Levin, G.; Gross, M.D. Interactive fabrication: New interfaces for digital fabrication. In Proceedings of the Fifth International Conference on Tangible, Embedded, and Embodied Interaction, Cork, Ireland, 25–27 January 2010.
102. Sass, L.; Botha, M. The instant house: A model of design production with digital fabrication. *Int. J. Archit. Comput.* **2006**, *4*, 109–123. [CrossRef]
103. Perry, V.; Zakariasen, D. First use of ultra-high performance concrete for an innovative train station canopy. *Concr. Technol. Today* **2004**, *25*, 1–2.
104. Hughes, N.; Ryan, B.; Hallewell, M.; Coad, N.; Grant, A.; Parrott, N.; Roberts, S.; Thompson, K. Identifying new concepts for innovative lighting-based interventions to influence movement and behaviours in train stations. *Light. Res. Technol.* **2020**, *52*, 976–990. [CrossRef]
105. Win, T.T.; Wattanapornprom, R.; Prasittisopin, L.; Pansuk, W.; Pheinsusom, P. Investigation of fineness and calcium-oxide content in fly ash from ASEAN region on properties and durability of cement–fly ash system. *Eng. J.* **2022**, *26*, 77–90. [CrossRef]
106. Lu, W.; Tan, T.; Xu, J.; Wang, J.; Chen, K.; Gao, S.; Xue, F. Design for manufacture and assembly (DfMA) in construction: The old and the new. *Archit. Eng. Des. Manag.* **2021**, *17*, 77–91. [CrossRef]
107. Tuvayanond, W.; Prasittisopin, L. Design for Manufacture and Assembly of Digital Fabrication and Additive Manufacturing in Construction: A Review. *Buildings* **2023**, *13*, 429. [CrossRef]
108. Sadakorn, W.; Prasertsuk, S.; Prasittisopin, L. 3D Cement Printing: DFMA Guideline of Patterned Load-Bearing Walls for Small Residential Units. In *Lecture Notes in Civil Engineering, Proceedings of 5th International Conference on Civil Engineering and Architecture. ICCEA 2022, Hanoi, Vietnam, 16–18 December 2022*; Kang, T., Ed.; Springer: Singapore, 2024; p. 369.
109. He, Y.; Yuan, H.; Yao, Q.; Wang, Z. Research and Exploration of Land Use in Core Area of Urban Central Rail Transit Station Based on AI Technology. In Proceedings of the 2021 4th International Conference on Artificial Intelligence and Big Data (ICAIBD), Chengdu, China, 28–31 May 2021.
110. Placino, P.; Rugkhapan, N.T. Making visible concrete's shadow places: Mixing environmental concerns and social inequalities into building materials. *Environ. Urban.* **2023**. [CrossRef]
111. Win, T.T.; Jongvivatsakul, P.; Jirawattanasomkul, T.; Prasittisopin, L.; Likitlersuang, S. Use of polypropylene fibers extracted from recycled surgical face masks in cement mortar. *Constr. Build. Mater.* **2023**, *391*, 131845.
112. Win, T.T.; Prasittisopin, L.; Nganglumpoon, R.; Pinthong, P.; Watmanee, S.; Tolek, W.; Panpranot, J. Innovative GQDs and supra-GQDs assemblies for developing high strength and conductive cement composites. *Constr. Build. Mater.* **2024**, *421*, 135693. [CrossRef]
113. Win, T.T.; Prasittisopin, L.; Nganglumpoon, R.; Pinthong, P.; Watmanee, S.; Tolek, W.; Panpranot, J. Chemo-physical mechanisms of high-strength cement composites with suprastructure of graphene quantum dots. *Clean. Mater.* **2024**, *11*, 100229. [CrossRef]
114. Prasittisopin, L.; Trejo, D. Performance characteristics of blended cementitious systems incorporating chemically transformed rice husk Ash. *Advanc. Civil Eng. Mater.* **2017**, *6*, 17–35. [CrossRef]
115. Wang, Z.; Liang, Q.; Duarte, F.; Zhang, F.; Charron, L.; Johnsen, L.; Cai, B.; Ratti, C. Navigating Indoor Spaces Using Machine Learning: Train Stations in Paris. In *Machine Learning and the City: Applications in Architecture and Urban Design*; Wiley Online Library: Hoboken, NJ, USA, 2022; pp. 293–296.
116. Kittinaraporn, W.; Tuprakay, S.; Prasittisopin, L. Effective Modeling for Construction Activities of Recycled Aggregate Concrete Using Artificial Neural Network. *J. Constr. Eng. Manag.* **2022**, *148*, 04021206. [CrossRef]
117. Hadavi, A.; Huang, J.C. Assessment of AEC students' performance using BIM-into-VR. *Appl. Sci.* **2021**, *11*, 3225.