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Research on the Relationship Between Airport Design and Energy Consumption—Kuala Lumpur Airport as a Case Study

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Abstract

This paper explores the correlation between airport design and energy consumption by analyzing the design and energy features of Kuala Lumpur International Airport (KLIA), which was constructed in 1998 by Japanese architect Kisho Kurokawa. The paper analyzes how the airport reflects the concept of symbiosis, which Kurokawa defines as a mutually beneficial relationship between different entities. It analyzes the spatial, structural, environmental, and cultural aspects of KLIA. The paper also discusses the environmental and economic challenges of operating a large-scale airport in a tropical country. It compares KLIA with other airports that have adopted energy-saving measures, such as Hartsfield Jackson Atlanta International Airport and Beijing Daxing International Airport. The paper highlights how these airports have utilized natural lighting and carbon offsetting to reduce their energy footprint. The paper concludes that airports and energy are inseparable, and that energy improvement starts with the building itself, including lighting, structure, environment, and other factors. The paper cites various sources, such as books, articles, websites, and lectures, to support its arguments.

Keywords

Airport Architecture, Symbiosis Concept, Energy Consumption

1. Introduction

In the contemporary era of globalization, airports stand as emblematic structures that evoke a mix of fascination and controversy [1]. As air travel becomes a dominant mode of transportation and airports strive to capture an expanding market share, commercial imperatives have given rise to a novel breed of airport designs. The evolution of airports in the West reflects a significant transformation. Initially, they were simple passenger terminal sheds, gradually adopting symbolism reminiscent of 20th-century European railway stations. This transformation not only signifies the engineering prowess of the region but also showcases the innovative use of cutting-edge materials, contributing to the airports' iconic status. The modern airport is no longer merely a functional hub for air travel; it has become a symbol of technological advancement, architectural innovation, and a gateway to global connectivity. The changing nature of airports mirrors the dynamic landscape of international travel, reflecting not only technological advancements but also the economic, cultural, and social shifts in the globalized world. The contemporary airport is, therefore, a multifaceted entity that goes beyond its utilitarian role, embodying the aspirations and complexities of our interconnected world.

Figure 1. Kuala Lumpur International Airport (KLIA).

On June 28, 1998, Kuala Lumpur International Airport (KLIA) was officially opened. After four and a half years of round-the-clock construction, this huge hub airport of world-class standard was finally completed.

Figure 2. Map of Malaysia.

Located 60 kilometers south of the capital, Kuala Lumpur, the new Kuala Lumpur International Airport covers a total area of 100 square kilometers, 10 times the size of Tokyo Narita Airport in Japan [2].

2. Main body

Kuala Lumpur airport is a classic example. The spatial design of the airport accommodates retail and dining Spaces in addition to the basic requirements of the airport, such as runways, boarding gates, waiting areas, etc. Terminal 2 has a shopping complex with 35,000 square meters of retail space and an eight-storey parking garage.

Figure 3. Model of KLIA.

"Symbiosis," as denoting "living together", takes on profound meaning in Kurokawa's vision, extending beyond mere coexistence to embody a relationship where multiple entities not only benefit but are indispensable to each other. In the context of Kuala Lumpur, where a year-round tropical rainforest climate prevails with warmth, sunshine, and ample rainfall, Kurokawa skillfully establishes a symbiotic alliance between nature and architecture.

This synergy goes beyond mere aesthetics; Kurokawa ingeniously utilizes the surrounding forest as a multifaceted asset. The forest acts as a natural sound buffer, shielding the airport from external noise disturbances. It provides natural shade, offering relief from the tropical sun, and facilitates natural ventilation, contributing to a comfortable and environmentally conscious design. This integration of the airport with its natural surroundings is not just an architectural choice; it is a strategic move to harmonize with the climate and ecosystem of the region.

In essence, the airport becomes a living entity in partnership with nature, the site, and the economy. Kurokawa's design goes beyond visual appeal; it becomes an integral part of the ecosystem, leveraging the forest as a valuable resource for sustainable energy. The airport, thus, stands as a testament to the potential of symbiosis, where architecture and nature coalesce in a harmonious dance of mutual benefit and necessity [3].

The reason the concept is symbiotic with the site is that palm and rubber trees take 75-100 years to grow to a height of 30 meters, but the weather conditions in Malaysia only take 20 years to achieve this. Thus, his concept for the project is "an airport in a forest, a forest in an airport" [4].

Figure 4. Aerial view of KLIA.

The location was chosen mainly because of the flatness and cheap land prices in rural areas surrounding cities.

It shows a view of the main buildings on the site. On the right are Kurokawa's main wharf, the liaison wharf, and the satellite building. A new terminal called KLIA2 was built in 2014 in the west [5].

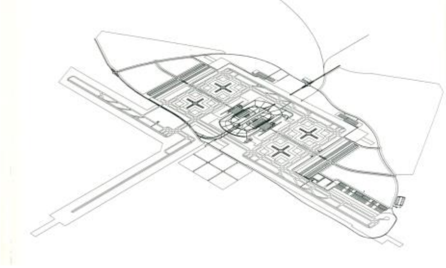

Figure 5. Site plan of KLIA.

The axonometric map shows that the surrounding area is relatively empty, as there is more noise and fewer residents near the airport.

Figure 6. Key structure of KLIA.

Structurally, the main terminal, with its six floors, exemplifies a meticulous approach to architectural design. At the core of its construction lies a flexible modular design anchored in a 38.4-meter square structural grid. This grid system serves as the backbone of the terminal, allowing for adaptability and scalability in response to evolving spatial requirements and functional needs.

The pivotal concept driving this architectural marvel is the deliberate separation of the main structural columns from the surrounding walls. This strategic decision serves a dual purpose. Firstly, it imparts a profound sense of openness to the interior spaces, creating an atmosphere of expansive grandeur that welcomes visitors. This design ethos aligns with contemporary architectural trends that prioritize fluidity and openness, fostering an environment that transcends traditional spatial constraints.

Secondly, the detachment of structural elements from the walls not only enhances the aesthetic appeal but also optimizes internal flow. The liberated floor plan, unencumbered by intrusive columns, allows for a seamless and efficient circulation of people within the terminal. This emphasis on smooth internal flow is crucial for a bustling transportation hub, where the movement of passengers needs to be both intuitive and unrestricted [6].

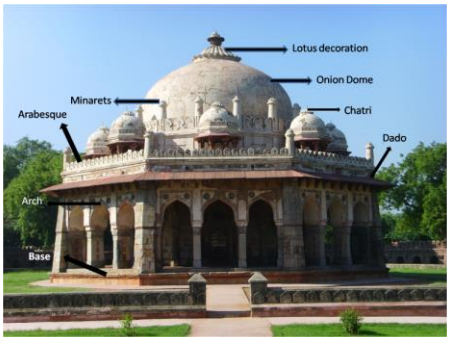

Figure 7. Typical Islamic architecture.

Kuala Lumpur is the capital of an Islamic country. The structure of the terminal is a hyperbolic canopy designed by the architects to combine the cutting edge of modern technology with traditional Islamic style and the columns refer to the forms of Malaysian oil palm trees. The traditional Islamic elements are abstracted to design a modern, geometric architectural language suitable for airports [7].

Figure 8. Photo of drop-off area at KLIA.

In order to meet the requirements of the environmental energy system, Kurokawa skillfully integrates drainage, air conditioning pipes, skylights, and lighting fixtures into the structural system. By doing so, the interior space of the airport becomes clean and interesting.

Contact piers and satellite buildings are structurally different from the main pier. The roof structure consists of sloped bowstring trusses spaced 9.6 metres across the width of the building. The trusses are supported at four points along their length by exposed pin joints and tilted pipe strings [8].

Creative and interesting structural details, small spaces, and fixtures give users a different experience. Because of the small size of Japan, this is the characteristic of Japanese architecture.

A view showing the nature of the circulation space for a typical gate area, this case being in one of the wings of the satellite building.

Gates lie behind the glass curtain walls to the left and right. The ceiling is finished with steel meant to give the impression of wood slats. Taper (Y shape) repeating structural members add scale and rhythm to the space [9].

The landscape of the same area better demonstrates the role of transparency in the design of the hall.

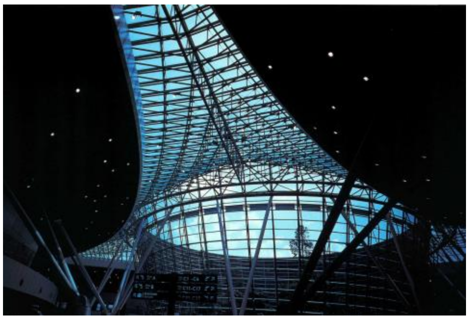

Figure 9. Bowl-shaped courtyard and skylight connected by roof truss in KLIA.

The designer used steel structure and bearing glass to circle a courtyard and plant many trees inside which not only shows the idea of symbiosis but also plants will breathe in carbon dioxide and release more oxygen (ventilation).

Airports are the most expensive energy facilities in modern cities [10].

The most intuitive is the size: the most basic space required by the airport: the runway is generally more than 3000 meters in length and less than 60 meters in width, which is only a part of the airport. Noisy and spacious runways must be combined with time-consuming passenger handling facilities and good access to the city centre. "Waiting" is an important part of the plan, in which passengers spend their time window-shopping and shopping, providing an attractive opportunity for retail facilities. With the expansion of air travel in the 1990s, airports were increasingly redesigned as shopping malls, and public spaces with multiple uses and uses. Kuala Lumpur Airport is a prime example.

Large structures are made of high-energy materials such as steel, aluminum and glass. Airport terminals are huge open areas with high ceilings that are difficult to heat and cool, and a huge waste of energy. But high ceilings are the best choice because of high mobility.

The second point is air conditioning: reliance on air conditioning creates very high operating costs, especially in tropical countries such as Malaysia. Unlike the traditional Malay houses Cited by Kurokawa, the airport roof structure is made of steel and is poorly insulated. Kurokawa's design certainly has its merits, as at some other airports, the wooden underside of the roof and banana-shaped skylights provide better cooling than glass roofs. But that doesn't change the fact that air-conditioning large Spaces in a tropical country is an energy-intensive task in itself.

Thirdly, automation infrastructure: operating costs are high in a high-tech environment filled with escalator conveyor belts, people vans, and cargo lifts. There are no exact operational statistics for Kuala Lumpur Airport, but estimates can be made from other airports. One example is Copenhagen airport, which is less than half the size of Kuala Lumpur and has to be heated rather than air-conditioned, with nearly 30 million passengers. In 2016, Copenhagen Airport consumed about 93 million kilowatt-hours of energy. That is about the same as a town of 70,000 residents.

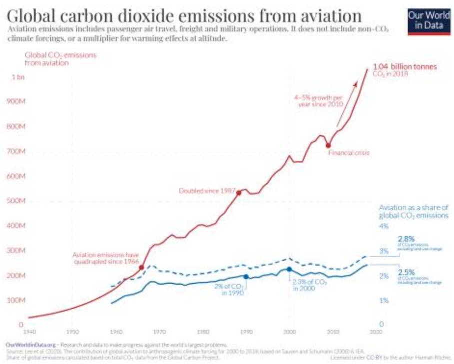

Figure 10. Global carbon dioxide emissions from aviation.

This is based on fuel consumption data from the International Energy Agency (IEA) and earlier estimates by Robert Thorson and Ulrich Schumann (2000) [11]. The accompanying chart shows a time series of global aviation emissions since 1940. There has been a continuous upward trend. “The global aviation industry, including passenger and freight transport, is estimated to have emitted 1.04 billion tons of carbon dioxide in 2018” [12]. This is equivalent to 2.5% of total CO2 emissions in 2018 [13].

Aviation emissions have doubled since the mid-1980s. But they are growing at the same rate as total carbon dioxide emissions: this means that CO2 accounts for a relatively stable share of global emissions: between 2 and 2.5 per cent [14].

In the context of sustainable development, many airports have made initiatives on energy use.

Hartsfield-Jackson Atlanta International Airport is located about 11 kilometers south of downtown Atlanta, Georgia, USA. It is also the busiest airport with the largest passenger traffic in the world. In 2018, the throughput was 110,531,300, and in 2019, the cargo throughput was 639,276 tons, with 944,101 takeoff and landing sorties. Such busy airports have taken steps to conserve energy.

Fortunately, The Good Traveler program is offsetting the emissions equivalent of over 115 million air miles, or taking 3,822 cars off the road for a year. "Reducing and offsetting emissions is an ongoing priority for Hartsfield-Jackson Atlanta International Airport. The Airport has offset over 60,000 tons since 2017" [15].

Another airport example is Zaha Hadid Architects' Beijing Daxing International Airport, which will open in 2019 with a terminal area of 780,000 square meters. The airport has a bionic design that resembles a giant butterfly or dragonfly. The airport's roof, which covers an area equivalent to 25 football fields, has a large hexagonal skylight in the center of the roof, which is connected with six strip skylights and eight bubble Windows to transform the interior of the airport into a large light courtyard. A total of 12,800 pieces of glass are used throughout the terminal, connected by 12,300 spherical joints and more than 60,000 connecting rods. The roof alone has 8,000 identical pieces of glass. The construction is the most difficult in the world. In order to maximize public space for passengers, the building was simplified [16].

By connecting the c-column top to the bubble skylight, the roof is integrated with the load-bearing structure. The entire roof is supported by eight C-columns, creating a huge atrium with almost no columns and pouring sunlight through the glass into the hall. This is an example of a large building that has been very successful in reducing energy. The use of an ingenious steel structure, to set up an indoor light court, greatly reduces the use of indoor lighting [17].

Another airport example is Zaha Hadid Architects' Beijing Daxing International Airport, which will open in 2019 with a terminal area of 780,000 square meters. The airport has a bionic design that resembles a giant butterfly or dragonfly. Its environmental protection concept is: Make full use of natural lighting to reduce the energy consumption of artificial lighting, daylighting skylight, exterior curtain wall shading treatment, green ecological environment, make full use of suitable technology and local materials, energy saving binnacle air supply system [18].

3. Conclusion

To conclude, airports and energy are inseparable, and each part affects energy. Energy improvement starts from the building itself, such as light, structure, environment, and so on.

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