Comparative Study of Construction Aspects of Two Data Centers in India – DC 1 vs DC 2

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Abstract

In today's digital age, the need for data centers in India is growing fast due to the rise of 5G, cloud computing, and the Digital India mission. For websites, apps, and online services, data centers—special buildings—where computer servers store and oversee data These buildings have to be robust, safe, energy-efficient, running without stopping capable. Two data centres, DC 1 and DC 2, constructed in Pune, are compared in this study. Made using conventional concrete techniques and air-based cooling systems, DC 1 is Modern precast materials and cutting-edge liquid cooling are used in the construction of DC 2 to save energy. Built to Tier III criteria, both centres feature backup systems designed to run even during maintenance or breakdowns. Their structure, foundation, cooling, fire safety, energy consumption, and future expansion simplicity are compared in this paper. The study is grounded on visual observation and reliable published sources since inside data was not accessible. While DC 1 is strong and dependable, DC 2 is more energy-efficient and better for future expansion according the comparison. Engineers and planners can use these findings to enhance the construction of data centres in India in the future.

Keywords : Data centers, Construction comparison, Structural design, Modular construction

1. Introduction

Over the past ten years, the digital economy has expanded rapidly and correspondingly increased demand for scalable, energy-efficient data centres. Ensuring 24/7 connectivity, data processing, and storage for industries including banking, healthcare, education, and e-commerce, these facilities constitute the operational backbone of contemporary infrastructure [1]. Demand for very strong and efficient data centres is more than ever as businesses migrate to cloud-based solutions and internet traffic rises.

Particularly India is seeing a fast change in her digital infrastructure. Data centres are now being built all around the nation thanks in large part to initiatives such as Digital India and the deployment of 5G technologies [1]. The exponential rise in real-time applications, mobile data usage, and IoT devices is severely taxing current infrastructure, thus design and construction of next-generation data centres become a national focus [2], [11].

Complex, high-performance structures, data centres demand accuracy in structural engineering, architectural planning, mechanical systems, and environmental sustainability. Their design allows for advanced security systems [3], [7], cooling equipment, large server racks, and continuous power supplies [3]. Recent research underline the need of high-performance building materials including precast concrete and steel frameworks to satisfy these needs [5], [8]. Furthermore under increasing focus for enhancing build quality and lowering construction times are modular and prefabricated building methods [5], [6].

Often accounting for up to 40% of total energy consumption [2], [4], cooling systems are essential component of data centre design. Studies have indicated that alternatives such as liquid immersion and direct-to--chip cooling are now regarded as necessary for lowering Power Usage Effectiveness (PUE) ratios [3], [4], [17], since conventional air-based cooling systems are insufficient for high-density server environments. Moreover, the application of smart HVAC systems compliant with ASHRAE criteria and thermal energy recovery is becoming rather common [17].

Another main issue is the security of data centres, especially in areas prone to disasters. Recent research has underlined in particular the integration of seismic-resistant buildings, base isolators, and advanced fire protection systems—such as FM200 and Inergen gas suppression—necessary to reduce structural and operational hazards [7], [9], [18], [19].

Regarding classification, global frameworks including the TIA-942 standard and the Tier system of the Uptime Institute offer thorough directions for building fault-tolerant and resilient data centres [14], [15], [26], [27]. In India's metropolitan IT centres, Tier III and Tier IV facilities—which support concurrent maintainability and fault tolerance—are growingly prevalent [15], [30]. Furthermore ensuring that facilities are structurally sound and environmentally compliant are Indian building rules (e.g., IS 456 and IS 875) and municipal codes [18], [24], [28].

Green building techniques have also become rather important recently. Using LEED guidelines and ISO 50001 energy management standards is enabling new data centre projects to reach higher sustainability and energy efficiency [20], [21], [31], [33]. These steps not only lower carbon footprint but also maximise long-term running costs.

Although national and international standards abound, the application of construction best practices differs greatly between projects. In order to assess the building techniques, structural systems, fire safety, energy management, and design efficiency, this paper thus offers a comparative analysis of two data centres situated in Pune, India: DC 1 and DC 2. Although both data centres fall under Tier III/IV, their building schedule, scalability, and system integration vary greatly. To pinpoint strengths, difficulties, and best practices, the study combines visual observation, publicly available data, and evaluation supported by literature.

This paper attempts to add to the growing body of knowledge on sustainable and resilient data centre construction in developing nations like India by matching this study with the most recent building and infrastructure trends recorded in academic literature [1]–[20].

2. Methodology

2.1 Selection Criteria of DC 1 and DC 2

This study compares two real-world data centers—DC 1 and DC 2—based on observable construction characteristics and publicly available information.

- DC 1 is a conventionally constructed data center using on-site concrete casting and traditional structural practices.
- DC 2 utilizes a precast concrete approach, featuring modular and pre-engineered components assembled on-site.

These two centers were selected based on similarities in:

2.1.1 Operational scale

Both DC 1 and DC 2 operate on a large-scale enterprise level, which means they handle a huge amount of digital work every day. These data centers are built to support big organizations such as banks, IT companies, telecom providers, and government platforms.

- DC 1 has a built-up area of around 45,000 to 50,000 square feet and includes G+4 floors, indicating that it can house a high number of server racks, electrical systems, cooling units, and control rooms. This size shows it is designed to support high-performance computing and storage operations for multiple clients at once.
- DC 2 has a slightly larger built-up area of around 60,000 to 65,000 square feet, with G+2 floors but a wider horizontal layout Its modular architecture lets one increase its operations in phases. Additionally supporting high-density server environments with sophisticated power and cooling systems is this architecture.

In simple terms, both data centers can support hundreds to thousands of servers, which makes them suitable for running cloud services, online banking systems, large websites, real-time apps, and internal company networks. The size and setup of both DC 1 and DC 2 clearly show they belong to the same operational category, allowing for a fair comparison.

2.1.2 Geographical and environmental conditions

Both DC 1 and DC 2 are based in Pune, a large western Indian city. Pune is well-known for its consistent temperature, growing IT infrastructure, and rather low risk of natural disasters like floods or major earthquakes. This makes this a highly sought-after location for large data centres.

Seismic Zone: Pune falls in Seismic Zone III (moderate risk), thus both centres are made to resist any effects of an earthquake. First focus in both projects is structural safety.

Soil Type: Most of Pune's soil is medium to stiff clay and decomposed rock, which allows foundation techniques depending on the load and depth either pile foundations or raft foundations. DC 1 and DC 2 most certainly used these techniques to give the building stability.

Climate: Pune has a tropical wet and dry climate with an average temperature ranging from 10°C in winter to 38°C in summer. This kind of temperature affects the systems of data centre cooling. The temperature is not too high, thus both centres can effectively regulate their internal temperature by means of air-cooling and liquid-cooling systems.

Rainfall: Monsoon season brings Pune between 700 and 800 mm of rain on average. Important during building are waterproofing and drainage design to protect the data centres' electrical systems and foundation.

Urban Setting: Both centres are in developed IT or industrial zones where infrastructure including wide highways, water connections, energy supplies, and fast fibre networks already exists. This makes the site ideal for linked and safe data centre establishment.

2.1.3 Tier classification (Tier III or above)

Each center follows Tier III standards or better. This means they are designed to work without stopping, even if one system fails or is under maintenance. This level of setup shows they are made for serious, non-stop work.

2.1.4 Visibility and access to external observation

Both buildings could be seen from outside. Even though we didn't go inside, we could still look at the structure, design, layout, and equipment setup from a safe distance. This helped us study and compare them without needing special permission.

2.2 Parameters for Comparison

Both data centres were investigated using the same set of points in order to fairly and practically compare DC 1 and DC 2. These points were chosen since they are crucial for comprehending the building techniques and performance capacity of a data centre. Every point is clarified here in basic language:

- **Methodology for Construction :** This implies the construction technique of the building. Using concrete and steel, DC 1 followed the conventional approach whereby most of the building is done straight on the site. DC 2 adopted a modular approach whereby several building components—many of which were manufactured in factories—were subsequently transported to the site for assembling. Usually, this is faster and more hygienic way.
- **Project Schedule in Construction :** This indicates the length of the building process. We calculated the completion time by consulting public news reports and changes observed in the building over time. DC 1's

simpler approach meant less time needed. DC 2 took more time since its design was more adaptable and futuristic.

- **Material Handling and Use :** This verifies the type of building components applied. From outside, we noted whether the materials appeared consistent, sturdy, and well-worn. We also examined the surface-level placement and finishing of materials including glass, steel, and concrete.
- **Modules and Scalability :** This indicates whether the data centre is prepared for upcoming expansion. We looked to see whether the structure allowed more server rooms or equipment to be added later without significant alterations or if it had extra space built in such manner.
- **structural and seismic characteristics :** Pune falls in a moderate earthquake zone, thus we sought for elements shielding the structure during an earthquake. These comprise flexible joints, base pads, and robust support columns able to withstand vibration without damage.
- **Safety Measures for Fire:** Data centres have to be kept fire-proof. We looked for obvious fire exits, emergency staircases, fireproof doors, and separate walls to stop fire from spreading. These indicators clarified the degree of fire safety preparedness of every centre.
- **Ventilation and Cooling Layout :** Servers need appropriate cooling and create heat. We examined the big air ducts, rooftop HVAC systems, exhaust fans, and cooling equipment. Visible systems for cooling DC 2 were more advanced than those of DC 1.
- **Redundancy and Backup Mechanisms:** Data centres have to keep running even in cases of power outage. We sought for two separate power supply lines, extra cooling systems, and backup generators. On both sites, these backup systems were abundantly evident.These parameters were chosen for their relevance to both structural quality and data center efficiency, and because they could be assessed without internal access.

2.3 Data Collection Sources

Given that internal documentation or direct access to the facilities was unavailable, the following **non-invasive data sources** were used:

- **On-Site External Observation**
  Multiple visits were made to observe construction details and infrastructure layouts externally.
- **Public Domain Visuals**
  Photos and videos from company websites, construction news, and published media were used for analysis.
- **Literature Review**
  Academic studies, case reports, and industry-specific publications helped frame the comparison criteria.
- **Expert Opinions (Informal)**
  General insights were obtained from civil engineers and industry professionals through off-site, informal discussions.

2.4 Limitations of the Study

The methodology, while grounded in realistic observation and literature, comes with several limitations:

- **No Access to Internal Documents**
  Architectural blueprints, cost details, structural calculations, or technical reports were not available.
- **Observation-Based Judgments**
  Many evaluations (like material type or modularity) are based on visual clues, not confirmed documentation.
- **Estimation-Based Assumptions**
  Construction timelines, design intentions, or performance metrics were estimated based on publicly accessible information and may not reflect exact values.
- **Lack of Operational Data**
  Key data like uptime, cooling efficiency (PUE), and load management were not part of this study due to access constraints.
- **Site-Specific Findings**
  The results may not apply universally to all data centers, as they are based on two specific case examples.

3. Overview of Data Centers

3.1 Data Center 1 (DC 1)

3.1.1 Location, Owner, and Size

DC 1 is located in Pune city, inside a dedicated IT zone. This location is ideal because it already has proper roads, electricity, and internet services. The data center is owned by a large international company that works in cloud technology and enterprise services. The building is quite big, with a total built-up area of about 45,000 to 50,000 square feet. It has a ground floor and four additional floors (G+4). Apart from the main building, the site also has a separate security unit, an electrical substation, and a yard where mechanical equipment is kept.

3.1.2 Structural System and Materials

The structure of DC 1 is made using a method called cast-in-situ reinforced concrete (RCC). This means concrete was poured and set at the site itself to form strong columns and beams. The floors use flat slabs with drop panels, which help support heavy loads like servers. The walls that don't carry weight are made of concrete blocks or AAC blocks. The building includes fire-rated doors and walls that help slow down fire if one breaks out. Inside the slabs, we could observe MEP risers and cable trays, which are used to pass wires and pipes neatly. Areas that carry heavy loads also have extra steel reinforcement. The outer walls are coated with special fire-resistant material for added safety.

3.1.3 Foundation Details

From the size and type of construction, we can say that DC 1 most certainly employs a deep pile foundation even though we cannot access the exact foundation design. All the heavy machinery including generators, rooftop HVAC systems, and servers depends on this kind of foundation to support their weight. It also provides great help in softer soil environments. A raft foundation could also be used to distribute the weight more fairly in some areas, including the middle of the building where server halls are situated.

3.1.4 Layout and Zoning

The arrangement of DC 1 seems to be derived from a sophisticated zoning technique. Usually found on the top levels in the centre area of the construction are the primary server rooms. Lower levels most certainly find home for important utility systems including UPS rooms, power systems, and cooling equipment. Around the structure are separate service corridors and emergency staircases meant to facilitate safe transit and fire evacuation. Additionally connected to the building but kept somewhat off from the main server facilities for security and administrative block is Platforms for diesel generators, transformer enclosures, equipment moving ramps outside the building, and robust fencing with a suitable entry checkpoint abound.

3.1.5 Energy Efficiency Features

DC 1 includes many features to save energy. It has vertical shading fins and roof extensions to block direct sunlight and reduce heat inside. Rooftop HVAC and air-cooled chiller systems are used for cooling, and they likely work with variable frequency drives (VFDs) to use only the energy needed. Office or admin areas have double-glazed glass panels to stop heat from entering. Also, smart lighting systems with motion sensors are probably used in areas like corridors and staircases to save electricity.

3.1.6 Tier Classification

Based on what was seen and known, DC 1 appears to be constructed in line with Tier III criteria—defined by the Uptime Institute. This makes it meant to remain running even if one component breaks or requires repairs. There are two diesel generators and two UPS systems, hence power is constantly accessible. Cooling is also set in a N+1 pattern, indicating a backup one extra unit is present. The facility most certainly has two different internet and power sources and seems to support repair without shutdown. For large corporations especially, these characteristics ensure that the data centre functions flawlessly for 99.982% of the year.

3.2 Data Center 2 (DC 2)

3.2.1 Location, Owner, and Size

DC 2 is in Pune on its own secure plot that has fences and limited entry points. A company that provides digital infrastructure services operates this center. The main building covers about 60,000 to 65,000 square feet and has a ground floor plus two more floors (G+2). Separate smaller buildings on the site hold generators, cooling units, and office space for staff. DC 2 is planned to meet strict Tier IV standards, meaning it is built for very high reliability.

3.2.2 Structural System and Materials

The framework applies a hybrid technique. While stair cores and service shafts are created with concrete poured on site, large beams, slabs, and columns are precast in a plant and then set in place. On the roof, steel platforms hold large mechanical equipment. Rising floor inside let cool air and cables move freely. The slabs are strong enough for heavy servers. While vibration isolators shield delicate machinery from shaking, fire rated walls and ceilings slow the spread of fire.

3.2.3 Foundation Details

Deep piles combined with a raft foundation allow DC 2 to be built where loads are most heavy. This building balances weight and controls forces acting during an earthquake. Waterproof layers keep moisture out while vibration pads and isolation strips reduce movement in utility ducts. These components help to prevent unequal building settling and maintain equipment stability.

3.2.4 Layout and Zoning

The ground floor mainly holds mechanical and electrical units such as UPS batteries and power gear. The first floor houses server halls and control rooms, and the second floor is set aside for extra storage, network gear, and disaster-recovery areas. On the roof are HVAC systems, cooling towers, and other support equipment. Service corridors are kept apart from staff walkways, emergency exits are clearly marked, and spaces are arranged for safe daily operation and quick maintenance.

3.2.5 Energy Efficiency Features

DC 2 uses advanced cooling, likely liquid or direct-to-chip, to remove heat more efficiently than normal air systems. Pipes are insulated, and thermal barriers cut heat loss. Solar panels on the roof add extra power. Smart sensors track energy use and temperature in real time. LED lights with motion detectors lower electricity use, and the whole setup follows modern green-building ideas.

3.2.6 Tier Classification

Visible systems show DC 2 targets Tier IV status. Power and cooling are built with full 2N redundancy—two complete, independent sets—so the center can keep running even if one set fails. Maintenance can be done without shutting anything down, and multiple backup generators, UPS units, and spare cooling machines provide fault tolerance. All of this is designed for continuous operation and very high uptime.

4. Parameters of Comparison

4.1 Location and Geotechnical Condition

Both DC 1 and DC 2 are situated in Pune city, a developed urban area noted for expanding IT infrastructure. Pune's relatively solid soil, made of worn rock and clay, supports big structures like data centres. Built in an existing IT zone, DC 1 makes use of all fundamental infrastructure like roads, internet, and energy currently in use. Its location in Seismic Zone III indicates a modest degree of earthquake risk, which was taken into account in its structural design and basis. Built on a guarded, isolated site with its own compound and entrance control, DC 2 is Deep foundations, waterproofing, and vibration isolators in the design help to guarantee stability under stress; the location seems to have appropriate geotechnical characteristics for big loads.

4.2 Building Schedule

DC 1 finished in around 12 to 15 months. Its building was quicker since it used conventional building techniques and cast-in- situ RCC in a clear plan. The design permitted structural and utility work to progress simultaneously. By contrast, DC 2 took roughly eighteen to twenty-four months. The design was more complicated even if it made use of precast and modular components that expedite some aspects of the construction. The coordination required for factory-made modules and integration with modern systems stretched the horizon.

4.3 building expenses

Strong structural systems, improved fire safety precautions, backup power and cooling systems for Tier IV operation all helped to drive DC 1's higher overall cost. Moreover, cast-in--situ building usually calls for more time and effort, so raising expenses. DC 2 was really expensive. Although it contained modern technologies like energy-efficient cooling, smart building systems, and modular expansion capabilities, it saved time and labour by using precast components. Though initially more expensive, these features lower running costs over time.

4.4 Structural Planning

Precast floor elements, reinforced concrete beams and columns, and elevated floors were used to build DC 1. With an eye towards managing huge server loads and resisting earthquake, the design emphasises dependability and strength. DC2 employs a hybrid architecture. It calls for cast-in-place concrete for stair cores and service shafts, precast concrete components for floor and column systems, and steel platforms on the roof for cooling units. Additionally supported by the architecture are simple updates and flexible extension.

4.5 Basis Type

DC 1 seems to combine reinforced raft slab with deep pile foundations. This arrangement adds earthquake resilience and helps to distribute the weight of the large construction. DC 2 likewise employs a raft foundation but only in high-load sections uses deep piles. The design calls for waterproof membranes and vibration-damping elements to guard delicate IT equipment and stop ground movement compromising the construction.

4.6 Resources Applied

Concrete, steel, and fire-rated materials form the construction in DC 1. In key places like offices and server halls, it features soundproof panels and insulation. DC 2 mixes modular and prefabricated components using like materials. DC 2's walls and ceilings are constructed with fire-rated panels, and cable and airflow control is accomplished via raised floors. Both centres mostly on durability, safety, and simplicity of maintenance.

4.7 Safety Regarding Fire

Modern fire suppression systems include FM200 and Inergen gas systems abound in both DCs, rapidly extinguishing flames without compromising electrical equipment. DC 2 also employs escape path planning, fire-rated walls, and improved smoke management. Although both are fire-safe, DC 2 exhibits extra measures meant to slow down the spread of fire and guard expensive machinery.

4.8 Design of Seismic and Wind Loads

In important locations, DC 1 incorporates seismic safety elements including reinforced wall panels and base isolators. These characteristics enable the absorption of an earthquake's generated shaking. By means of vibration isolators and reinforced constructions, DC 2 additionally offers seismic protection for both the structure and machinery. The structural designs of both centres now consider wind loads.

4.9 MEP Integration and HVAC

HVAC systems are centralised with duplicated cooling units in DC 1. These systems guarantee, even in case of a failure, the server spaces remain within the specified temperature range. Newer technologies like direct-to---chip cooling, which more effectively cools the server hardware using less energy, are included into DC 2. DC 2's building services cleverly combine temperature monitoring tools with energy systems.

4.10 Redundancy and Uptime Level

Designed for Tier IV classification, both DCs call for fault tolerance and great availability. These comprise several UPS configurations, N+1 cooling systems, backup diesel generators, and dual power sources. Should one system fail, the other runs without disturbance to provide uptime of up to 99.995%.

4.11 Various Cooling Methods

DC 1 most certainly makes use of conventional air-cooled systems, perhaps under support from chilled water systems. Reliable but less energy-efficient are these. DC 2 makes advantage of contemporary cooling technologies such direct-to--chip cooling or liquid immersion. Better for high-performance server loads, these techniques dissipate heat faster and use less electricity.

4.12 Ecological Approaches

Although neither property is formally LEED certified, both follow green principles. To cut power utilisation, DC 1 employs thermal insulation, clever motion sensors, and energy-efficient lighting. To lower running costs and environmental effect even more, DC 2 employs smart building controls, insulated pipes, smart HVAC systems and solar panels.

4.13 Infrastructure for Power Back-off

Diesel generators, twin N+1 power feeds, and many UPS banks are among DC 1's backup measures meant to guarantee that power never stops. Though it is better integrated with smart switching and isolation to prevent any downtime during power changes or maintenance, DC 2 features a similar arrangement.

4.14 Scalability and Expansion ability

Built to enable future improvements such more server racks or more electrical capacity, DC 1 is DC 2 is considerably more adaptable since its modular design lets new systems or rooms be added without pausing current work. This architecture supports future growth without influencing present activities.

4.15 Space Conservation

Both data centres make reasonable use of the space at hand. Clear zones for power systems, cooling equipment, IT operations, and administrative areas abound at DC 1. Though with more emphasis on flexibility and efficiency, DC 2 is built with like zoning. Appropriately planned are areas set aside for personnel access, equipment transportation, and maintenance.

5. Results and Discussion

5.1 Differences and Similarities

5.1.1 Differences

The Construction Schedule

Completing both data centres took somewhat different times. Built in less time—between twelve and fifteen months—DC 1 was This was achievable since the cast-in-- situ reinforced concrete (RCC) technique was applied in design. Every stage—foundation, structure, and mechanical systems—was completed using tried-and-true techniques under a clear, targeted strategy. The project progressed fast since most work was completed right on-site and there were less design revisions. DC 2 took more time—between eighteen and twenty-four months. Its modular architecture, whereby many of the building's components were manufactured in factories (precast) then constructed on-site, was one element influencing this. This approach increases long-term flexibility but calls more rigorous coordination, inspection, and system integration with cooling, electricity, and fire safety. This expanded the whole project schedule.

Building Cost

DC 1 initially priced more. Strong structural elements, sophisticated security systems, fire-resistant building, and twin power and cooling systems were used to satisfy Tier IV criteria and hence produce this. Furthermore needed for conventional building were extra labour and on-site materials. At the beginning, DC 2 was more affordable since it made use of modular and precast components, so saving time and minimising labour. It did, however, devote more money to smart monitoring, energy-efficient cooling systems, and future expansion flexibility. DC 2 adds more modules or systems, so its long-term investment may be costlier even if it may save running expenses over time. DC 2 is meant to distribute its expenses over time; DC 1 invested more upfront for strength and stability.

Methods of Cooling

Common in many data centres, DC 1 makes use of air-cooled systems—probably with chilled water connections. Though they run more electricity—especially in hot weather—these systems are dependable and easy to maintain. DC 2 makes advantage of contemporary cooling methods including direct-to--chip cooling and liquid immersion cooling. These systems remove heat more precisely by supplying coolant straight to the heat source. This approach lowers the Power Usage Effectiveness (PUE), so the data centre runs less energy to maintain server cool-ability. DC 2 thus offers greater performance in terms of energy economy and environmental effect as well as fit for high-density server loads.

Power Backup Systems

Using N+1 power redundancy, both DC 1 and DC 2 provide one additional backup unit for every system. This guarantees that, should one unit fail, the data centre continues to run. DC 2 does, however, provide more sophisticated power management capabilities. These comprise several generator sets, dual power feeds, and UPS systems with intelligent energy control. Designed to more effectively modify power distribution depending on load and usage, the backup system in DC 2 This guarantees dependability as well as enhances the energy efficiency in mechanical systems including cooling ones. DC 2 is, all things considered more versatile and intelligent in how it handles backup power.

Design in seismic and wind loads

Safety against shaking is crucial since both data centres are constructed in an area with moderate seismic zone III. Special devices positioned between the foundation and the construction, DC 1 is built with base isolators. These lessen the force applied to the building and assist to absorb the energy during an earthquake. Conversely, DC 2 makes advantage of under- Equipment vibration isolating technologies included into the building. These devices guard the delicate electronic components and servers against both vibrations from heavy machines and seismic forces. Particularly in modern settings where equipment is sensitive to even minor disturbances, DC 2's technique provides more versatility and fine control.

5.1.2 Similarities:

Uptime Tier & Redundancy

Following the Tier IV classification—one of the highest data centre criteria set by the Uptime Institute—both DC 1 and DC 2 are intended to This tier level implies that, even during maintenance or equipment breakdown, both centres are able to run constantly without stopping. Power supply, cooling systems, and network lines are among their totally redundant systems. One system fails; the second one steps in right away to guarantee no downtime. We call this fault tolerance. This architecture allows both data centres to reach up to 99.995% uptime, so they are expected to be operating all year with only few minutes of possible downtime. For banks, hospitals, and cloud service providers where even a minor interruption in service can lead to major issues, this degree of dependability is quite critical.

Structural design

Both data centres' basic construction calls for reinforced concrete (RCC), steel, and other robust components. These materials were selected since they can manage the large weight of servers, UPS systems, chillers, and other equipment housed within the structure. Both DCs have structural designs with an eye on load-bearing strength, durability, and safety. Particularly in sections like server rooms and electrical zones, both centres incorporate fire-resistant materials in their walls, ceilings, and flooring. Common in contemporary data centres, the elevated flooring in both buildings aids control cables and let cool air circulate under the equipment. The objective of both designs is the same: to support significant IT operations securely and effectively, regardless of the varied building techniques: DC 1 is more traditional while DC 2 uses modular components.

Fire Safety

FM200 and Inergen gas suppression systems are used in both DC 1 and DC 2 to guard the data centre should a fire strike. These systems are designed especially for locations with electrical equipment. They deploy unique gases that eliminate heat or oxygen to end the fire without destroying machines, instead of water, which might compromise servers. Acting fast, these gases can extinguish a fire in a few of seconds. To further protect the employees and equipment, data centres also feature smoke alarms, escape pathways, and fire-rated walls. The design of fire safety guarantees that the damage will be very low even in an emergency and that the systems can react fast to resume functioning.

5.2 Which Data Center is More Efficient and Why

Because of its sophisticated cooling methods and modular design, which prioritises scalability and energy conservation, DC 2 seems to be more efficient. Compared to DC 1, which uses conventional air cooling systems, DC 2's use of liquid immersion cooling greatly improves energy efficiency by lowering the PUE (Power Usage Effectiveness) ratio. Furthermore, DC 2's modular design makes expansion simple, which improves space utilisation and long-term operational efficiency as demand increases. Furthermore, DC 2 stands out as a more environmentally friendly choice due to its emphasis on renewable energy sources (such as solar panels) and energy-efficient HVAC systems.

However, despite being more robust and reliable, DC 1 is more expensive to run, mostly because it uses traditional energy and cooling systems that might not perform as well as the more sophisticated ones in DC 2.

5.3 Challenges Faced in Construction

- The intricacies of designing a high-performance data centre with seismic resistance and cutting-edge security features presented scheduling and material availability issues for DC 1. Cost and logistical issues were also brought on by the infrastructure needs for the energy efficiency systems (fire safety, power backup, and HVAC).
- DC 2 faced challenges managing the supply chain for its modular components, necessitating careful planning to guarantee that every module reached the assembly site on schedule. Adopting liquid immersion cooling also presented difficulties with system integration and guaranteeing the scalability of cooling systems.

In order to obtain certifications, meet local safety standards, and guarantee adequate testing of seismic designs and fire suppression systems, both data centres had to overcome regulatory obstacles. During the building stages, there were additional challenges related to environmental impact assessments and energy regulation compliance.

5.4 Lessons Learned from Comparison

- Among the main lessons from DC 2 is the efficiency and scalability that a modular design provides. Long-term survival depends critically on the capacity to expand as demand increases without interfering with business processes.
- The comparison reveals that advanced cooling systems—such as direct-to--chip and liquid cooling—not only lower running costs but also enhance facility energy performance. Future data centre architecture should take these approaches under consideration in order to lower environmental impact and increase operational effectiveness.
- Both data centres show the need of designing for seismic and environmental safety. Using isolation systems in both data centres guarantees that the buildings can resist natural disasters, so avoiding significant damage to the IT infrastructure.
- Space Use: Both data centres clearly showed the need of optimising space. Especially, DC 2's use of modular design to maximise available space while planning for future expansion was a significant learning about enhancing operational efficiency and scalability.

6. Conclusion

- Designed to satisfy high-performance criteria, both data centres (DC 1 and DC 2) guarantee dependability, economy, and scalability for contemporary IT systems.
- For immediate, high-demand operations, DC 1 stands out for its strong structural design, fast construction schedule, and higher initial investment in materials and energy systems; DC 2, on the other hand, offers greater long-term scalability, energy efficiency via advanced cooling techniques (liquid immersion), and modular design that enables future development and adaptability.
- Thanks to its sophisticated cooling systems and emphasis on sustainable practices including energy-efficient HVAC systems and renewable energy integration, DC 2 is more energy-efficient with lower PUE ratios.
- DC 1 is best in offering strong infrastructure and seismic resilience, which qualifies for places where environmental issues like earthquakes are a main worry.
- Both data centres guarantee great availability and low downtime by including redundancy and uptime characteristics (Tier IV classification).
- DC 2's modular architecture and emphasis on space optimisation provide insightful information for next data centre construction aiming at scalability and flexibility.
- With each data centre using different strategies to handle supply chain management, integration of advanced systems, and regulatory compliance—key issues in construction—key challenges are addressed.
- Lessons gained from this comparison underline the need of adaptability, sophisticated cooling systems, redundancy, and scalability in the design of contemporary data centres for operations guaranteed for the future.

- Considered fundamental for future data centre projects are best practices in fire safety, energy economy, and seismic protection seen in both data centres.

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