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Integrating the COCOSO Method and CBA Technique with MADM Intuitionistic Fuzzy Set for Analyzing Millennium Chola Dynasty Temple Architecture in South India

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Abstract:- The antiquity of Chola's Architect has numerous paintings, sculptures and designs. By prioritizing the temple of Chola 's Art and Architecture over millennium year through architectural typologies and methods that make precast work easier whenever the building is structured. MADM effective tool for the decision maker to decide finer architecture among the temple, weight of alternatives converted to intuitionistic fuzzy set values and weight of temple's architecture has preferences ranking by Combined and Compromise solution (COCOSO) method and CBA technique is used for analytical for selecting a finest temple. Integrating both COCOSO and CBA, the purpose is to determine which temple stands better than others. The aim to appreciate & prioritize value of architectural types and choice, help the decision maker solve the contemporary needs of architects/people with ancient wisdom.

Keywords: Intuitionistic fuzzy set; COCOSO Method; CBA Techinque.

1. Introduction

Intuitionistic Fuzzy Set(IFS) 1983[1, 2], was introduced as an extended approach to Zadeh's fuzzy set theory, which was initially proposed in 1967. IFS was introduced by Atanassov in 1983. In contrast to fuzzy sets, which rely solely on membership values, degrees of membership and non-membership that vary from 0 to 1. IFS plays a significant part in MADM (Multi Attributes Decision Making) by providing a preference solution across many sectors. Even in field like commercial design, engineering and business management, modern decision-making processes are evident. Exercise careful consideration when choosing construction sites or designs. Multiple criteria are utilized by grouping the options to address these considerations and select the most suitable and straightforward attribute

The goal of decision-making is to leverage the expertise of an expert and choose the optimal option based on their knowledge. Even in fields like engineering and business management, modern life decision-making is visible in commercial design. When deciding on construction sites or designs, we must have guts. With these issues in mind, multicriteria are used by grouping the possibilities in order to choose the best and simplest feature. The goal of decision-making is to obtain knowledge or an opinion from an expert and select the best option based on their experience.

People invest in architecture and use categories like commercial architecture, landscape architecture, restoration architecture, etc. to draw in customers. India is one of the nations with a significant presence in the timeline of architecture, particularly for its cave, rock-cut, and temple structures. The Chola Dynasty is also notable for its

elaborate temple structures. Both society and the family must be considered by an architect. We evaluate the strongest architecture among its varieties by combining Chola architecture with the CoCoSo MADM approach, and we then propose our plan site to the architect for building using the knowledge gained from classical works.

The problem's logistics are addressed by Yazdani et al in 2019[18] with the CoCoSo approach (Combine Compromise Solution). The weight of the alternatives in the IFS was standardized using this technique. By merging and aggregating the value into a strategic score in a matrix and evaluating the score value from the least valuable alternative, the CoCoSo Method is also used to prioritize the alternative weight. After ranking the alternatives using the CoCoSo method, the decision to prioritize the Chola temple's architecture is determined and categorized using the CBA (change by Advantage method/cost Analysis Method), a collaborative and open decision-making system created by Jim Suhr in 1999[16]. CBA is most commonly used in architecture.

1.2 Aim of the research /Objective:

- To integrate two or more Decision making methodologies to formulate the algorithm in Fuzzy environment.
- To appreciate and prioritize the architecture design among chola's temple.
- With the help of formulated algorithm, real life decision- making problem is evaluated

1.3 Research Description:

This paper describes the architectural intricacies of chola's temple during the epic period. There are various fields of architecture focused on today's world, by considering the features of the temple work from an expert's perspective and determining the ideal architecture to be focused on building by an architect or people.

2. **Review of Literature**

In ordinary circumstances, decision-making touches both qualitative and quantitative issues. When a subject choice was made from the available options with the help of an expert, the problem was solved effectively. In this case, the decision-maker is a subject-matter expert for the situation at hand. According to Yanger (1978) and Chen (1988), decision-making belongs to a fuzzy set. Intuitionistic fuzzy set theory was developed after fuzzy set theory was introduced by Zadeh in 1970 [Atanassov, (1983)]. Zadeh's work in 1970 showed how fuzzy logic could be used in decision-making contexts. Fuzzy sets are used in operations research, artificial intelligence, decision-making, etc. major technique for making outcomes of decision making [Fulop, J., 2005]. Implementation strategy for the decision-making criteria(MCDM) [Kashid US, Kashid D, & Mehta 2019]. Multi-attribute decision-making (MADM) and multi-objective decision-making (MODM) were developed by Husain, S., and Khan, A. A. in 2013 and Zavadskas, E. K., Z. Turkis, and S. Kildiene in 2014. The elements of the MCDM are explained in [Yu, P.L.(2013)] for the decision maker's preference structure. A number of techniques, such as ELECTRE [Roy, 1968], TOPSIS [Hwang., Yoon, 1981], and AHP [Saaty, T. (1988 & 1995)] were developed to make the Decision Maker simple. COCOSO was built by M. Yazdani, P. Zarate, E.K. Zavadskas, and Z. Turskis in 2019. Utilizing the COCOSO Preference Method, acquire evidence that is either factual or primary in nature, combine the options, and present the result.

The research has produced results in several sectors. [Tan, C., & Chen, X. (2013)] IFS analyze the finer selection of the problem if the answer is ambiguous and insufficient. Rouyendugh (2015) integrated TOPSIS and AHP, and Rouyendugh, Yildizbasi, and Arikan (2018) used IFS for choosing a power plant station. Time prediction via intuitionistic fuzzy set (2019), offshore IFS site selection with PROMETHEE for wind power station (2020). Making decisions using TOPSIS and IFS to evaluate bank credit. CoCoSo with IFS approach for evaluating financial risk [Peng, X., & Huang, H., (2020)] in the IFS soft decision environment [Peng, X., Garg, H, (2021)]. [Chang Gou, (2022)] A vocational college is teaching entrepreneurship using IFS and a COCOSO-based methodology

3. The Chola Dynasty: A Study

The first commence interregnum ruler Vijaya Chola arrived in South India from Karnataka in the eighth century CE at the summit of Brahmagiri in the western ghats, where the river Kaveri begins. The tactful control of a nation is done by the flow of the water, as in the case of Tanjore, which is close to the Kaveri delta in Tamil Nadu. The longest rule from ninth and thirteenth centuries CE occurred under the Eunoia of Chola. Tanjore was taken over around 850 A.D. and eventually designated as the capital of the Chola dynasty. Their scholars had a trading route in the Maldives, an island in the Indian Ocean, and en-routed cities like plane, Palembang, and Indrapura, where they expanded their authority throughout southeast Asia. The ascent of the chola's ancestors nearly took over South India. Chola-related monuments in a god-centered temple. Inscription and old master painting by Rajendra I and his heir from the 9th and 12th century in south India, combatant chola - Rajaraja chola, Rajendra chola, chalukya chola kulathunga, and other monuments of cholas in architectural temples dedicated to Lord Shiva and epigraph for Tamil language and province with the triumph myth are master-pieces in temples. Architectural landmarks have survived the millennia and continue to stand firm.

3.2 Signature of Chola Dynasty Architecture:

The Chola work are friendly and reveal the culture, the people's beliefs, and the kinds of animals and flowers that were present. These things are only provided to those who are ensconced within the walls where their memories are kept. The tiger in the epigraph is a contradiction to Lord Shiva's extreme spirituality and his attire is made out of tiger hide. All temple pillars are made with the fewest intricate details. In the past, between the ninth and the thirteenth centuries CE, the Eunoia of Chola was the longest reigning period. Tanjore was taken over around 850 A.D. and eventually designated as the capital of the Chola dynasty. The Commence Interregnum ruler Vijaya chola arrived in South India from Karnataka in the eighth century CE at the summit of Brahmagiri in the western ghats, where the river Kaveri begins. The tactful control of a nation is done by the flow of the water, as in the case of Tanjore, which is close to the Kaveri delta in Tamil Nadu. Their scholars had a trading route in the Maldives, an island in the Indian Ocean, and en-routed cities like plane, Palembang, and Indrapura, where they expanded their authority throughout southeast Asia. The ascent of the chola's ancestors nearly took over South India. The lotus, which explodes as a dancing statue and represents the Bharatanatyam, is carved out of granite and metal in temples. The temple of Lord Shiva has two or three sides, including Murugan, Vinayaka, and the victory goddess Periyanayaki Amman-Durgai Amman. Each temple represents the specialty of the chola ruler-victory, time (sun dial), and water management. The lingam symbolizes the deity Shiva, and the nanthi is thought of as his vehicle. Intricacies and creativity are now looked forward to for progress in architecture.

3.3 Choice of temples:

Option for a temple by hand to study based on its vimana, Dravidian style, complexity, sand history as depicted in its paintings and texts. The features of the temples are determined by their design, pattern-shapes, HVAC, materials, complexity-of-sculpture, and interior layout. The temples Brahadeeswarar and Gangai Konda cholapuram Airavatesvara are outstanding time living temples, according to UNESCO's heritage list. Due to the fact that Vijaya chola was the first chola triumph in Tamil Nadu.

3.3 Figure of Millennium chola temple of Tamil Nadu:

(a) Vijayalaya Cholеeswaram Temple (b) Brihadeeswara Temple [6]


(c) Gangaikonda Choleeswaram Temple [15] **(d) Airavastesvara Temple [6]**

3.3.1Vijayalaya Choleeswaram Temple(T4):

This temple was constructed by Vijaya Chola in the year 1100. It is formed entirely of rocks, is buried on a hilltop, and lacks an entrance like other temples. During the conflict, this temple was demolished. On top, it has a doom-like shape. This temple is renowned for its LIGER (elephant + tiger) sculpture, an animal that is now becoming well-known simply by its name (tiger). The sculpture of the tiger is a cross between a deer, elephant, bird, etc., as well as a tiger and human features, creating new flavors. People think that these types of hybrid animals have existed since prehistoric times. On the exterior wall and inside, there are carvings of designs and sculptures. The exterior wall is decorated and sculptured, whereas the interior pillars are plain and unadorned. The strangest thing is that 12 sculptures of Lord Vishnu have the exact same design. As a result, the lingam has 24 depressions, 6 small chambers, and 3 big shines.

3.3.2 Brihadeeswara Temple(T1):

Raja Rajeshwaram, built by Raja Raj Chola in the 11th century, is the largest temple in India. It is 13 feet high and 16 feet broad, and is known in Tamil as periya kovil, English as Big Temple, and Pragatheswara Temple in Sanskrit. Patriot in tamil made the temple in form of 12 feet nandi ,18 feet garbhagriha and 247 epigraphy Tamil letter are imprinted. The history of the temple and the cholas are imprinted on the walls, which is significant for Tamil style writing. Chola Nandi is the nandi on the left, and Nayakar has taken the place of the enormous nandi that faces the temple in the front.18 Fruits, vegetables, and leaves were painted on the ceiling in maratha style. The flag staff is made of silver burma teak wood, copper, and 32 rings that are shaped like the bones of the human body. Later, the pandian, nayakar, and maratha built this temple. Clay, boulders, granites, and slaked lime were used to create the sculptures in this temple. It has stood for more than 1013 years [6].

3.3.3 Gangaikonda Choleeswaram Temple(T2):

Rajendra Chola I, the son of Rajaraja Chola, constructed this temple between the years of 1012 and 1044 CE in the Ariyalur District. This temple was constructed to commemorate the war's success. Given that the terrain is dry, this temperature is crucial for the storage of water, as is Chandigarh Rock, Black Rock, or Indian Rock (which provides chilly summer temperatures and hot winter temperatures). It is a two-story temple with steps on either side. There are nine steps total, four of which are wider and five of which are normal and narrow. Due to a natural disaster and a conflict against a temple during the British era, Tamil writing was completed after the third kulathunga chola. The temple sculpture has a Guardian that holds a lingam at the entry way. The 25-foot-tall Red Ochre or burned brick and clay nandhi dates back to around 997 years [15].

3.3.4 Airavastesvara Temple(T3):

When compared to the Brihadisvara temples in Thanjavur and Gangai-Konda Cholapuram, this temple in Kumbakonam was built by Rajaraja Chola's grandson, Chola King Rajaraja II (1143-1173 CE). Due to the inability of the earth beneath to support the height and weight of the rock and granite, this temple is essential for sculpting (also known as the dream world of sculpture). This is also well-known for its sa re ga ma-based musical moves. The sculpture design skills on the flag staff surpass those of Gangai Konda Cholapuram and Periya Kovil. Elephant trunk direction and the tail in the pillar provide the mental route into and out of the temple. Nayakas and Pandiyan’s afterwards developed and renovated it. This temple is built like a chariot[figure3.3.4(a)], with dual

sculptures of an elephant and a buffoon created during the time of the epics, and Lord Shiva has various structures carved out of the wall's rocks.

4. Approach for COCOSO & CBA Algorithm

The Algorithm is framed for quantify ranking of chola architecture by combining Intuitionistic fuzzy set with COCOSO method and CBA method, method is outlined below [8,9].

Step1: Obtained Linguistic Variable for alternative and attributes from the expert then Convert linguistic variables to Intuitionistic Fuzzy value

Step 2: Changing it from an intuitionistic fuzzy decision matrix to a fuzzy decision matrix were,

$$\mu_B(x) = \mu_B(x) + \frac{\pi_B(x)}{2} \quad \dots (1)$$

i:e $\mu_B(x) = \frac{\mu_B(x)+(1-v_B(x))}{2}$ …(2)

To perform stages 3, 4, and 5, the phyton code is utilized.

Step 3: The matrix's values are normalized from the previous phase to get crisp values for the alternatives.

$$T_{eij} = \frac{x_{ij}-x_{ij}}{x_{ij}-x_{ij}} \quad \dots (3)$$

Step 4: Sum and Power for the weight of the matrix are calculated using

$$(T_s) = \sum_{j=1}^{n} (wj\ teij) \quad \dots(4)$$

$$(T_p) = \sum_{j=1}^{n} (teij)^{wj} \quad \dots(5)$$

for the comparability of alternative weights.

Step 5: Three strategies for accumulating assets

$$(kw)_{i_1} = \frac{t_s + t_p}{\sum_{i=1}^{m}(t_s + t_p)} \quad \dots(6)$$

$$(kw)_{i_2} = \frac{t_p}{t_s} + \frac{t_s}{t_p} \quad \dots(7)$$

$$(kw)_{i_3} = \frac{t_s + (1+\lambda)(t_p)}{max\ t_s + (1-max\ t_p)} \quad 0 \le \lambda \le 1 \quad \text{for } \lambda = 0.5 \quad \dots(8)$$

Step 6: Organizing the choices according to the (kw)i Assessment

$$K_i = (k_{i1} \times k_{i2} \times k_{i3})^{\frac{1}{3}} + \frac{1}{3}(k_{i1} + k_{i2} + k_{i3}) \quad \dots(9)$$

Step 7: The orderly succession of the score arrangements, The sequencing of the score arrangements.

Step 8: Quantifying the sequence order by CBA method.

5. Implementing the Algorithm for Ranking

The linguistics value of decision maker, the expert and IFS value are tabled.

Table1: Intuitionistic fuzzy value for Linguistic value

LINGUISTIC VALUE	IFS
Excellent	<0.8, 0.01>
Very Good	<0.7,0.06>

Good	< 0.5,0.05>
Neutral	<0.3,0.4>
Undecidable	<0.2, 0.7>

the value converts it into Ifs number using table1 and each attribute's IFS value has a crisp value i: e fuzzy decision matrix form, Weight values are W_1 = 0.41, W_2 =0.3, W_3= 0.25, W_4= 0.1, W_5= 0.5.

Stated from the step3 the alternative (temples)as T and their attributes as I

Table 2: fuzzy normalized value

	I_1 (Architectural designs)	I_2 (Materials)	I_3 (Patterns)	I_4 (Visual and feel)	I_5 (Intricacies)
T_1 (Brihadeshwara temple)	0.895	0.82	0.725	0.82	0.82
T_2(Gangaikonda cholapuram)	0.75	0.82	0.75	0.725	0.25
T_3 (Airavatesvara temple)	0.895	0.725	0.82	0.82	0.895
T_4(Vijayalaya choleeswaram)	0.725	0.725	0.25	0.75	0.25

The table to matrix form as

$$\begin{bmatrix} 0.895 & 0.82 & 0.725 & 0.82 & 0.82 \\ 0.75 & 0.82 & 0.75 & 0.725 & 0.25 \\ 0.895 & 0.725 & 0.82 & 0.82 & 0.895 \\ 0.725 & 0.725 & 0.25 & 0.75 & 0.25 \end{bmatrix}_{4\times5}$$

By utilizing the phyton, these operations are accessible for Step 3,4&5.

Step3:

```
def res(mat):
  result = []
  for i in range(len(mat)):
    row = []
    for j in range(len(mat[0])):
      val = (mat[i][j]-find(mat,'min',j))/(find(mat,'max',j)-find(mat,'min',j))
      row.append(val)
    result.append(row)
  return result
```

Step 4:

Matrix Multiplication :

```
def weight(mat1,mat2):
    result = []
    for i in range(len(mat1)):
        row = []
        vsum=0
        for j in range(len(mat1[0])):
            vsum = vsum + (mat1[i][j]*mat2[0][j])
        row.append(vsum)
        result.append(row)
```

Power of Matrix :

```
def find(mat,operation,col):
    val=mat[0][col]
    for i in range(len(mat)):
        if(operation == 'min'):
            val=min(val,mat[i][col])
        elif(operation == 'max'):
            val=max(val,mat[i][col])
    return val
```

Step5:

```
   def l(mat1,mat2):
    result = []
    for i in range(len(mat1)):
        row = []
        for j in range(len(mat1[0])):
            val =  (mat1[i][j]+mat2[i][j])/(findsum(mat1,j)+findsum(mat2,j))
            row.append(val)
        result.append(row)
    return result


def m(mat1,mat2):
    result = []
```

```
    for I    in range(len(mat1)):
        row = []
        for j in range(len(mat1[0])):
            val =  (mat1[i][j]/find(mat2,'min',j))+(mat2[i][j]/find(mat1,'min',j))
            row.append(val)
        result.append(row)
    return result


def n(mat1,mat2):
    result = []
    for i in range(len(mat1)):
        row = []
        for j in range(len(mat1[0])):
            val =  -((0.5*mat1[i][j])+(1.5*mat2[i][j]))/((0.5*find(mat1,'max',j))+(1-find(mat2,'max',j)))
            row.append(val)
        result.append(row)
    return result
```

Approaching on the beneficial criteria from step 3, the normalizes value is done.

Weight	0.41	0.3	0.25	0.1	0.5
Min	0.725	0.725	0.25	0.725	0.25
Max	0.895	0.82	0.82	0.82	0.895

$$T_{eij} = \begin{bmatrix} 1.0 & 0.88372 & 0.73643 & 0.88372 & 0.88372 \\ 0.77519 & 0.88372 & 0.77519 & 0.73643 & 0.0 \\ 1.0 & 0.73643 & 0.88372 & 0.88372 & 1.0 \\ 0.73643 & 0.73643 & 0.0 & 0.77519 & 0.0 \end{bmatrix}_{4\times5}$$

By applying the sum and power for the matrix we get the matrix as

$$T_s = = \begin{bmatrix} 1.389457 \\ 0.850387 \\ 1.440232 \\ 0.600387 \end{bmatrix}_{4\times1}$$

$$T_p = \begin{bmatrix} 4.817741 \\ 3.772650 \\ 4.869589 \\ 2.769276 \end{bmatrix}_{4\times1}$$

The alternatives are in compared with weight and the score strategy value is obtain from step6

$$(kw)_{i1} = \begin{bmatrix} 1.0 \\ 1.0 \\ 1.0 \\ 1.0 \end{bmatrix}_{4\times1}$$

$$(kw)_{i2} = \begin{bmatrix} 3.755759 \\ 4.661800 \\ 3.676874 \\ 4.829287 \end{bmatrix}_{4\times1}$$

$$(kw)_{i3} = \begin{bmatrix} 2.536441 \\ 2.591813 \\ 2.547886 \\ 3.031886 \end{bmatrix}_{4\times1}$$ and hence step7 the

$$K = \begin{bmatrix} 5.606154 \\ 6.778709 \\ 5.531005 \\ 7.834362 \end{bmatrix}_{4\times1}$$ ranking the alternatives $\begin{matrix} T1 \\ T2 \\ T3 \\ T4 \end{matrix} \begin{bmatrix} 5.606154 \\ 6.778709 \\ 5.531005 \\ 7.834362 \end{bmatrix}_{4\times1}$

The k-ranking formulation above affords with

- T3 >T1 >T2 >T4; … (*)
- T1 >T3 >T2 >T4; … (**)

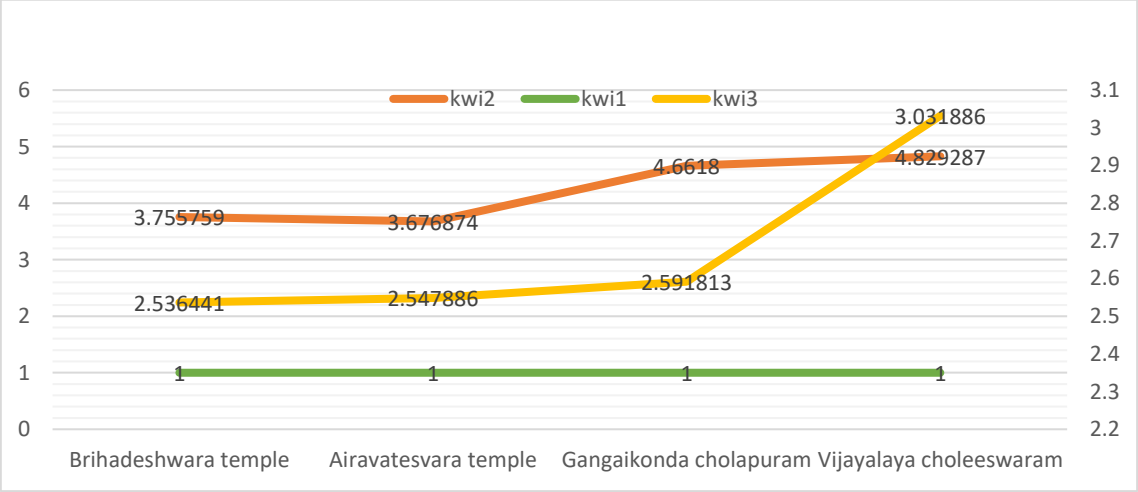

Figure 5.1: [COCOSO & CBA ranking]

5.2 Discussion

Commercial architecture, particularly for its interior designs structure includes pillars and an exterior wall. It makes no economic sense to focus development efforts exclusively on commercial and interior architecture projects; rather, excellent architecture benefits people and make great constructions.

The sequence order difference between * and **. $(kw)_{i_2}$ and K for (*) and $(kw)_{i_3}$ for (**) respectively [figure 4.1]. Consequently, T1-Brihadeshwara temple and T3- Airavastesvara temple, since there are two parts to the ranking order, we used the CBA method (choosing by advantage method/cost-benefit analysis) to revalue the top

two contenders (Airavastesvara Temple of Brihadeshwara Temple) as the finest temple for people to visit, commercial and residential uses.

5.2.1 Application of CBA:

Jim developed the CBA (Choosing by Advantage) method in 1999 to create an advantage for each aspect for determining the solution. In situations when evidence from a single expert may or may not lead to the same solution, the CBA method—which is frequently used by stakeholders to increase the quality of the characteristic is beneficial because it examines the advantages of all the attributes. Concise explanation of CBA: Cost Analysis, Advantage-Based Selection, and Collaboratively Making Reasonable Decisions for Transparent Decision Making. From the above order of comparison, the calculation of the T1 and T3 temples (i.e., Brihadeshwara Temple and Airavastesvara Temple) is compared with the number of visitors who may be able to go to the temple by train, bus, or airplane both inside and outside of Tamil Nadu.

Comparison work for temple

- **Brihadeshwara temple:**

Thanjavur is recognized as an agricultural region and is situated in a delta region, which keeps the temperature moderate and the breeze light. This temple is located in a neighborhood where buses are frequently available. It is 382 kilometres from Chennai and 61 kilometres from Tiruchirappalli's international airport, which is connected to Kumbakonam via the NH road and the rail line.

- **Airavastesvara temple:**

The temple is situated 3 kilometres (3 miles) west of the temple town of Kumbakonam district in Darasuram, close to the Kollidam River and the Kaveri (Cauvery) delta. Tiruchirappali is separated by 91 kilometres. Local buses and taxis are available because it is a tiny town.

3.6.2 Comparison Study Discussion:

When compared to Airavastesvara Temple, Brihadeeswara Temple requires less time and money to go to, which results in a higher volume of visitors (both tourists and laypeople). Because of its increased popularity among nations and states, Brihadeeswara Temple is positioned foremost.

6. Results

In conclusion, the accessibility and affordability of reaching the Brihadeeswara Temple in comparison to the Airavatesvara Temple make it a more frequently visited destination for both tourists and laypeople. The lower time and financial investment required contribute to its heightened popularity among people from various nations and states. As a result, Brihadeeswara Temple holds a prominent position as a cultural and religious landmark, drawing in a larger volume of visitors and enriching the cultural fabric of the region. The affordability depends on landscape Architecture (landmarks, outdoor space, plant covering and reaching possibilities). Therefore, when a person or architect wants to develop a project, they should consider it before establishing the construction site plan.

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