

Design Guidelines to achieve Optimum Shading Strategies for different window orientations across various geographical locations in India

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Abstract

Shading devices are used to maintain thermal and visual comfort in a space. They aid in reducing the cooling loads and visual glare by reducing the amount of direct solar radiation entering the space. However, it also leads to an increase in the heating load for a heating-dominated climate or winter season. Therefore, a universal solution or a one size fits all approach for the type and characteristics of shading devices cannot work for every space or building and will depend on the location and orientation. This study suggests optimum shading strategies like horizontal louvers, vertical louvers, inclined louvers and overhangs, their characteristics like the number of louvers and angle of inclination that are location and orientation specific for India. A shading device is an imperative design component for an architect and hence, the optimum solutions from this study can be used by an architect or designer for window design.

Keywords: shading device, angle of inclination, direct solar radiation, optimization

I. INTRODUCTION

A. UNSDGs and the built environment

The United Nations' 2030 agenda for Sustainable Development defined 17 sustainable development goals (UNSDGs) for a holistic approach towards sustainable development [1]. UNSDG 3: Good Health and Well Being, highlights the importance of healthy living and a healthy built environment. Indoor climates are of major importance because humans spend a majority of their time indoors, which in turn has major effects on health [2,3]. Goal 7: Affordable and Clean Energy and Goal 9: Industry, Innovation and Infrastructure, highlight how the built environment is a major contributor to energy consumption hence, energy efficiency is the need of the hour [4,5]. By the year 2022, it is expected that the Indian

building and construction market will become the third-largest in the world [6].

B. Indian climate and shading devices

ECBC 2017 has classified the Indian climate into five climate zones [7]. Except for the regions classified under the cold climate typology, the other regions experience harsh summer. Hence, India can be characterized as a country that prominently has a warm climate [8]. The impact of heat from solar radiation that enters the buildings are mitigated using external shading devices. External shading devices also help control the amount of daylight and glare entering the building thereby aiding in maintaining visual comfort which in turn affects the productivity of the users [9, 10]. The use of daylight has been associated with a large set of benefits for architectural spaces, energy-saving and the occupants' visual comfort [11]. But in the field of view, certain limits have been defined for Luminance ratios. If the value is too high, the eyes would have difficulty adapting. Glare from daylight can cause visual discomfort and hamper the execution of a task (disability glare) or decreases the performance of the viewer (discomfort glare). Disability glare is caused due to bright light while discomfort glare is caused due to visual contrast [12]. Hence, it is imperative to control the glare and design an appropriate external shading device that can be a viable solution.

C. Indian building codes- shading device design

The National Building Code (NBC-2016) suggest ways to design shading device after fixing one parameter like the overhang depth and then the calculation of spacing and louvers [13]. BIS SP-41 has divided India into geographical zones and has given recommendations for the type of overhang [8]. However, location specific overhang design has not been specified.

II. LITERATURE STUDY

Daylight availability and daylight glare index has been used to calculate the type of fixed shading device required for a space [14]. Genetic optimization for an office building space with a south-facing window has been studied for the design of an optimal fixed shading device to minimize the overall energy consumption. Genetic optimization proved to be a viable tool for the designer to get the solutions [15]. UDI (useful daylight index) and DA (daylight autonomy) have been used as parameters to decide the effectiveness

of a shading device. Results obtained showed that the use of a shading device decreased the DA but increased the UDI for an indoor space [16]. For composite, hot and humid and hot and dry climatic zones appropriate shading devices can decrease the cooling loads and the polluting effects of the building [17].

III. GAP FINDING

Studies providing the type of shading device and its characteristics like, the number of louvers and angle of inclination according to the architect’s need for various locations and orientations have not been conducted in the Indian context. Overhang design that can abide by the overhang depth requirements while optimizing the construction cost for a specific location and orientation has not been explicitly defined for India. The proposed study covers the above-mentioned aspects of shading device design.

IV. METHODOLOGY

A. Location and orientation selection

Twenty-nine states and six union territories (UTs) have been considered with five cities taken up from each state according to the demarcation as Central, North, East, West and South zones (C-N-E-W-S) [18]. Eight cardinal and sub cardinal directions have been considered for the orientation of the window for which the shading design needs to be provided. North (N) is taken as 0 degrees similarly, in clockwise direction North-East (NE) is 45°, East (E) is 90°, South-East (SE) is 135°, South (S) is 180°, South-West (SW) is 225°, West (W) is 270° and North-West (NW) is 315° [19]. A window of 1200mm height (according to the standard window sizes in India) [13,20] and 900mm width (according to Indian ergonomics) [21] has been considered for shading device calculations in the algorithm but they can be changed according to the architect’s need and specifications.

B. Solar position angles and shadow angles

Azimuth and altitude angles are the solar position angles that define the sun’s position in the sky. They depend on the declination, latitude and hour angle [19]. The equations are mentioned below:

$$\text{Altitude} = \sin^{-1} (\sin \text{Declination} \times \sin \text{Latitude} + \cos \text{Declination} \times \cos \text{Latitude} \times \cos \text{Hour angle}) \dots \dots \dots (1)$$

$$\text{Azimuth} = \cos^{-1} [(\cos \text{Latitude} \times \sin \text{Declination} - \cos \text{Declination} \times \sin \text{Latitude} \times \cos \text{Hour angle}) / \cos \text{Altitude}] \dots \dots \dots (2)$$

Horizontal shadow angle (HSA) equation (3) and Vertical shadow angle (VSA) equation (4) express the sun’s position for a building façade in a specific orientation [8,19]. They are used for shading device calculation. Equations are as follows:

$$\text{HSA} = \text{Azimuth} - \text{Orientation} \dots \dots \dots (3)$$

$$\text{VSA} = \tan^{-1} \frac{\tan \text{Altitude}}{\cos \text{HSA}} \dots \dots \dots (4)$$

The shadow angles have been used to calculate the required overhang depth to prevent the direct radiation component of the sun to enter through the window [9].

$$\text{Horizontal overhang depth} = \frac{\text{Window height}}{\tan \text{VSA}} \dots \dots \dots (5)$$

$$\text{Vertical fin depth} = \frac{\text{Window width}}{\tan \text{HSA}} \dots \dots \dots (6)$$

The maximum depth of the required horizontal or vertical shading device has been calculated from 365 or 366 days of the year between the timings of 9 a.m. and 4 p.m. The depth of the required shading device has a constraint of 1200mm beyond which the algorithm does not give a solution. To obtain the maximum number of louvers possible, for horizontal louvers the height of the window is divided

by a value taken as the minimum spacing between the louvers i.e., 250mm; and the window width is divided by 250mm to get the number of vertical louvers. For the angle of inclination calculations in the case of inclined louvers the maximum angle of inclination possible is calculated using the equation below:

$$\text{Max. angle of inclination} = \tan^{-1} \frac{\text{Depth of louver}}{\text{Spacing between the louvers}} \dots \dots \dots (7)$$

C. Shading device types and cost optimization

Eight overhang typologies have been considered in the study that is explained in the following table:

Table 1. Shading devices

| S. No. | Overhang type |
|--------|---|
| 1 | Horizontal shading device – one overhang |
| 2 | Vertical shading device – one fin |
| 3 | Horizontal inclined shading device – one overhang |
| 4 | Vertical inclined shading device – one fin |
| 5 | Horizontal louvers |
| 6 | Vertical louvers |
| 7 | Horizontal inclined louvers |
| 8 | Vertical inclined louvers |

The type of shading device, the angle of inclination and the number of louvers has been taken as variables in the algorithm to get the optimum solution. The type of shading device varies from 1 to 8. The angle of inclination varies from 0 (which means normal to the wall) to the maximum value calculated from the above-mentioned formula in equation (7). To calculate the volume of the shading device, Reinforced Cement Concrete (RCC) has been considered as the building material with overhang/louver thickness of 50mm. A market study has been conducted and the cost of RCC per cubic meter is derived as 6000 INR. Excel solver has been used for optimization, keeping cost minimization as the objective function. Therefore, the results generated are first and second-best strategies for a certain location and orientation with their specifications i.e., angle of inclination and number of louvers that are feasible with minimal cost. Shading device depths have been rounded up to the nearest hundred millimeters (mm). The angle of inclination has been rounded into an integer and number louvers have been rounded up to the nearest whole number.

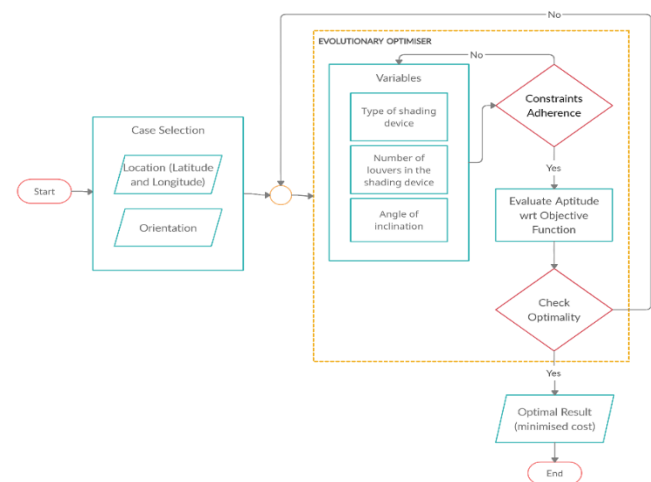


Figure 1. Process flowchart for the algorithm

V. RESULTS AND DISCUSSION

Table 2 and figures (graphs) 2,3,4 and 5 have been used for denoting the results. Graphs have been presented for 6 states and 6 UTs. The selection criteria of states for which graphs have been presented is based on a logic to cover all five climate zones defined by ECBC, where mostly one state belongs to a specific climate zone.

The graphs denote the type of overhang/louvers (ref. Table 1) and the number of louvers on the primary y-axis. The secondary y-axis

shows the overhang depth (in cm) and angle of inclination. The x-axis denotes the state, city and orientations in alphabetical order.

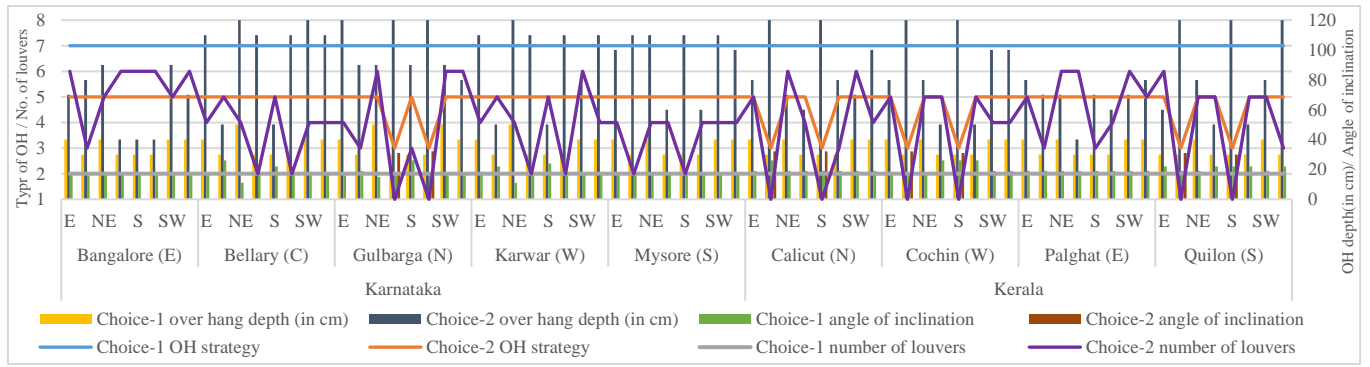


Figure 2. Graph showing best and next best shading device strategies for the states Karnataka and Kerala

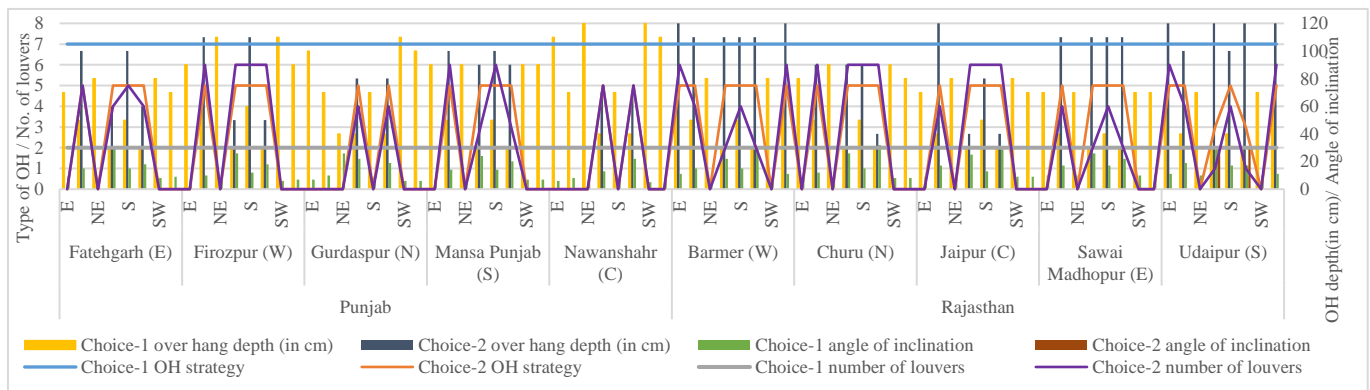


Figure 3. Graph showing best and next best shading device strategies for the states Punjab and Rajasthan

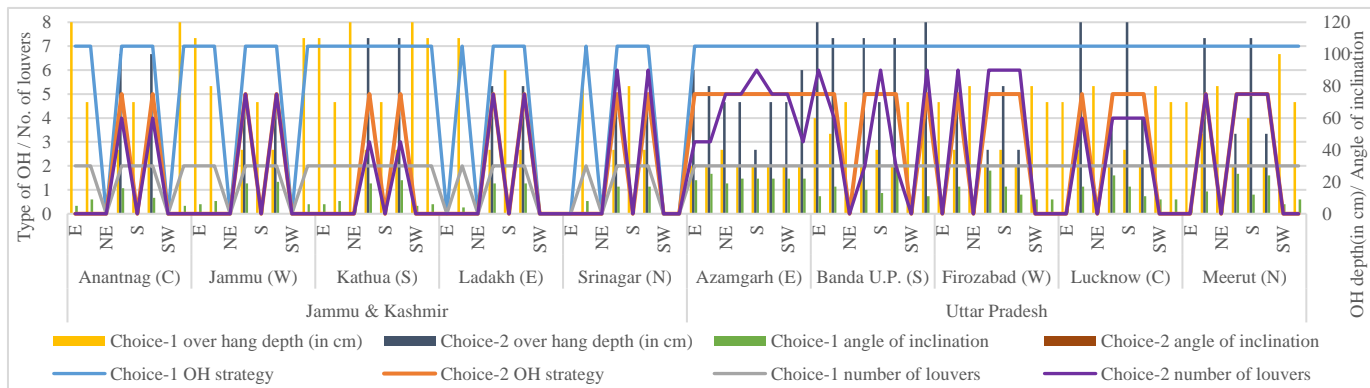


Figure 4. Graph showing best and next best shading device strategies for the states Jammu & Kashmir and Uttar Pradesh

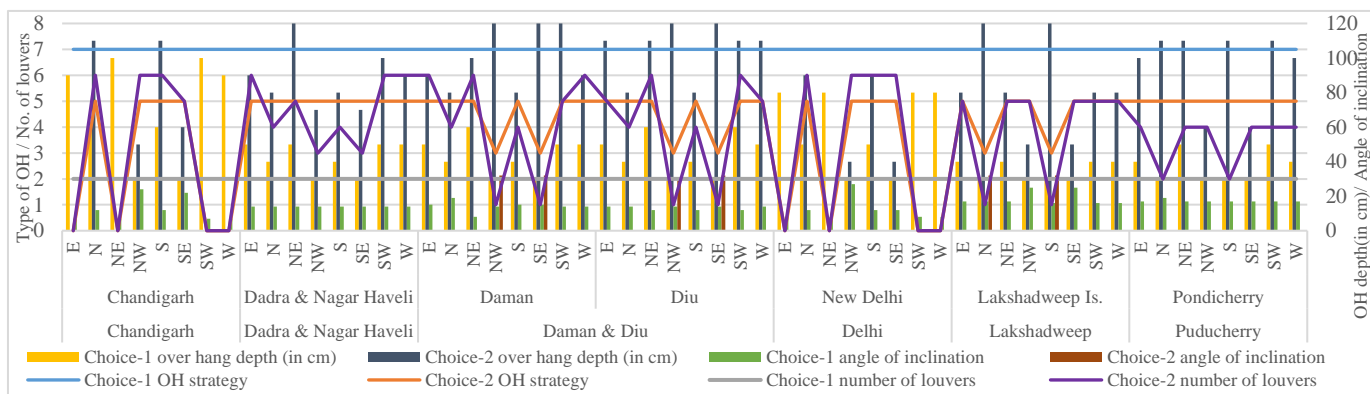


Figure 5. Graph showing best and next best shading device strategies for the six Union Territories

In Figure 2, the orientations at which the windows have been considered are arranged as E, N, NE, NW, S, SE, SW and W in the graphs. For the states of Karnataka (which has Bangalore which falls under the Temperate climate zone) and Kerala (Warm and Humid Climate zone), the best shading device strategy is 7 i.e., Horizontal inclined louvers and the number of louvers that would serve the purpose at minimal cost is 2. For Karnataka, the depth of horizontal inclined louvers varies from 300mm to 500mm and for Kerala it varies from 300mm to 400mm. The angle of inclination varies from 11 degrees to 26 degrees for Karnataka, while for Kerala it varies from 17 to 26 degrees as per the orientation. The next-best strategy for Karnataka is 5 i.e., horizontal louvers without any inclination for all five cities and eight orientations under consideration except for Gulbarga in the NW and SE orientations where the suitable strategy suggested is 3 i.e., one inclined horizontal overhang with a depth of 1200mm and angle inclination as 31 and 32 degrees respectively. For all the cases where horizontal louvers without any inclination (strategy 5) is the solution, the number of louvers varies from 2 to 6 and the louver depth varies from 400mm to 1200mm. The next-best strategy for Kerala is also 5 except for the N and S orientations in Calicut, Cochin and Quilon where one inclined horizontal overhang (strategy 3) is the most feasible solution with overhang depth as 1200mm and angle of inclination is 32 degrees. For the other cases where strategy 5 is the solution, the number of louvers vary from 3 to 6 and louver depths varies from 400mm to 1200mm.

In Figure 3, for the states of Punjab (Composite climatic zone) and Rajasthan (mostly Hot and Dry climatic zone), the best shading device strategy is 7 i.e., Horizontal inclined louvers and the number of louvers which would serve the purpose at minimal cost is 2. For Punjab, the depth of horizontal inclined louvers varies from 300mm to 1200mm while for Rajasthan it varies from 300mm to 900mm. The angle of inclination varies from 5 to 31 degrees for Punjab and 7 to 32 degrees for Rajasthan. The next-best strategy for Punjab is 5 i.e., horizontal louvers without any inclination for all cities of Punjab for the NW and SE window orientations with the louver depth varying from 500mm to 1200mm and the number of louvers varying from 4 to 6. For Rajasthan also the next best strategy 5 i.e., horizontal louvers without any inclination for all cities with window orientations as N, NW, S and SE. The louver depth varies from 400mm to 1200mm and the number of louvers varies from 2 to 6.

In Figure 4, for the cities of Jammu and Kashmir (Cold climatic zone) there is no shading strategy following the defined constraints of the algorithm that can completely shade the windows in all orientations except for the city of Kathua where shading strategy 7 i.e., Horizontal inclined louvers (having 2 louvers) is the optimum solution for all 8 orientations with the angle of inclination varying from 5 to 21 degrees and louver depth ranging from 700mm to 1200mm. The next-best strategy for all cities of Jammu and Kashmir under consideration is horizontal louvers without any inclination (strategy 5) for NW and SE window orientations. For Uttar Pradesh (Composite climatic zone) Horizontal inclined louvers (strategy 7) is the optimum solution for all cities and orientations with the number of louvers required being 2. The louver depths vary from 300mm to 1000mm and the angle of inclination varies from 6 to 31 degrees. The next-best shading strategy for both the states for orientations where solutions are possible is strategy 5 i.e., horizontal louvers without any inclination. For Jammu and Kashmir horizontal louvers without any inclination (strategy 5) gives the second-best solution for all 5 cities with window orientations as NW and SE with louver depths varying from 700mm to 1100mm. In Uttar Pradesh, the city of Azamgarh shows horizontal louvers without any inclination (strategy 5) as the second-best solution for all 8 orientations where the louver depth varies from 400mm to 900mm.

In figure 5, which represents the details of the optimum and next-best shading device strategies for 6 union territories (UTs). For all UTs the optimum shading strategy is 7 i.e., Horizontal inclined louvers (having 2 louvers) for all 8 orientations. For Chandigarh, the louver depths vary from 300mm to 1000mm and angle of inclination

ranges from 7 to 24 degrees. For Dadra & Nagar Haveli, the louver depth varies from 300mm to 500mm and the angle of inclination of the louver is 14 degrees for windows in all orientations. For Daman and Diu, the louver depth varies from 400 mm to 600 mm and the angle of inclination ranges between 8 to 19 degrees. For New Delhi, the louver depth varies from 300 mm to 800 mm and the angle of inclination ranges from 8 to 27 degrees. For Lakshadweep Islands, the louver depth varies from 300 mm to 400 mm and the angle of inclination ranges from 16 to 25 degrees. For Puducherry, the louver depth varies from 300 mm to 500 mm and the angle of inclination ranges from 17 to 19 degrees. For Chandigarh, the next best shading strategy is 5 i.e., horizontal louvers without any inclination for N, NW, S and SE window orientations where the louver depth varies from 500 mm to 1100 mm and the number of louvers to used are 5 or 6. For Dadra & Nagar Haveli, horizontal louvers without any inclination (strategy 5) is the next-best shading strategy for all 8 orientations where the number of louvers varies between 3 to 6, the louver depth varies from 700 mm to 1200 mm. At Daman and Diu, for NW and SE window orientations the next-best strategy is 3 i.e., one inclined horizontal overhang with a depth of 1200mm and angle inclination as 32 degrees. For all other orientations in Daman and Diu horizontal louvers without any inclination (strategy 5) is the next-best shading strategy where the number of louvers ranges from 4 to 6 and the louver depth varies from 800 mm to 1200 mm. For New Delhi, the next best strategy for N, NW, S and SE window orientations is horizontal louvers without any inclination (strategy 5) where the number of louvers is 6 and the louver depth varies from 400 mm to 900 mm. At Lakshadweep Islands, for N and S window orientations the next-best shading strategy is 3 i.e., one inclined horizontal overhang with a depth of 1200mm and angle of inclination as 32 degrees; for all other window orientations the next-best shading strategy is horizontal louvers without any inclination (strategy 5) where the number of louvers is 5 and the louver depth varies from 500 mm to 800 mm. For Puducherry, the next-best shading strategy for all 8 window orientations is horizontal louvers without any inclination (strategy 5) where the number of louvers ranges from 2 to 4 and the louver depth is either 1000 mm or 1100 mm.

The following table (Table 2) shows results for optimum and next-best shading strategy for 8 different orientations and cities of the remaining 23 states. The results also provide information about the depth of the shading device, the angle of inclination and the number of louvers. Results for different states and cities (according to zones C-N-E-W-S) are represented in the order: **Shading device strategy number (refer Table 1) / shading device depth / number of louvers / angle of inclination of the shading device.**

The results mentioned in the table are the optimum solution for a window of height 1200 mm and width 900 mm which is a standard dimension of a window in the Indian scenario [13,20]. However, these results can be used to extract data for windows of different dimensions. For e.g.: - the first city for which the results have been presented in the table is Guntur, Andhra Pradesh. According to the results, the optimum shading strategy for a window (1200mm*900mm) is 7 i.e., horizontal inclined louvers where the number of louvers required is 2. For a North oriented window, the depth of the required louvers is 300 mm at an angle of inclination as 24 degrees. From the tabular data, it can be inferred that the 2 horizontal inclined louvers would be installed at a gap of 600 mm for a window height of 1200 mm. Hence, for a window height of 1800 mm the number of louvers required would be 3 placed at 600 mm distance from each other. In the case of a window height of 1500 mm, 2 louvers of 300 mm depth would not serve the purpose but 3 louvers placed at a 500 mm distance from each other would be a functional solution. A similar method can be followed for vertical shading devices. Hence, a functional overhang design can be derived from the results for any given window size.

Table 2. Results of 23 states and their respective cities for the 8 cardinal and sub cardinal orientations

| State | City | Results | N | NE | E | SE | S | SW | W | NW |
|-------------------|--------------------|-------------|-------------|------------|------------|-------------|-------------|------------|------------|-------------|
| Andhra Pradesh | Guntur (C) | Choice 1 OH | 7/300/2/24 | 7/500/2/15 | 7/400/2/16 | 7/300/2/16 | 7/300/2/20 | 7/500/2/15 | 7/400/2/16 | 7/300/2/24 |
| | | Choice 2 OH | 5/900/3/0 | 5/900/6/0 | 5/800/6/0 | 5/1100/2/0 | 5/900/3/0 | 5/900/6/0 | 5/800/6/0 | 5/1100/2/0 |
| | Vishakhapatnam (N) | Choice 1 OH | 7/200/2/30 | 7/300/2/26 | 7/300/2/26 | 7/300/2/26 | 7/200/2/28 | 7/300/2/26 | 7/300/2/26 | 7/300/2/26 |
| | | Choice 2 OH | 3/1100/1/31 | 5/900/3/0 | 5/1100/2/0 | 5/900/3/0 | 3/1100/1/32 | 5/900/3/0 | 5/1100/2/0 | 5/900/3/0 |
| | Nellore (E) | Choice 1 OH | 7/300/2/26 | 7/400/2/17 | 7/500/2/17 | 7/300/2/17 | 7/300/2/17 | 7/400/2/17 | 7/500/2/17 | 7/300/2/17 |
| | | Choice 2 OH | 5/800/3/0 | 5/1200/4/0 | 5/1100/4/0 | 5/600/4/0 | 5/600/4/0 | 5/1200/4/0 | 5/1100/4/0 | 5/600/4/0 |
| | Kurnool (W) | Choice 1 OH | 7/300/2/23 | 7/500/2/14 | 7/400/2/17 | 7/300/2/17 | 7/300/2/21 | 7/500/2/12 | 7/400/2/17 | 7/300/2/17 |
| | | Choice 2 OH | 5/500/5/0 | 5/1000/5/0 | 5/900/5/0 | 5/1100/2/0 | 5/500/5/0 | 5/1000/5/0 | 5/900/5/0 | 5/1100/2/0 |
| | Chittoor (S) | Choice 1 OH | 7/300/2/17 | 7/400/2/17 | 7/400/2/17 | 7/300/2/17 | 7/300/2/17 | 7/400/2/17 | 7/400/2/17 | 7/300/2/17 |
| | | Choice 2 OH | 5/1200/2/0 | 5/900/5/0 | 5/700/6/0 | 5/400/6/0 | 5/400/6/0 | 5/900/5/0 | 5/700/6/0 | 5/400/6/0 |
| Arunachal Pradesh | Doporijo (C) | Choice 1 OH | 7/300/2/23 | 7/400/2/15 | 7/300/2/19 | 7/400/2/19 | 7/300/2/26 | 7/400/2/19 | 7/300/2/19 | 7/400/2/19 |
| | | Choice 2 OH | 5/500/5/0 | 5/800/5/0 | 5/600/5/0 | 5/800/5/0 | 5/500/5/0 | 5/800/5/0 | 5/600/5/0 | 5/800/5/0 |
| | Yingkiong (N) | Choice 1 OH | 7/300/2/21 | 7/400/2/19 | 7/300/2/19 | 7/400/2/19 | 7/300/2/25 | 7/400/2/19 | 7/300/2/19 | 7/400/2/19 |
| | | Choice 2 OH | 5/500/5/0 | 5/800/5/0 | 5/600/5/0 | 5/800/5/0 | 5/500/5/0 | 5/800/5/0 | 5/600/5/0 | 5/800/5/0 |
| | Chonglong (E) | Choice 1 OH | 7/500/2/14 | 7/300/2/22 | 7/800/2/8 | 7/1000/2/7 | 7/500/2/14 | 7/300/2/22 | 7/800/2/8 | 7/1000/2/7 |
| | | Choice 2 OH | 5/1200/5/0 | 5/900/3/0 | 0/0/0/0 | 0/0/0/0 | 5/1000/6/0 | 5/900/3/0 | 0/0/0/0 | 0/0/0/0 |
| | Upper Subansi (W) | Choice 1 OH | 7/300/2/19 | 7/400/2/19 | 7/300/2/19 | 7/400/2/19 | 7/300/2/19 | 7/400/2/19 | 7/300/2/19 | 7/400/2/19 |
| | | Choice 2 OH | 5/800/3/0 | 5/800/5/0 | 5/600/5/0 | 5/800/5/0 | 5/800/3/0 | 5/800/5/0 | 5/600/5/0 | 5/800/5/0 |
| | Itanagar (S) | Choice 1 OH | 7/300/2/32 | 7/300/2/22 | 7/300/2/22 | 7/300/2/22 | 7/300/2/22 | 7/300/2/22 | 7/300/2/22 | 7/300/2/22 |
| | | Choice 2 OH | 5/800/3/0 | 5/1200/3/0 | 5/700/4/0 | 5/900/4/0 | 5/600/4/0 | 5/900/4/0 | 5/700/4/0 | 5/900/4/0 |
| Assam | Tezpur (C) | Choice 1 OH | 7/300/2/17 | 7/300/2/26 | 7/200/2/28 | 7/300/2/26 | 7/300/2/26 | 7/300/2/26 | 7/300/2/26 | 7/400/2/17 |
| | | Choice 2 OH | 5/400/6/0 | 5/600/6/0 | 5/700/4/0 | 5/900/4/0 | 5/600/4/0 | 5/900/4/0 | 5/700/4/0 | 5/900/4/0 |
| | Dibrugarh (N) | Choice 1 OH | 7/300/2/22 | 7/400/2/19 | 7/300/2/19 | 7/400/2/19 | 7/300/2/19 | 7/400/2/19 | 7/300/2/19 | 7/400/2/19 |
| | | Choice 2 OH | 5/600/4/0 | 5/1000/4/0 | 5/600/5/0 | 5/800/5/0 | 5/600/4/0 | 5/1000/4/0 | 5/600/5/0 | 5/800/5/0 |
| | Jorhat (E) | Choice 1 OH | 7/300/2/19 | 7/300/2/22 | 7/300/2/22 | 7/300/2/22 | 7/300/2/22 | 7/300/2/22 | 7/300/2/22 | 7/300/2/22 |
| | | Choice 2 OH | 5/800/3/0 | 5/1200/3/0 | 5/700/4/0 | 5/900/4/0 | 5/600/4/0 | 5/900/4/0 | 5/700/4/0 | 5/900/4/0 |
| | Barpeta (W) | Choice 1 OH | 7/300/2/22 | 7/300/2/22 | 7/300/2/22 | 7/300/2/22 | 7/300/2/22 | 7/300/2/22 | 7/300/2/22 | 7/300/2/22 |
| | | Choice 2 OH | 5/600/4/0 | 5/700/5/0 | 5/900/3/0 | 5/700/5/0 | 5/800/3/0 | 5/700/5/0 | 5/900/3/0 | 5/700/5/0 |
| | Silchar (S) | Choice 1 OH | 7/300/2/22 | 7/400/2/22 | 7/300/2/22 | 7/400/2/22 | 7/300/2/22 | 7/400/2/22 | 7/300/2/22 | 7/400/2/22 |
| | | Choice 2 OH | 5/1100/2/0 | 5/700/5/0 | 5/900/3/0 | 5/700/5/0 | 5/1100/2/0 | 5/700/5/0 | 5/900/3/0 | 5/700/5/0 |
| Bihar | Patna (C) | Choice 1 OH | 7/300/2/15 | 7/300/2/24 | 7/600/2/12 | 7/1000/2/6 | 7/700/2/9 | 7/300/2/25 | 7/300/2/25 | 7/400/2/19 |
| | | Choice 2 OH | 5/1100/2/0 | 5/700/5/0 | 5/900/3/0 | 5/700/5/0 | 5/1100/2/0 | 5/700/5/0 | 5/900/3/0 | 5/700/5/0 |
| | Darbhanga (N) | Choice 1 OH | 7/300/2/22 | 7/300/2/22 | 7/300/2/22 | 7/300/2/22 | 7/300/2/22 | 7/300/2/22 | 7/300/2/22 | 7/300/2/22 |
| | | Choice 2 OH | 5/600/4/0 | 5/700/5/0 | 5/900/3/0 | 5/700/5/0 | 5/600/4/0 | 5/700/5/0 | 5/900/3/0 | 5/1200/3/0 |
| | Siwan (E) | Choice 1 OH | 7/300/2/22 | 7/300/2/22 | 7/300/2/22 | 7/400/2/17 | 7/300/2/29 | 7/400/2/19 | 7/300/2/22 | 7/300/2/22 |
| | | Choice 2 OH | 5/800/3/0 | 5/700/5/0 | 5/900/3/0 | 5/700/5/0 | 5/600/4/0 | 5/700/5/0 | 5/900/3/0 | 5/700/5/0 |
| | Katihar (W) | Choice 1 OH | 7/300/2/22 | 7/400/2/14 | 7/300/2/24 | 7/400/2/22 | 7/300/2/22 | 7/400/2/22 | 7/300/2/22 | 7/400/2/22 |
| | | Choice 2 OH | 5/1100/2/0 | 5/700/5/0 | 5/900/3/0 | 5/700/5/0 | 5/1100/2/0 | 5/700/5/0 | 5/900/3/0 | 5/1200/3/0 |
| | Nawada (S) | Choice 1 OH | 7/300/2/15 | 7/400/2/12 | 7/300/2/23 | 7/400/2/21 | 7/300/2/17 | 7/400/2/17 | 7/300/2/25 | 7/400/2/22 |
| | | Choice 2 OH | 5/1100/2/0 | 5/700/5/0 | 5/900/3/0 | 5/700/5/0 | 5/1100/2/0 | 5/700/5/0 | 5/900/3/0 | 5/700/5/0 |
| Chhattisgarh | Raipur (C) | Choice 1 OH | 7/400/2/20 | 7/600/2/12 | 7/500/2/13 | 7/300/2/13 | 7/400/2/13 | 7/600/2/12 | 7/500/2/14 | 7/300/2/20 |
| | | Choice 2 OH | 5/1100/3/0 | 5/1100/6/0 | 5/1000/6/0 | 3/1200/1/29 | 5/1100/3/0 | 5/1100/6/0 | 5/1000/6/0 | 3/1200/1/32 |
| | Baikunthpur (N) | Choice 1 OH | 7/300/2/14 | 7/400/2/14 | 7/300/2/23 | 7/400/2/19 | 7/300/2/19 | 7/400/2/19 | 7/300/2/23 | 7/400/2/19 |
| | | Choice 2 OH | 3/1200/1/32 | 5/800/4/0 | 5/500/5/0 | 5/800/4/0 | 3/1200/1/29 | 5/800/4/0 | 5/500/5/0 | 5/800/4/0 |
| | Raigarh (E) | Choice 1 OH | 7/300/2/17 | 7/300/2/20 | 7/300/2/20 | 7/300/2/20 | 7/300/2/17 | 7/300/2/17 | 7/300/2/17 | 7/300/2/17 |
| | | Choice 2 OH | 3/1200/1/29 | 5/600/5/0 | 5/800/3/0 | 5/1000/3/0 | 3/1200/1/29 | 5/600/5/0 | 5/800/3/0 | 5/1000/3/0 |
| | Kawardha (W) | Choice 1 OH | 7/400/2/18 | 7/600/2/10 | 7/500/2/14 | 7/300/2/14 | 7/400/2/14 | 7/600/2/12 | 7/500/2/14 | 7/300/2/14 |
| | | Choice 2 OH | 5/700/5/0 | 5/1100/6/0 | 5/1000/6/0 | 3/1200/1/31 | 5/700/5/0 | 5/1100/6/0 | 5/1000/6/0 | 3/1200/1/30 |
| | Bijapur (S) | Choice 1 OH | 7/300/2/18 | 7/500/2/14 | 7/500/2/14 | 7/300/2/14 | 7/300/2/20 | 7/500/2/14 | 7/500/2/14 | 7/300/2/14 |
| | | Choice 2 OH | 5/1000/3/0 | 5/1200/5/0 | 5/1000/5/0 | 3/1200/1/32 | 5/600/5/0 | 5/1200/5/0 | 5/1000/5/0 | 3/1200/1/32 |
| Goa | Panjim (C) | Choice 1 OH | 7/300/2/22 | 7/500/2/15 | 7/400/2/17 | 7/300/2/17 | 7/300/2/23 | 7/500/2/13 | 7/400/2/17 | 7/300/2/17 |
| | | Choice 2 OH | 5/500/5/0 | 5/1000/5/0 | 5/1100/4/0 | 5/1100/2/0 | 5/500/5/0 | 5/1000/5/0 | 5/1100/4/0 | 5/1100/2/0 |
| Marmagao (S) | Choice 1 OH | 7/300/2/22 | 7/500/2/15 | 7/400/2/17 | 7/300/2/17 | 7/300/2/23 | 7/500/2/13 | 7/400/2/17 | 7/300/2/17 | |
| | Choice 2 OH | 5/500/5/0 | 5/1000/5/0 | 5/1100/4/0 | 5/1100/2/0 | 5/500/5/0 | 5/1000/5/0 | 5/1100/4/0 | 5/1100/2/0 | |
| Gujarat | Ahemadabad (C) | Choice 1 OH | 7/400/2/19 | 7/600/2/11 | 7/600/2/11 | 7/300/2/16 | 7/400/2/14 | 7/600/2/11 | 7/600/2/11 | 7/400/2/11 |
| | | Choice 2 OH | 5/1000/4/0 | 5/1200/6/0 | 5/1100/6/0 | 3/1200/1/30 | 5/1200/3/0 | 5/1200/6/0 | 5/1100/6/0 | 3/1200/1/32 |
| | Palanpur (N) | Choice 1 OH | 7/400/2/16 | 7/700/2/10 | 7/600/2/10 | 7/300/2/28 | 7/400/2/16 | 7/700/2/10 | 7/600/2/10 | 7/300/2/21 |
| | | Choice 2 OH | 5/1000/4/0 | 5/1200/6/0 | 5/1100/6/0 | 3/1200/1/31 | 5/600/6/0 | 5/1200/6/0 | 5/1100/6/0 | 3/1200/1/31 |
| | Vadodara (E) | Choice 1 OH | 7/300/2/22 | 7/600/2/11 | 7/500/2/14 | 7/300/2/14 | 7/300/2/22 | 7/600/2/11 | 7/500/2/14 | 7/300/2/14 |
| | | Choice 2 OH | 5/700/5/0 | 5/1200/6/0 | 5/1000/6/0 | 3/1200/1/32 | 5/700/5/0 | 5/1200/6/0 | 5/1000/6/0 | 3/1200/1/32 |
| | Jamnagar (W) | Choice 1 OH | 7/300/2/22 | 7/600/2/11 | 7/500/2/14 | 7/300/2/14 | 7/300/2/22 | 7/600/2/11 | 7/500/2/14 | 7/300/2/14 |
| | | Choice 2 OH | 5/1200/3/0 | 5/1200/6/0 | 5/1000/6/0 | 3/1200/1/32 | 5/700/5/0 | 5/1200/6/0 | 5/1000/6/0 | 3/1200/1/30 |
| | Bhavnagar (S) | Choice 1 OH | 7/400/2/14 | 7/600/2/12 | 7/500/2/13 | 7/300/2/13 | 7/400/2/13 | 7/600/2/12 | 7/500/2/13 | 7/300/2/13 |
| | | Choice 2 OH | 5/700/5/0 | 5/1100/6/0 | 5/1000/6/0 | 3/1200/1/30 | 5/700/5/0 | 5/1100/6/0 | 5/1000/6/0 | 3/1200/1/31 |
| Haryana | Rohtak (C) | Choice 1 OH | 7/500/2/14 | 7/300/2/28 | 7/400/2/16 | 7/700/2/10 | 7/600/2/10 | 7/300/2/21 | 7/300/2/22 | 7/600/2/11 |
| | | Choice 2 OH | 5/1100/5/0 | 0/0/0/0 | 0/0/0/0 | 5/500/5/0 | 5/1100/5/0 | 0/0/0/0 | 0/0/0/0 | 5/500/5/0 |
| | Kaithal (N) | Choice 1 OH | 7/600/2/10 | 7/1000/2/7 | 7/800/2/8 | 7/300/2/20 | 7/500/2/14 | 7/1000/2/7 | 7/800/2/8 | 7/300/2/22 |
| | | Choice 2 OH | 5/1200/5/0 | 0/0/0/0 | 0/0/0/0 | 5/900/3/0 | 5/1200/5/0 | 0/0/0/0 | 0/0/0/0 | 5/900/3/0 |
| | Panipat (E) | Choice 1 OH | 7/500/2/14 | 7/900/2/7 | 7/800/2/8 | 7/300/2/21 | 7/500/2/14 | 7/900/2/7 | 7/800/2/8 | 7/300/2/23 |
| | | Choice 2 OH | 5/1200/5/0 | 0/0/0/0 | 0/0/0/0 | 5/900/3/0 | 5/1200/5/0 | 0/0/0/0 | 0/0/0/0 | 5/900/3/0 |
| | Sirsa (W) | Choice 1 OH | 7/400/2/17 | 7/800/2/9 | 7/700/2/9 | 7/300/2/20 | 7/400/2/17 | 7/800/2/9 | 7/700/2/9 | 7/300/2/31 |
| | | Choice 2 OH | 5/1200/4/0 | 0/0/0/0 | 0/0/0/0 | 5/600/4/0 | 5/1200/4/0 | 0/0/0/0 | 0/0/0/0 | 5/600/4/0 |
| | Rewari (S) | Choice 1 OH | 7/500/2/15 | 7/800/2/8 | 7/800/2/8 | 7/300/2/25 | 7/500/2/12 | 7/800/2/8 | 7/800/2/8 | 7/300/2/23 |
| | | Choice 2 OH | 5/900/6/0 | 0/0/0/0 | 0/0/0/0 | 5/400/6/0 | 5/900/6/0 | 0/0/0/0 | 0/0/0/0 | 5/400/6/0 |

| State | City | Results | N | NE | E | SE | S | SW | W | NW |
|------------------|----------------------|-------------|-------------|------------|------------|-------------|-------------|------------|------------|-------------|
| Himachal Pradesh | Mandi (C) | Choice 1 OH | 7/700/2/8 | 7/1100/2/6 | 7/900/2/7 | 7/400/2/20 | 7/700/2/9 | 7/1100/2/6 | 7/900/2/7 | 7/400/2/15 |
| | | Choice 2 OH | 5/1200/6/0 | 0/0/0/0 | 0/0/0/0 | 5/800/4/0 | 5/1200/6/0 | 0/0/0/0 | 0/0/0/0 | 5/800/4/0 |
| | Chamba (N) | Choice 1 OH | 7/700/2/10 | 7/1200/2/5 | 7/1200/2/5 | 7/400/2/22 | 7/700/2/8 | 7/1200/2/5 | 7/1100/2/6 | 7/400/2/16 |
| | | Choice 2 OH | 0/0/0/0 | 0/0/0/0 | 0/0/0/0 | 5/700/5/0 | 0/0/0/0 | 0/0/0/0 | 0/0/0/0 | 5/700/5/0 |
| | Kullu (E) | Choice 1 OH | 7/700/2/10 | 7/1100/2/6 | 7/1000/2/6 | 7/400/2/12 | 7/600/2/11 | 7/1100/2/6 | 7/1000/2/6 | 7/400/2/22 |
| | | Choice 2 OH | 0/0/0/0 | 0/0/0/0 | 0/0/0/0 | 5/800/4/0 | 5/1200/6/0 | 0/0/0/0 | 0/0/0/0 | 5/800/4/0 |
| | Dharamsala (W) | Choice 1 OH | 7/700/2/9 | 7/500/2/25 | 7/1100/2/6 | 7/400/2/15 | 7/700/2/10 | 7/500/2/25 | 7/1100/2/6 | 7/400/2/22 |
| | | Choice 2 OH | 0/0/0/0 | 0/0/0/0 | 0/0/0/0 | 5/1100/3/0 | 0/0/0/0 | 0/0/0/0 | 0/0/0/0 | 5/1100/3/0 |
| Shimla (S) | Choice 1 OH | 7/600/2/9 | 7/1100/2/6 | 7/900/2/7 | 7/300/2/21 | 7/600/2/12 | 7/1100/2/6 | 7/900/2/7 | 7/300/2/19 | |
| | Choice 2 OH | 5/1100/6/0 | 0/0/0/0 | 0/0/0/0 | 5/500/6/0 | 5/1100/6/0 | 0/0/0/0 | 0/0/0/0 | 5/500/6/0 | |
| Jharkhand | Ranchi (C) | Choice 1 OH | 7/300/2/19 | 7/400/2/22 | 7/700/2/8 | 7/1200/2/5 | 7/1100/2/6 | 7/400/2/16 | 7/700/2/10 | 7/1100/2/6 |
| | | Choice 2 OH | 3/1200/1/29 | 5/800/4/0 | 5/500/5/0 | 5/800/4/0 | 3/1200/1/30 | 5/800/4/0 | 5/500/5/0 | 5/800/4/0 |
| | Hazaribag (N) | Choice 1 OH | 7/300/2/16 | 7/400/2/16 | 7/300/2/21 | 7/400/2/21 | 7/300/2/21 | 7/400/2/21 | 7/300/2/21 | 7/400/2/21 |
| | | Choice 2 OH | 5/700/3/0 | 5/1100/3/0 | 5/900/3/0 | 5/1100/3/0 | 5/700/3/0 | 5/1100/3/0 | 5/900/3/0 | 5/1100/3/0 |
| | Dumka (E) | Choice 1 OH | 7/300/2/21 | 7/400/2/21 | 7/300/2/21 | 7/300/2/21 | 7/300/2/21 | 7/300/2/21 | 7/300/2/21 | 7/300/2/21 |
| | | Choice 2 OH | 3/1200/1/32 | 5/1100/3/0 | 5/900/3/0 | 5/1100/3/0 | 3/1200/1/32 | 5/1100/3/0 | 5/900/3/0 | 5/1100/3/0 |
| | Latehar (W) | Choice 1 OH | 7/300/2/21 | 7/400/2/21 | 7/300/2/21 | 7/400/2/21 | 7/300/2/21 | 7/400/2/21 | 7/300/2/21 | 7/400/2/21 |
| | | Choice 2 OH | 5/700/3/0 | 5/800/4/0 | 5/500/5/0 | 5/800/4/0 | 5/700/3/0 | 5/800/4/0 | 5/500/5/0 | 5/800/4/0 |
| | Chaibasa (S) | Choice 1 OH | 7/300/2/21 | 7/400/2/21 | 7/300/2/26 | 7/400/2/19 | 7/300/2/19 | 7/400/2/19 | 7/300/2/22 | 7/400/2/19 |
| | | Choice 2 OH | 3/1200/1/30 | 5/800/4/0 | 5/500/5/0 | 5/800/4/0 | 3/1200/1/31 | 5/800/4/0 | 5/500/5/0 | 5/800/4/0 |
| Madhya Pradesh | Sagar (C) | Choice 1 OH | 7/300/2/24 | 7/500/2/12 | 7/400/2/14 | 7/300/2/14 | 7/300/2/14 | 7/400/2/16 | 7/400/2/16 | 7/300/2/16 |
| | | Choice 2 OH | 5/1000/4/0 | 5/1200/6/0 | 5/1100/6/0 | 5/700/3/0 | 5/1000/4/0 | 5/1200/6/0 | 5/1100/6/0 | 5/700/3/0 |
| | Gwalior (N) | Choice 1 OH | 7/400/2/17 | 7/700/2/10 | 7/700/2/10 | 7/300/2/25 | 7/500/2/15 | 7/800/2/8 | 7/700/2/9 | 7/300/2/26 |
| | | Choice 2 OH | 5/900/5/0 | 0/0/0/0 | 0/0/0/0 | 5/1100/2/0 | 5/900/5/0 | 0/0/0/0 | 0/0/0/0 | 5/1100/2/0 |
| | Umaria (E) | Choice 1 OH | 7/400/2/19 | 7/600/2/11 | 7/600/2/11 | 7/300/2/18 | 7/400/2/18 | 7/600/2/11 | 7/600/2/11 | 7/300/2/29 |
| | | Choice 2 OH | 5/800/5/0 | 5/1200/6/0 | 5/1100/6/0 | 5/700/3/0 | 5/1000/4/0 | 5/1200/6/0 | 5/1100/6/0 | 5/700/3/0 |
| | Indore (W) | Choice 1 OH | 7/300/2/22 | 7/600/2/11 | 7/500/2/14 | 7/300/2/14 | 7/300/2/22 | 7/600/2/11 | 7/500/2/12 | 7/300/2/27 |
| | | Choice 2 OH | 5/600/6/0 | 5/1200/6/0 | 5/1000/6/0 | 3/1200/1/29 | 5/900/4/0 | 5/1200/6/0 | 5/1000/6/0 | 3/1200/1/29 |
| | Betul (S) | Choice 1 OH | 7/400/2/19 | 7/600/2/10 | 7/500/2/14 | 7/300/2/14 | 7/400/2/14 | 7/600/2/12 | 7/500/2/13 | 7/300/2/13 |
| | | Choice 2 OH | 5/700/5/0 | 5/1100/6/0 | 5/1000/6/0 | 3/1200/1/32 | 5/700/5/0 | 5/1100/6/0 | 5/1000/6/0 | 3/1200/1/32 |
| Maharashtra | Parbhani (C) | Choice 1 OH | 7/300/2/24 | 7/300/2/25 | 7/500/2/15 | 7/800/2/8 | 7/700/2/9 | 7/300/2/26 | 7/400/2/19 | 7/600/2/11 |
| | | Choice 2 OH | 5/500/6/0 | 5/1000/6/0 | 5/900/6/0 | 5/700/3/0 | 5/1000/3/0 | 5/1200/5/0 | 5/900/6/0 | 5/700/3/0 |
| | Jalgaon (N) | Choice 1 OH | 7/400/2/14 | 7/600/2/12 | 7/500/2/13 | 7/300/2/13 | 7/400/2/13 | 7/600/2/12 | 7/500/2/13 | 7/300/2/13 |
| | | Choice 2 OH | 5/1100/3/0 | 5/1100/6/0 | 5/1100/6/0 | 3/1200/1/29 | 5/1100/3/0 | 5/1100/6/0 | 5/1100/6/0 | 3/1200/1/31 |
| | Chandrapur (E) | Choice 1 OH | 7/400/2/13 | 7/500/2/13 | 7/500/2/13 | 7/300/2/13 | 7/400/2/13 | 7/500/2/13 | 7/500/2/13 | 7/300/2/13 |
| | | Choice 2 OH | 5/800/4/0 | 5/1000/6/0 | 5/900/6/0 | 5/700/3/0 | 5/800/4/0 | 5/1200/5/0 | 5/900/6/0 | 5/700/3/0 |
| | Mumbai (W) | Choice 1 OH | 7/300/2/22 | 7/500/2/14 | 7/500/2/14 | 7/300/2/14 | 7/300/2/18 | 7/500/2/14 | 7/500/2/14 | 7/300/2/14 |
| | | Choice 2 OH | 5/600/6/0 | 5/1200/5/0 | 5/900/6/0 | 5/700/3/0 | 5/1000/3/0 | 5/1200/5/0 | 5/900/6/0 | 5/700/3/0 |
| | Satara (S) | Choice 1 OH | 7/300/2/25 | 7/500/2/15 | 7/400/2/16 | 7/300/2/16 | 7/300/2/25 | 7/500/2/15 | 7/400/2/17 | 7/300/2/17 |
| | | Choice 2 OH | 5/700/4/0 | 5/900/6/0 | 5/800/6/0 | 3/1200/1/31 | 5/700/4/0 | 5/900/6/0 | 5/800/6/0 | 3/1200/1/32 |
| Manipur | Imphal (C) | Choice 1 OH | 7/300/2/17 | 7/400/2/17 | 7/300/2/20 | 7/400/2/20 | 7/300/2/20 | 7/400/2/20 | 7/300/2/20 | 7/400/2/20 |
| | | Choice 2 OH | 5/1100/2/0 | 5/700/5/0 | 5/900/3/0 | 5/700/5/0 | 5/1100/2/0 | 5/700/5/0 | 5/900/3/0 | 5/700/5/0 |
| | Senapati (N) | Choice 1 OH | 7/300/2/22 | 7/400/2/22 | 7/300/2/22 | 7/400/2/22 | 7/300/2/22 | 7/400/2/22 | 7/300/2/22 | 7/400/2/22 |
| | | Choice 2 OH | 5/1100/2/0 | 5/700/5/0 | 5/900/3/0 | 5/700/5/0 | 5/1100/2/0 | 5/700/5/0 | 5/900/3/0 | 5/700/5/0 |
| | Kamjong (E) | Choice 1 OH | 7/300/2/22 | 7/400/2/22 | 7/300/2/22 | 7/400/2/22 | 7/300/2/22 | 7/400/2/22 | 7/300/2/22 | 7/400/2/22 |
| | | Choice 2 OH | 5/1100/2/0 | 5/700/5/0 | 5/900/3/0 | 5/700/5/0 | 5/1100/2/0 | 5/700/5/0 | 5/900/3/0 | 5/700/5/0 |
| | Tamenglong (W) | Choice 1 OH | 7/300/2/20 | 7/400/2/20 | 7/300/2/20 | 7/400/2/20 | 7/300/2/20 | 7/400/2/20 | 7/300/2/20 | 7/400/2/20 |
| | | Choice 2 OH | 5/1100/2/0 | 5/700/5/0 | 5/900/3/0 | 5/700/5/0 | 5/1100/2/0 | 5/700/5/0 | 5/900/3/0 | 5/700/5/0 |
| | Churachandpur (S) | Choice 1 OH | 7/200/2/37 | 7/300/2/26 | 7/300/2/26 | 7/300/2/26 | 7/200/2/26 | 7/300/2/26 | 7/300/2/26 | 7/300/2/26 |
| | | Choice 2 OH | 3/1200/1/32 | 5/1100/3/0 | 5/900/3/0 | 5/1100/3/0 | 3/1200/1/32 | 5/1100/3/0 | 5/900/3/0 | 5/1100/3/0 |
| Meghalaya | West-khasi-hills(C) | Choice 1 OH | 7/300/2/22 | 7/400/2/22 | 7/300/2/22 | 7/400/2/22 | 7/300/2/22 | 7/400/2/22 | 7/300/2/22 | 7/400/2/22 |
| | | Choice 2 OH | 5/1100/2/0 | 5/700/5/0 | 5/900/3/0 | 5/700/5/0 | 5/1100/2/0 | 5/700/5/0 | 5/900/3/0 | 5/700/5/0 |
| | Ribhoi (N) | Choice 1 OH | 7/300/2/22 | 7/400/2/22 | 7/300/2/22 | 7/400/2/22 | 7/300/2/22 | 7/400/2/22 | 7/300/2/22 | 7/400/2/22 |
| | | Choice 2 OH | 5/1100/2/0 | 5/700/5/0 | 5/900/3/0 | 5/700/5/0 | 5/1100/2/0 | 5/700/5/0 | 5/900/3/0 | 5/700/5/0 |
| | Jaintia Hills (E) | Choice 1 OH | 7/300/2/22 | 7/400/2/22 | 7/300/2/22 | 7/400/2/22 | 7/300/2/22 | 7/400/2/22 | 7/300/2/22 | 7/400/2/22 |
| | | Choice 2 OH | 5/1100/2/0 | 5/700/5/0 | 5/900/3/0 | 5/700/5/0 | 5/1100/2/0 | 5/700/5/0 | 5/900/3/0 | 5/700/5/0 |
| | Garo Hills (W) | Choice 1 OH | 7/300/2/26 | 7/400/2/22 | 7/300/2/22 | 7/400/2/22 | 7/300/2/22 | 7/400/2/22 | 7/300/2/22 | 7/400/2/22 |
| | | Choice 2 OH | 5/1100/2/0 | 5/700/5/0 | 5/900/3/0 | 5/700/5/0 | 5/1100/2/0 | 5/700/5/0 | 5/900/3/0 | 5/700/5/0 |
| | East-khasi-hills (S) | Choice 1 OH | 7/300/2/22 | 7/400/2/22 | 7/300/2/22 | 7/400/2/22 | 7/300/2/22 | 7/400/2/22 | 7/300/2/22 | 7/400/2/22 |
| | | Choice 2 OH | 5/1100/2/0 | 5/700/5/0 | 5/900/3/0 | 5/700/5/0 | 5/1100/2/0 | 5/700/5/0 | 5/900/3/0 | 5/700/5/0 |
| Mizoram | Lunglei (C) | Choice 1 OH | 7/300/2/26 | 7/400/2/22 | 7/300/2/22 | 7/400/2/22 | 7/300/2/22 | 7/400/2/22 | 7/300/2/22 | 7/400/2/22 |
| | | Choice 2 OH | 3/1200/1/32 | 5/800/4/0 | 5/500/5/0 | 5/800/4/0 | 3/1200/1/30 | 5/800/4/0 | 5/500/5/0 | 5/800/4/0 |
| | Aizawl (N) | Choice 1 OH | 7/300/2/22 | 7/400/2/22 | 7/300/2/22 | 7/400/2/22 | 7/300/2/22 | 7/400/2/22 | 7/300/2/22 | 7/400/2/22 |
| | | Choice 2 OH | 5/700/3/0 | 5/800/4/0 | 5/500/5/0 | 5/800/4/0 | 5/700/3/0 | 5/800/4/0 | 5/500/5/0 | 5/800/4/0 |
| | Champhoi (E) | Choice 1 OH | 7/300/2/21 | 7/400/2/21 | 7/300/2/21 | 7/400/2/21 | 7/300/2/21 | 7/400/2/21 | 7/300/2/21 | 7/400/2/21 |
| | | Choice 2 OH | 3/1200/1/30 | 5/800/4/0 | 5/500/5/0 | 5/800/4/0 | 3/1200/1/30 | 5/800/4/0 | 5/500/5/0 | 5/800/4/0 |
| | Mamit (W) | Choice 1 OH | 7/300/2/15 | 7/400/2/15 | 7/300/2/21 | 7/400/2/21 | 7/300/2/21 | 7/400/2/21 | 7/300/2/21 | 7/400/2/21 |
| | | Choice 2 OH | 5/700/3/0 | 5/1100/3/0 | 5/900/3/0 | 5/1100/3/0 | 5/700/3/0 | 5/1100/3/0 | 5/900/3/0 | 5/1100/3/0 |
| | Saiha (S) | Choice 1 OH | 7/300/2/17 | 7/400/2/17 | 7/300/2/26 | 7/400/2/19 | 7/300/2/19 | 7/400/2/19 | 7/300/2/24 | 7/400/2/19 |
| | | Choice 2 OH | 3/1200/1/32 | 5/800/4/0 | 5/500/5/0 | 5/800/4/0 | 3/1200/1/32 | 5/800/4/0 | 5/500/5/0 | 5/800/4/0 |

| State | City | Results | N | NE | E | SE | S | SW | W | NW | |
|-----------------|---------------------|-------------|-------------|------------|------------|-------------|-------------|------------|------------|-------------|------------|
| Nagaland | Zunheboto (C) | Choice 1 OH | 7/300/2/22 | 7/400/2/22 | 7/300/2/22 | 7/400/2/22 | 7/300/2/22 | 7/400/2/22 | 7/300/2/21 | 7/400/2/21 | |
| | | Choice 2 OH | 5/600/4/0 | 5/700/5/0 | 5/900/3/0 | 5/700/5/0 | 5/600/4/0 | 5/700/5/0 | 5/900/3/0 | 5/700/5/0 | |
| | Mon (N) | Choice 1 OH | 7/300/2/22 | 7/300/2/22 | 7/300/2/22 | 7/300/2/22 | 7/300/2/22 | 7/300/2/22 | 7/300/2/22 | 7/300/2/22 | 7/300/2/22 |
| | | Choice 2 OH | 5/600/4/0 | 5/700/5/0 | 5/900/3/0 | 5/700/5/0 | 5/600/4/0 | 5/700/5/0 | 5/900/3/0 | 5/700/5/0 | |
| | Kiphire (E) | Choice 1 OH | 7/300/2/22 | 7/400/2/22 | 7/300/2/22 | 7/400/2/22 | 7/300/2/22 | 7/400/2/22 | 7/300/2/22 | 7/400/2/22 | 7/400/2/22 |
| | | Choice 2 OH | 5/600/4/0 | 5/700/5/0 | 5/900/3/0 | 5/700/5/0 | 5/600/4/0 | 5/700/5/0 | 5/900/3/0 | 5/700/5/0 | |
| | Mokokchung (W) | Choice 1 OH | 7/300/2/20 | 7/300/2/22 | 7/300/2/22 | 7/300/2/22 | 7/300/2/22 | 7/300/2/22 | 7/300/2/22 | 7/300/2/22 | 7/300/2/22 |
| | | Choice 2 OH | 5/1200/2/0 | 5/700/5/0 | 5/900/3/0 | 5/700/5/0 | 5/1200/2/0 | 5/700/5/0 | 5/900/3/0 | 5/700/5/0 | |
| Kohima (S) | Choice 1 OH | 7/300/2/22 | 7/400/2/22 | 7/300/2/22 | 7/400/2/22 | 7/300/2/22 | 7/400/2/22 | 7/300/2/22 | 7/400/2/22 | 7/400/2/22 | |
| | Choice 2 OH | 5/1100/2/0 | 5/700/5/0 | 5/900/3/0 | 5/700/5/0 | 5/1100/2/0 | 5/700/5/0 | 5/900/3/0 | 5/700/5/0 | | |
| Odisha | Deogarh (C) | Choice 1 OH | 7/500/2/17 | 7/700/2/10 | 7/600/2/11 | 7/300/2/31 | 7/500/2/15 | 7/500/2/15 | 7/600/2/11 | 7/300/2/28 | |
| | | Choice 2 OH | 3/1200/1/31 | 5/500/6/0 | 5/400/6/0 | 5/500/6/0 | 3/1200/1/31 | 5/500/6/0 | 5/400/6/0 | 5/500/6/0 | |
| | Baleshwar (N) | Choice 1 OH | 7/300/2/28 | 7/300/2/19 | 7/300/2/19 | 7/300/2/19 | 7/300/2/19 | 7/300/2/19 | 7/300/2/19 | 7/300/2/19 | |
| | | Choice 2 OH | 3/1200/1/31 | 5/500/6/0 | 5/400/6/0 | 3/1200/1/31 | 3/1200/1/31 | 5/500/6/0 | 5/400/6/0 | 3/1200/1/31 | |
| | Cuttack (E) | Choice 1 OH | 7/200/2/26 | 7/300/2/26 | 7/300/2/26 | 7/200/2/26 | 7/200/2/26 | 7/300/2/26 | 7/300/2/26 | 7/300/2/26 | |
| | | Choice 2 OH | 3/1200/1/29 | 5/500/6/0 | 5/400/6/0 | 5/500/6/0 | 3/1200/1/29 | 5/500/6/0 | 5/400/6/0 | 5/500/6/0 | |
| | Sonepur (W) | Choice 1 OH | 7/300/2/26 | 7/300/2/26 | 7/300/2/26 | 7/300/2/26 | 7/300/2/26 | 7/300/2/26 | 7/300/2/26 | 7/300/2/26 | |
| | | Choice 2 OH | 3/1200/1/29 | 5/500/6/0 | 5/400/6/0 | 5/500/6/0 | 3/1200/1/29 | 5/500/6/0 | 5/400/6/0 | 5/500/6/0 | |
| | Rayagada (S) | Choice 1 OH | 7/200/2/26 | 7/300/2/26 | 7/300/2/26 | 7/200/2/26 | 7/200/2/26 | 7/300/2/26 | 7/300/2/26 | 7/300/2/26 | |
| | | Choice 2 OH | 3/1100/1/28 | 5/700/4/0 | 5/600/4/0 | 5/700/4/0 | 3/1200/1/25 | 5/700/4/0 | 5/600/4/0 | 5/700/4/0 | |
| Sikkim | Mangan (N) | Choice 1 OH | 7/300/2/17 | 7/400/2/17 | 7/300/2/19 | 7/400/2/19 | 7/300/2/19 | 7/400/2/19 | 7/300/2/19 | 7/400/2/19 | |
| | | Choice 2 OH | 5/800/3/0 | 5/1000/4/0 | 5/1000/3/0 | 5/1000/4/0 | 5/600/4/0 | 5/1000/4/0 | 5/500/6/0 | 5/800/5/0 | |
| | Gangtok (E) | Choice 1 OH | 7/300/2/19 | 7/400/2/19 | 7/300/2/19 | 7/400/2/19 | 7/300/2/19 | 7/400/2/19 | 7/300/2/19 | 7/400/2/19 | |
| | | Choice 2 OH | 5/600/4/0 | 5/1000/4/0 | 5/700/4/0 | 5/1000/4/0 | 5/600/4/0 | 5/1000/4/0 | 5/700/4/0 | 5/1000/4/0 | |
| | Gezingo (W) | Choice 1 OH | 7/300/2/22 | 7/400/2/19 | 7/300/2/19 | 7/400/2/19 | 7/300/2/19 | 7/400/2/19 | 7/300/2/19 | 7/400/2/19 | |
| | | Choice 2 OH | 5/600/4/0 | 5/1000/4/0 | 5/700/4/0 | 5/1000/4/0 | 5/600/4/0 | 5/1000/4/0 | 5/700/4/0 | 5/1000/4/0 | |
| Namchi (S) | Choice 1 OH | 7/300/2/22 | 7/400/2/19 | 7/300/2/19 | 7/400/2/19 | 7/300/2/19 | 7/400/2/19 | 7/300/2/19 | 7/400/2/19 | | |
| | Choice 2 OH | 5/800/3/0 | 5/1000/4/0 | 5/700/4/0 | 5/1000/4/0 | 5/800/3/0 | 5/1000/4/0 | 5/700/4/0 | 5/1000/4/0 | | |
| Tamil Nadu | Tiruchirappalli (C) | Choice 1 OH | 7/300/2/26 | 7/300/2/19 | 7/300/2/19 | 7/300/2/19 | 7/300/2/19 | 7/300/2/19 | 7/200/2/26 | 7/300/2/26 | |
| | | Choice 2 OH | 5/700/3/0 | 5/700/6/0 | 5/800/5/0 | 5/600/4/0 | 5/700/3/0 | 5/700/6/0 | 5/800/5/0 | 5/600/4/0 | |
| | Tiruvannamalai (N) | Choice 1 OH | 7/300/2/19 | 7/400/2/17 | 7/400/2/17 | 7/300/2/17 | 7/300/2/17 | 7/400/2/17 | 7/400/2/17 | 7/300/2/17 | |
| | | Choice 2 OH | 5/1100/2/0 | 5/1100/4/0 | 5/1000/4/0 | 5/600/4/0 | 5/1100/2/0 | 5/1100/4/0 | 5/1000/4/0 | 5/600/4/0 | |
| | Thanjavur (E) | Choice 1 OH | 7/300/2/17 | 7/400/2/17 | 7/400/2/17 | 7/300/2/17 | 7/300/2/17 | 7/400/2/17 | 7/400/2/17 | 7/300/2/17 | |
| | | Choice 2 OH | 5/700/3/0 | 5/700/6/0 | 5/1000/4/0 | 5/600/4/0 | 5/700/3/0 | 5/700/6/0 | 5/1000/4/0 | 5/600/4/0 | |
| | Erode (W) | Choice 1 OH | 7/300/2/17 | 7/400/2/17 | 7/400/2/17 | 7/300/2/17 | 7/300/2/17 | 7/400/2/17 | 7/400/2/17 | 7/300/2/17 | |
| | | Choice 2 OH | 3/1200/1/32 | 5/700/6/0 | 5/1000/4/0 | 5/600/4/0 | 3/1200/1/32 | 5/700/6/0 | 5/1000/4/0 | 5/600/4/0 | |
| Virudunagar (S) | Choice 1 OH | 7/300/2/17 | 7/400/2/17 | 7/400/2/17 | 7/300/2/22 | 7/300/2/22 | 7/400/2/19 | 7/400/2/19 | 7/300/2/22 | | |
| | Choice 2 OH | 3/1200/1/30 | 5/1000/4/0 | 5/1000/4/0 | 5/500/5/0 | 3/1200/1/30 | 5/800/5/0 | 5/800/5/0 | 5/500/5/0 | | |
| Telangana | Hyderabad (C) | Choice 1 OH | 7/300/2/22 | 7/500/2/15 | 7/400/2/16 | 7/300/2/16 | 7/300/2/20 | 7/500/2/15 | 7/400/2/17 | 7/300/2/17 | |
| | | Choice 2 OH | 5/900/3/0 | 5/900/6/0 | 5/800/6/0 | 3/1200/1/31 | 5/900/3/0 | 5/900/6/0 | 5/800/6/0 | 3/1200/1/31 | |
| | Jagtial (N) | Choice 1 OH | 7/300/2/18 | 7/500/2/14 | 7/500/2/14 | 7/300/2/14 | 7/300/2/23 | 7/500/2/14 | 7/500/2/14 | 7/300/2/14 | |
| | | Choice 2 OH | 5/600/5/0 | 5/1200/5/0 | 5/1000/5/0 | 3/1200/1/32 | 5/500/6/0 | 5/1000/6/0 | 5/1000/5/0 | 3/1200/1/32 | |
| | Warangal (E) | Choice 1 OH | 7/300/2/24 | 7/500/2/15 | 7/500/2/15 | 7/300/2/15 | 7/300/2/20 | 7/500/2/15 | 7/500/2/15 | 7/300/2/15 | |
| | | Choice 2 OH | 5/700/4/0 | 5/900/6/0 | 5/1000/5/0 | 3/1200/1/32 | 5/700/4/0 | 5/900/6/0 | 5/1000/5/0 | 3/1200/1/32 | |
| | Medak (W) | Choice 1 OH | 7/300/2/22 | 7/400/2/15 | 7/400/2/15 | 7/300/2/15 | 7/300/2/25 | 7/300/2/15 | 7/400/2/15 | 7/300/2/15 | |
| | | Choice 2 OH | 5/700/4/0 | 5/900/6/0 | 5/800/6/0 | 3/1200/1/32 | 5/700/4/0 | 5/900/6/0 | 5/800/6/0 | 3/1200/1/32 | |
| Nalgonda (S) | Choice 1 OH | 7/300/2/26 | 7/500/2/15 | 7/400/2/17 | 7/300/2/17 | 7/300/2/20 | 7/500/2/15 | 7/400/2/17 | 7/300/2/17 | | |
| | Choice 2 OH | 5/900/3/0 | 5/900/6/0 | 5/800/6/0 | 5/1100/2/0 | 5/900/3/0 | 5/900/6/0 | 5/800/6/0 | 5/1100/2/0 | | |
| Tripura | Gomati (C) | Choice 1 OH | 7/300/2/19 | 7/300/2/14 | 7/300/2/23 | 7/500/2/14 | 7/500/2/14 | 7/300/2/14 | 7/300/2/24 | 7/500/2/15 | |
| | | Choice 2 OH | 3/1200/1/30 | 5/800/4/0 | 5/500/5/0 | 5/800/4/0 | 5/700/3/0 | 5/800/4/0 | 5/500/5/0 | 5/800/4/0 | |
| | Dharmanagar (N) | Choice 1 OH | 7/300/2/22 | 7/400/2/22 | 7/300/2/22 | 7/400/2/22 | 7/300/2/22 | 7/400/2/22 | 7/300/2/22 | 7/400/2/22 | |
| | | Choice 2 OH | 3/1200/1/30 | 5/1100/3/0 | 5/900/3/0 | 5/1100/3/0 | 3/1200/1/32 | 5/1100/3/0 | 5/900/3/0 | 5/1100/3/0 | |
| | Ambassa (E) | Choice 1 OH | 7/300/2/22 | 7/400/2/22 | 7/300/2/22 | 7/400/2/22 | 7/300/2/22 | 7/400/2/22 | 7/300/2/22 | 7/400/2/22 | |
| | | Choice 2 OH | 5/700/3/0 | 5/1100/3/0 | 5/900/3/0 | 5/1100/3/0 | 5/700/3/0 | 5/1100/3/0 | 5/900/3/0 | 5/1100/3/0 | |
| | Agartala (W) | Choice 1 OH | 7/300/2/17 | 7/400/2/17 | 7/300/2/24 | 7/400/2/22 | 7/300/2/22 | 7/400/2/22 | 7/300/2/22 | 7/400/2/22 | |
| | | Choice 2 OH | 5/700/3/0 | 5/800/4/0 | 5/500/5/0 | 5/800/4/0 | 5/700/3/0 | 5/800/4/0 | 5/500/5/0 | 5/800/4/0 | |
| Belonia (S) | Choice 1 OH | 7/300/2/22 | 7/400/2/22 | 7/300/2/22 | 7/400/2/22 | 7/300/2/22 | 7/400/2/22 | 7/300/2/22 | 7/400/2/22 | | |
| | Choice 2 OH | 3/1200/1/32 | 5/800/4/0 | 5/500/5/0 | 5/800/4/0 | 3/1200/1/29 | 5/800/4/0 | 5/500/5/0 | 5/800/4/0 | | |
| Uttarakhand | Almora (C) | Choice 1 OH | 7/500/2/14 | 7/900/2/7 | 7/800/2/8 | 7/300/2/25 | 7/500/2/14 | 7/900/2/7 | 7/800/2/8 | 7/300/2/26 | |
| | | Choice 2 OH | 5/1200/5/0 | 0/0/0/0 | 0/0/0/0 | 5/900/3/0 | 5/1000/6/0 | 0/0/0/0 | 0/0/0/0 | 5/900/3/0 | |
| | Chamoli (N) | Choice 1 OH | 7/600/2/12 | 7/1000/2/7 | 7/800/2/8 | 7/300/2/22 | 7/600/2/12 | 7/1000/2/7 | 7/800/2/8 | 7/300/2/25 | |
| | | Choice 2 OH | 5/1100/6/0 | 0/0/0/0 | 0/0/0/0 | 5/700/4/0 | 5/1100/6/0 | 0/0/0/0 | 0/0/0/0 | 5/700/4/0 | |
| | Pithoragarh (E) | Choice 1 OH | 7/500/2/14 | 7/900/2/7 | 7/800/2/8 | 7/300/2/21 | 7/500/2/14 | 7/900/2/7 | 7/800/2/8 | 7/300/2/24 | |
| | | Choice 2 OH | 5/1000/6/0 | 0/0/0/0 | 0/0/0/0 | 5/900/3/0 | 5/1000/6/0 | 0/0/0/0 | 0/0/0/0 | 5/900/3/0 | |
| | Dehra Dun (W) | Choice 1 OH | 7/600/2/12 | 7/900/2/7 | 7/800/2/8 | 7/300/2/26 | 7/600/2/12 | 7/900/2/7 | 7/800/2/8 | 7/300/2/20 | |
| | | Choice 2 OH | 5/1100/6/0 | 0/0/0/0 | 0/0/0/0 | 5/700/4/0 | 5/1100/6/0 | 0/0/0/0 | 0/0/0/0 | 5/700/4/0 | |
| Nainital (S) | Choice 1 OH | 7/500/2/14 | 7/900/2/7 | 7/800/2/8 | 7/300/2/26 | 7/500/2/14 | 7/900/2/7 | 7/800/2/8 | 7/300/2/26 | | |
| | Choice 2 OH | 5/1200/5/0 | 0/0/0/0 | 0/0/0/0 | 5/900/3/0 | 5/1200/5/0 | 0/0/0/0 | 0/0/0/0 | 5/900/3/0 | | |
| West Bengal | Berhampur (C) | Choice 1 OH | 7/200/2/39 | 7/300/2/22 | 7/600/2/12 | 7/1000/2/7 | 7/800/2/8 | 7/300/2/25 | 7/500/2/14 | 7/900/2/7 | |
| | | Choice 2 OH | 3/1100/1/29 | 5/700/4/0 | 5/600/4/0 | 5/700/4/0 | 3/1200/1/29 | 5/700/4/0 | 5/600/4/0 | 5/700/4/0 | |
| | Jalpaiguri (N) | Choice 1 OH | 7/300/2/26 | 7/300/2/22 | 7/300/2/22 | 7/300/2/22 | 7/300/2/22 | 7/300/2/22 | 7/300/2/22 | 7/300/2/22 | |
| | | Choice 2 OH | 5/600/4/0 | 5/900/4/0 | 5/700/4/0 | 5/900/4/0 | 5/600/4/0 | 5/900/4/0 | 5/700/4/0 | 5/900/4/0 | |
| | Kolkata (E) | Choice 1 OH | 7/300/2/22 | 7/400/2/22 | 7/300/2/22 | 7/400/2/22 | 7/300/2/22 | 7/400/2/22 | 7/300/2/22 | 7/400/2/22 | |
| | | Choice 2 OH | 3/1200/1/32 | 5/800/4/0 | 5/500/5/0 | 5/800/4/0 | 3/1200/1/30 | 5/800/4/0 | 5/500/5/0 | 5/800/4/0 | |
| | Puruliya (W) | Choice 1 OH | 7/300/2/22 | 7/400/2/22 | 7/300/2/22 | 7/400/2/22 | 7/300/2/22 | 7/400/2/22 | 7/300/2/22 | 7/400/2/22 | |
| | | Choice 2 OH | 3/1200/1/30 | 5/800/4/0 | 5/500/5/0 | 5/800/4/0 | 3/1200/1/30 | 5/800/4/0 | 5/500/5/0 | 5/800/4/0 | |
| Tamluk (S) | Choice 1 OH | 7/300/2/22 | 7/400/2/22 | 7/300/2/22 | 7/300/2/22 | 7/300/2/22 | 7/400/2/22 | 7/300/2/22 | 7/400/2/22 | | |
| | Choice 2 OH | 3/1200/1/32 | 5/800/4/0 | 5/600/4/0 | 5/800/4/0 | 3/1200/1/31 | 5/800/4/0 | 5/600/4/0 | 5/800/4/0 | | |

In Table 2 for certain cities and orientations, the result shown is '0/0/0/0', which means that no results are possible for that specific orientation for the selected location, which adhere to the shading device depth constraints specified in the algorithm. For the window orientations where the results are '0/0/0/0', has a design implication that for that space inside a building windows should not be provided for those wall orientations during the specified hours and if necessary then there should be a provision of a buffer space or a portico which can shade the window. Hence, an optimum shading strategy for a window of standard dimensions (1200mm*900mm) has been suggested for the selected locations in all cardinal and sub cardinal directions for most of the cases.

Limitations of the study are that an optimum and the next-best solution have been provided only for a window of standard dimensions (1200mm*900mm). For other window dimensions, sub-optimal solutions that provide functional shading device design can be derived from the results.

VI. CONCLUSION

The design of shading devices should be location and orientation specific to get the optimum benefit and tradeoff between first cost and operational energy cost. Use of horizontal inclined louvers (with two louvers) is the best strategy for all locations because it prevents direct radiation to enter a space or building while keeping the cost minimum. Horizontal louvers without any inclination and one inclined horizontal overhang are the next-best suggested shading device strategies. The Architects and designers can incorporate the results presented in the study to provide shading device strategies for windows in building design. A universal solution or a one size fits all approach for the type and characteristics of shading device that is used in standard practice cannot work for every space or building and will depend on the location and orientation. This gap has been covered by making the results location and orientation specific with shading device characteristics like the angle of inclination of the overhang/louvers, the number of louvers and the overhang/louver depth being defined explicitly for all cases. The results from this paper can also be incorporated into the Indian building codes to provide the architects and designers with a much more precise and location specific shading strategy. Further studies can explore how the different shading strategies affect the natural lighting inside spaces in a building. The shading strategies will also affect the overall carbon emission of a building by changing the heating and cooling loads.

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