Feature Ranking for Predicting Occupant Visual Comfort in Hospital Lobby Using Artificial Neural Networks (ANNs)

Ramisa Anjum[1], Md. Faisal Rahman Dhrubo[2*], Md. Mashnur Hossain Pobon[2], Maisha Mahmud[1]

[1] Department of Agriculture, IUBAT- International University of Business Agriculture and Technology
Dhaka, Bangladesh
22206057@iubat.edu

Abstract. Maintaining appropriate visual levels in hospital spaces is vital for occupant comfort and adaptive healthcare environments, particularly in dense urban areas such as Dhaka, Bangladesh, which strongly influence indoor performance and user perception. Existing research has primarily focused on energy efficiency and lighting comfort in specific hospital zones such as wards and intensive care units (ICUs), while hospital lobby spaces are often overlooked despite their significant impact on lighting comfort and overall indoor environmental quality (IEQ). To address this research gap, this study employs Artificial Neural Networks (ANNs) to identify and rank the most influential features affecting occupant visual comfort in an artificially ventilated hospital lobby in Dhaka, Bangladesh. The research was conducted through a questionnaire-based field survey, resulting in 400 valid data samples with 32 key features representing human, environmental, and indoor-related variables. These features include demographic characteristics (i.e., gender, age, visitor type, etc.), environmental features (i.e., temperature, humidity, CO_2 concentration, etc.), indoor landscape factors (i.e., surface materials, sitting direction, etc.), and building attributes such as room orientation and window direction. The dataset was divided into 80% for training and 20% for testing, and hyperparameter tuning was performed. Feature importance and ranking were evaluated using Principal Component Analysis (PCA), Random Forest (RF), Recursive Feature Elimination (RFE), and Lasso Regularization (LR), revealing sitting direction, lighting level, number of windows, and lobby location as dominant predictors, while sitting orientation, number of lights, window state, and floor level also influence visual comfort. The findings support improved health outcomes, energy efficiency, and sustainability.

Keywords: Feature ranking, Hospital lobby, Artificial Neural Network (ANN), Visual Comfort, Sustainable Environment.

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1. Introduction

In hospital buildings, some factors like thermal comfort, ventilation systems, ward auditory, natural or artificial lighting, indoor air quality impact indoor environmental quality (IEQ). Among of them, most important components of IEQ are creating suitable visual environments in hospital lobby spaces as having a direct impact on the psychological well-being and perception of occupants [16]. The people who work at the reception area are visually demanding and need both upward-focused, task-oriented lighting and soft, low-glare ambient lighting to make sure that they can easily switch between working on their devices and talking to visitors (Toodekharman)[21]. Therefore, visual comfort in these areas serves multiple functions simultaneously: it facilitates task accuracy (reading patient information and badges accurately), interpersonal effectiveness (faces and facial expressions), directions (spotting indications and directional hints quickly), and regulation (reducing stress for staff and visitors). Attendants experience eye strain, perform worse, and make more mistakes when they often go from gloomy waiting areas to bright corridors. On the other hand, balanced lobby lighting enhances visitor safety, lessens employee fatigue, lowers stress, fosters favorable first impressions, and promotes staff focus.
While artificially ventilated (AV) lobbies have received minimal attention in studies, especially with regard to the visual demands of attendants, personnel, and visitors, lighting in operating and patient rooms has received a great deal of attention [3, 15, 20]. Nevertheless, despite technological progression, there are still few standard techniques for assessing hospital illumination. By focusing on insufficient information, assumptions, and the lack of user-centered feedback, traditional evaluation techniques such as architectural models and standard lighting metrics frequently oversimplify actual situations and fall short of accurately reflecting true visual comfort. Hospital lobbies are understudied since the majority of research focuses on clinical settings and patient rooms. Current techniques are too inflexible to capture the complexity of the real world. The use of ML, which can analyze vast and complicated information to identify the architectural and environmental elements that influence comfort levels, is a potential approach to closing this gap [10]. This work demonstrates the necessity of sophisticated, data driven techniques to precisely evaluate and enhance visual comfort in hospital lobbies.

2. Literature Review

Hospital lobby design has a significant impact on the mental and physical well-being of patients, guests, and medical personnel. An increasing amount of research demonstrates that environmental elements, such as daylight availability, artificial lighting qualities, and general spatial arrangement, are critical to promoting human well-being. Exposure to natural light can speed up patient recovery, according to foundational research by Ulrich and others that were among the first to emphasize the importance of environmental design in healthcare facilities [17]. This claim was reinforced by further studies that demonstrated increased exposure to daylight is linked to shorter hospital admissions, better emotional states, and a decreased need for medication [2, 19]. When taken as a whole, these results highlight the significant influence of illumination and visual comfort on patient outcomes. Consequently, there has been substantial support for research that combines objective performance measures with subjective user experiences. Hospital lobby design has a significant impact on the mental and physical well-being of patients, guests, and medical personnel. An increasing amount of research demonstrates that environmental elements, such as daylight availability, artificial lighting qualities, and general spatial arrangement, are critical to promoting human well-being. Exposure to natural light can speed up patient recovery, according to foundational research by Ulrich and others that were among the first to emphasize the importance of environmental design in healthcare facilities [17]. This claim was reinforced by further studies that demonstrated increased exposure to daylight is linked to shorter hospital admissions, better emotional states, and a decreased need for medication [2, 19]. When taken as a whole, these results highlight the significant influence of illumination and visual comfort on patient outcomes. Consequently, there has been substantial support for research that combines objective performance measures with subjective user experiences.

The study's focus has grown over time to encompass a variety of aspects of visual comfort, including how sunshine, electric illumination, and circadian cycles interact. For instance, Davis and Schledermann examined how employees react to various lighting conditions, showing how well-thought-out lighting systems may promote circadian synchronization and employee wellbeing [3, 15]. In a similar vein, Verso and Hosseini evaluated the impact of lighting on general comfort and happiness in medical settings, going beyond patient recuperation [7, 18]. Research by Joseph and Jafarifiroozabadi confirmed the physiological and psychological advantages of enough natural light [8, 9]. These findings have been expanded to non-clinical contexts in more recent study. Wei, for example, looked at the emotional impact of interior lighting color in hospitality spaces and provided ideas that may be applicable to hospital lobbies. When designing lighting systems, it is crucial to balance human-centered comfort, functional requirements, and energy efficiency, as this research together highlights.

Conventional assessment methods are still constrained in spite of these developments. A number of scholars have used engineering or architectural models to examine daylight distribution or visual performance, such as Mehrotra, Mousavi Asl, and Safari [11, 12]. Small sample sizes, inflexible assumptions, and a lack of real-time user feedback sometimes limit these models, despite their informative value. Additionally, standard assessment criteria like spatial daylight autonomy and illuminance measurements frequently deviate from real user satisfaction [1]. According to research by Toodekharman, Abravesh, and Heidari, adaptable façade systems in hospital rooms can enhance daylight penetration and minimize glare; the best window-to-wall ratio is 60% [21]. However, glare problems continued to exist based on the patient's location. In the meanwhile, advances in data science have led to the introduction of machine learning methods that can handle unbalanced datasets and generate results for both classification and prediction [5, 13]. Nevertheless, the majority of current research is either descriptive or correlation-based, which restricts its use for improving visual comfort in medical environments.

Intelligent models and simulations have been used in recent studies to improve visual comfort evaluations. Research in Nagpur showed how spatial geometry influences glare and sunshine penetration, whereas research in New Delhi revealed discrepancies between quantitative lighting measurements and subjective well-being [4, 6]. This was extended by Manipal's work to include integrated thermal-visual comfort evaluations using soft computing technologies [14]. Particularly in South Asian healthcare settings, where these methods are still rare, hospital lobbies offer a unique chance to implement these new strategies.

In conclusion, hospital lobbies in low-income nations like Bangladesh are still relatively unexplored, despite the fact that several research have looked at daylight, artificial lighting, and environmental design in clinical areas. The accuracy required to capture subjective visual comfort in real-world circumstances is lacking in current evaluation methods, which are frequently static. A viable approach to addressing data imbalance, revealing intricate linkages, and identifying important comfort variables is using machine learning-based feature-ranking and prediction models. Therefore, to provide precise, real-time visual comfort forecasts for hospital lobby settings, sophisticated computational techniques are required.

3. Methodology

The methods of research that were implied in the study is briefly described here:

The study was initially started by selecting a hospital building with access to natural ventilation in the outskirts of Dhaka, Bangladesh. Field data was collected from the lobby areas of the 15 storied hospital building during operational hours. Using on site measurements and surveys, a total of 410 samples were collected. The dataset consisted of 32 features that captured demographic characteristics (age, gender, occupation), environmental variables (temperature, humidity, CO2, AC temperature), window conditions, sitting orientation, floor level, and subjective comfort responses (PMV, perceived lighting, seating experience). These factors made it possible to provide an accurate portrayal of lobby conditions and user impression.

The raw data was cleaned, duplicates were removed and handling of missing values and outlier correction was done. Oversampling was not applied since the data distribution did not present any imbalance [5, 13]. This study uses Artificial Neural Networks (ANNs) to determine the most important aspects or ranking of features on occupant visual comfort in an artificially ventilated lobby, acknowledging the significance of elements. In order to determine the visual comfort levels, these features use demographic characteristics (e.g., gender, age, visitors, etc.), environmental conditions (e.g., temperature, humidity, CO2, lighting level), landscape factors (e.g., surface materials, sitting direction, floor locations), and building attributes (e.g., room orientation and window direction) as parameters.

4. Results and Discussion

Feature Selection in Artificial Neural Networks (ANNs):

Feature selection is an essential stage in Artificial Neural Network (ANN) modeling that improves model efficiency, accuracy, and interpretability. In complex domains like visual comfort prediction or environmental quality assessment, large datasets often contain redundant or irrelevant factors that increase computational costs and the risk of overfitting. Predicted accuracy on unknown data is increased through feature selection, which also reduces model complexity, enhances generalization, and enables ANNs to learn more effectively. To rank the parameters, four feature selection techniques were employed: PCA, Tree-based RF, RFE, and LR. These methods identified and prioritized the most influential features.

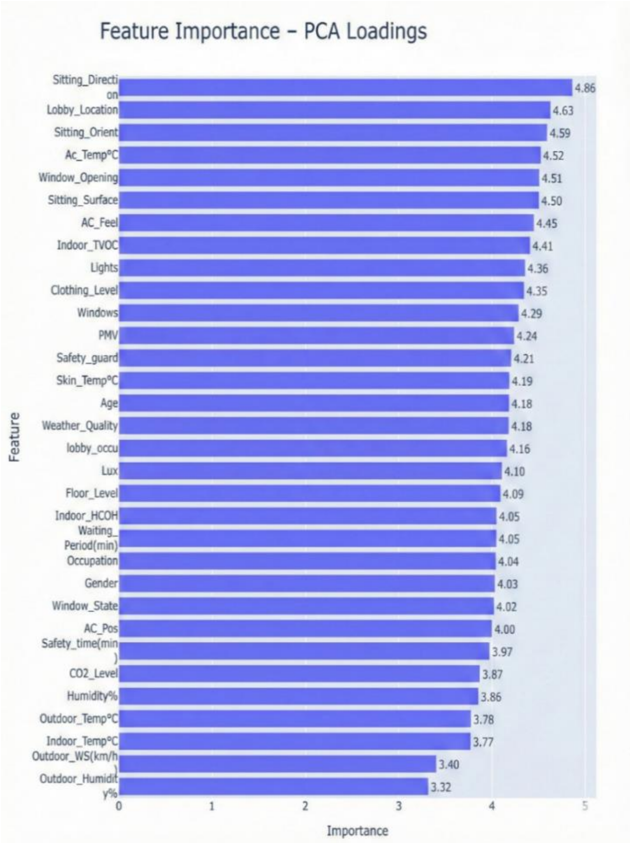

Fig. 1. PCA

Principal components analysis (PCA):

In the context of the ANN model, the PCA-based feature ranking in Fig:1 demonstrates that each variable contributes differently to the dataset's variance. Sitting direction of the lobby area exhibits the highest loading value (4.86), signifying its dominant influence on the principal components and overall variance. Lobby location (4.63) and sitting orientation (4.59) also show strong associations with data variability. Additional variables, including AC_Temp°C as temperature of the air conditioner in degree Celsius, window's opening, sitting surface, AC_Feel as feeling in air conditioner, indoor TVOC, lights as number of lights, number of windows each possess loadings above 4.0, confirming their substantial influence in explaining dataset variance. Meanwhile, features such as AC_Pos as position of air conditioner, CO_2 level (ppm), humidity (%), outdoor and indoor temperature in °C through displaying slightly lower loadings, still play an important role in capturing the underlying structural patterns of the data.

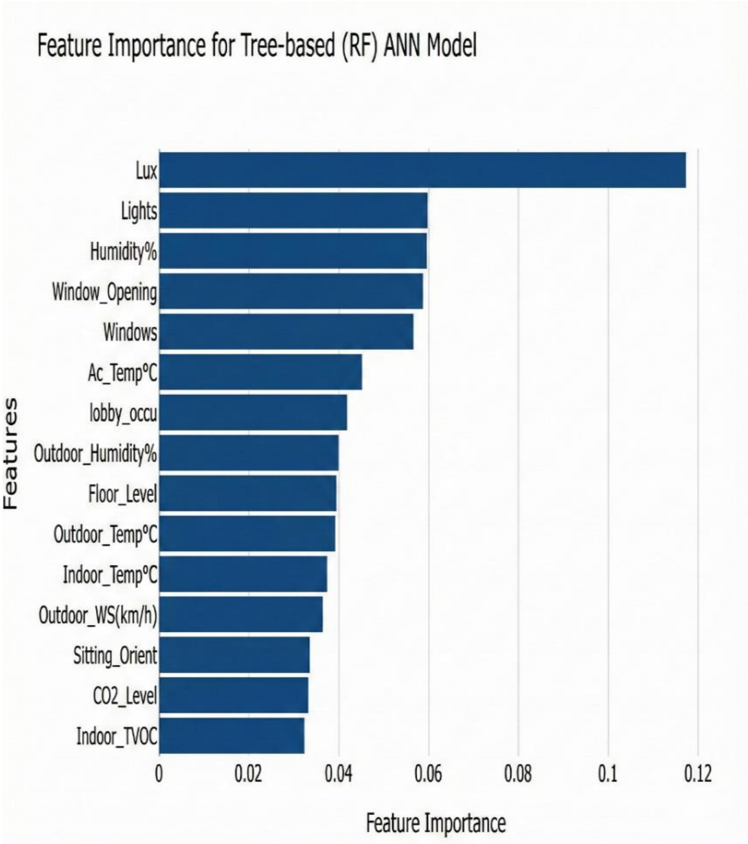

Fig. 2. RF

The ANN model's Random Forest-based ranking identifies the most important predictors based on significance scores and their contribution to model performance, as seen in Figure 2. With a score of 0.1173, Lux is ranked highest, followed by lights as number of lights (0.05998) and humidity in percent (0.05972), demonstrating their significant impact on model predictions. In decreasing order of significance, the other variables- Window_Opening, number of windows, Ac_Temp°C, lobby_occu as number of occupants in lobby area, Outdoor_Humidity%, Floor_Level, Outdoor_Temp°C, Indoor_Temp°C, Outdoor_WS(km/h) as outdoor wind speed in kilometer per hour, Sitting_Orientation, CO_2_Level (ppm) and Indoor_TVOC each have a distinct impact on the predicted results.

The hospital lobby's visual comfort was found to be most significantly influenced by environmental, spatial, and demographic aspects using the ANN with Recursive Feature Elimination (RFE). The highest-impact variables identified by the model were floor level (9.425), window opening (9.48), indoor HCHO levels (9.44), and indoor occupancy (9.432).

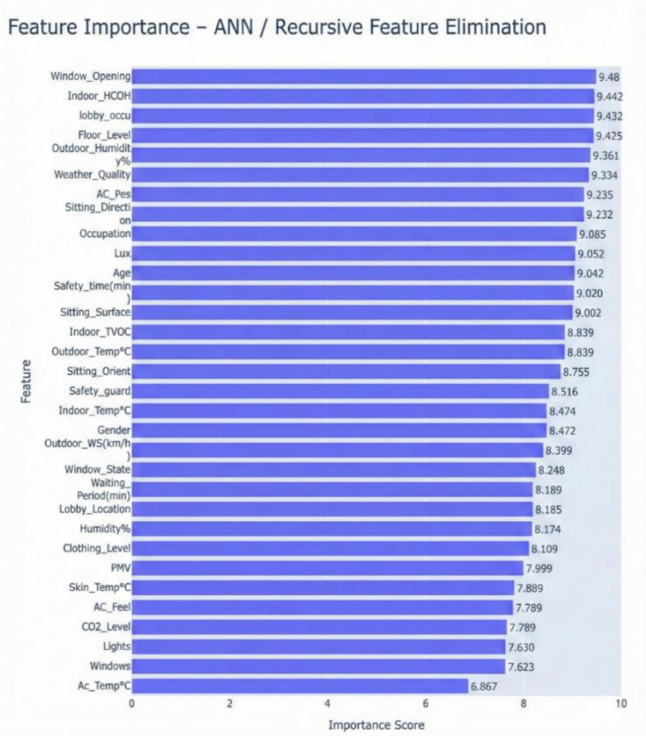

Fig.3. RFE

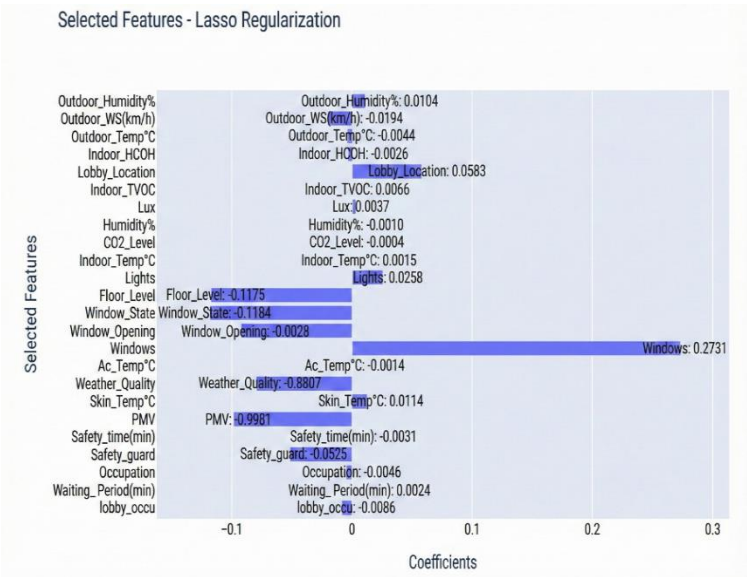

Fig. 4. LR

The results of the various feature-ranking techniques varied slightly, indicating the distinct advantages and disadvantages of each strategy. These differences emphasize how crucial it is to use a variety of approaches in order to have a more thorough grasp of the major variables affecting visual comfort. Future studies should examine how feature significance varies under other preparation techniques or data configurations, as the rankings are influenced by the dataset's properties and each algorithm's behavior.

5. Conclusion

The findings suggest that combining environmental factors with user input might improve the accuracy of comfort evaluations and encourage more adaptable lighting design techniques. The paper also emphasizes the significance of explainable machine learning techniques, which enhance prediction accuracy and offer useful information for evidence-based design. Decision-makers may create more flexible, sustainable, and user-centered lobby settings by concentrating on the critical elements influencing visual comfort. To improve model performance and applicability, future research should take into account real-time adaptive lighting systems, seasonal fluctuations, and various lobby layouts.

Furthermore, maintaining visual comfort under a variety of circumstances may be facilitated by giving priority to glare control, calibrated reception lighting, and responsive daylight-electric lighting systems—all of which are supported by ongoing post-occupancy assessments. In the end, these tactics can enhance employee performance, lessen pain for guests, and promote healthier, friendlier hospital lobbies. This highlights the environmental factors that have the most essential impact on occupant visual pleasure. The results offer essential understanding for creating adaptive, occupant-centered lighting strategies in hospital lobbies. This could effectively enhance staff efficiency, promote patient recovery, and improve the experience for visitors.

Conflict of Interest
Confirmation assured of no association of the study with any conflicts of interest.

Data Availability
When a fair request is made, the associated author guarantees to supply data.

Declaration of generative AI
During the preparation of this manuscript, the author utilized pre-trained large language models to assist with grammar refinement and clarity enhancement.

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