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Optimization of HVAC Position through Different Furniture Configurations

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Abstract: **Air conditioning is used to maintain temperature, humidity, air circulation, and air quality within an indoor environment. Although health, safety, and economics are being given increased attention; comfort is still a major concern in the HVAC industry. This paper investigates the airflow pattern, comfort, and discomfort zones inside a seminar room. The flow patterns inside the seminar room are obtained using Computational Fluid Dynamics (Fluent Code). This paper is to use the Computational Fluid Dynamics as a design tool to get the optimum location for furniture, supply, return, and exhaust in such manner that does not affect the architectural aesthetics. Comfort air velocity for occupants is related to their position. The location of supply, return and exhaust has a great effect on the airflow distribution inside the room. Supply, return and exhaust should be located with respect to furniture location to avoid draft which affects comfort inside the room.**

Keywords: **Air flow, air condition, comfort, furniture distribution.**

I. INTRODUCTION

The introduction of paper contains the nature of research work, purpose of work, and the contribution of this paper. It contains the references of the previous work done. This template is in Word document, provides authors with most of the formatting specifications required by the author for preparation of their research paper.

The architect's ultimate goal is to create comfortable work-place environments with good access to successful interior design and interior view. Meanwhile the heating, ventilation, and air conditioning engineer's goal is to design and implement a HVAC system with accepted air draft flow while maintaining appropriate comfort conditions. This paper explores alternatives of furniture arrangements that would develop flexible internal furniture plan configurations and systems to accommodate short, medium and long-term satisfaction of the architect and HVAC engineer's goals. The subjective feeling of comfort is closely related to air velocity and temperature. Thus two important features in the user satisfaction with a building are closely related; dissatisfaction with the thermal environment and draft is widespread, even in buildings with sophisticated controls. Complaints of overheating in winter and coldness in air-conditioned buildings in summer time are common problem; room air near the jet is entrained and must then be replaced by other room air. The room air always moves towards the supply and thus sets all the room air into motion. The intention of this work is to present solutions provided by Computational Fluid Dynamics in studying the configurations of a room ventilation set-up. This type of information will help HVAC practitioners, and ultimately architects, to find the best distribution of space early in the design phase. An important goal of this study is to improve the analysis of real-life environments. Thus, particular emphasis is placed on the complexity of the geometry where the three-dimensional (3D) flow occurs.

As an important complement to this approach, care was taken with the post-processing elements. Indeed, in the design of building environments, deep awareness of both the space and the field of computed parameters is a valuable tool in evaluating the quality of the proposed environment. Thus, clear and realistic representation of these dimensions in the seminar room is an important aspect of the design process. Awbi [1] investigated the performance evaluation of different ventilation systems (wall, floor and the impinging jet ventilation systems). Karimipanah [2] investigated comfort parameters for different air supply systems in classrooms. Lee [3] investigated the effects of inlet, exhausts locations and emitted gas density concentrations in a workroom. Said [4] investigated the effect of door opening on the performance of displacement ventilation. He also Investigated and predict the typical pollutant emission pattern for buses. Cheong [5] investigated the air flow and pollutant distribution patterns based on various ventilation strategies in a negative pressure isolation room.

II. APPLICATION OF CFD IN HVAC SYSTEMS

The main application of the CFD modelling of the indoor environment is in building design, the predicted microscopic (point by point) values, such as velocity vector, temperature, pressure, airborne particles concentration, are useful for deriving the global parameters needed for engineering design. Numerical prediction of air flow patterns in mechanically ventilated rooms has been a research direction for almost three decades. Since 1970s, CFD showed that it was capable to predict the flow field in large domains with relatively small openings. In the recent years, the field of ventilation engineering has started to use CFD as a design and analytical tool since it offers a radical change in available analytical tools. The engineer can predict the impact of a certain design of an air conditioning system on the indoor climate and the energy management of real buildings.

For many years CFD has been applied in the simulation of room air movement in air conditioned spaces. In the earlier applications description of the analysis of 3-dimensional flow in an office type room with cooling using CFD analysis combined with experimental verification [6].

The usefulness of CFD as a design tool illustrated for ventilation system. It enables the velocity and temperature fields to be investigated in significantly greater detail than is possible with either analytical or experimental models [7].

The effect of air velocity over the whole body was studied and found thermal acceptability unaffected in neutral environments by air speed of (0.25m/s) or less. No interaction between air speed and radiant temperature asymmetry on subjective responses. This means that acceptability changes or the parent dissatisfied due to draft and radiant asymmetry is independent and additive [8].

The effect of turbulence intensity on sensation of draft and the turbulence intensity had a significant effect on the occurrence of draft sensation [9]. Using CFD in recent years has helped engineers to improve the performance of automotive HVAC systems and reduce design lead-time. In the past it took a lot of time to develop an HVAC system for a new model using conventional physical testing methods.

Also the ability to quickly evaluate many alternatives at low cost early in the design process often leads to significant performance improvements. Numerical techniques make it possible for engineers to model complex HVAC components in a single day.

III. CASE STUDY

Numerical simulation was carried out in the seminar room at the Egyptian Liquefied Natural Gas (ELNG) administration building (Fig. 1) of size 5.8m x 8.25m x 3.5m as shown in Fig. (2). The room is served by a variable air volume box via four air supply square diffusers and air is exhausted via exhaust and return grilles. The room has desks and chairs to accommodate up to 22 occupants. The activity in the room is usually sedentary with heat generation from the overhead projector during presentations, from the students, fluorescent lamps and solar heat gain. Fig. (3) represents the room when it is unfurnished. Two cases of furniture configuration are studied, Fig. (4) represents the transverse furniture (case A) and Fig. (5) represents the longitudinal furniture (case B). Both transverse and longitudinal furniture room case (A) and (B) have the same components where it consists of two doors, two windows, one board, two cupboards, 22 chairs, disk with a box and one lecturer chair.

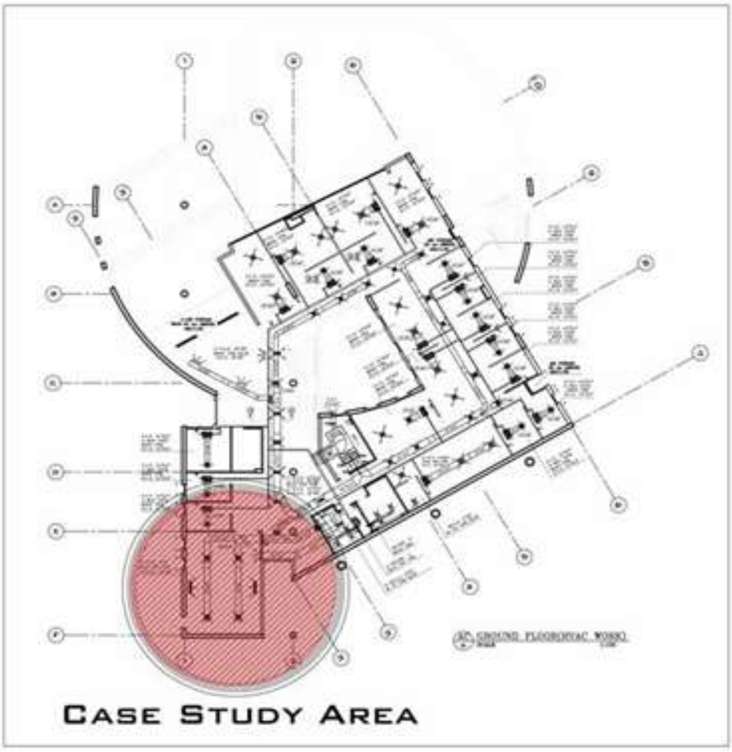

Fig. 1: ELNG Administration Building

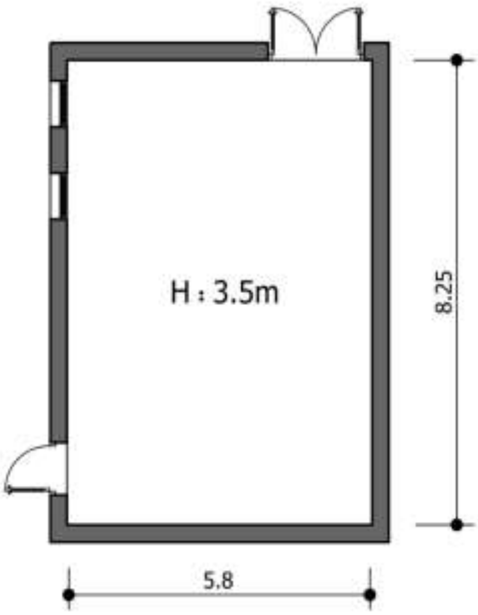

Fig. 2: Seminar Room Dimensions

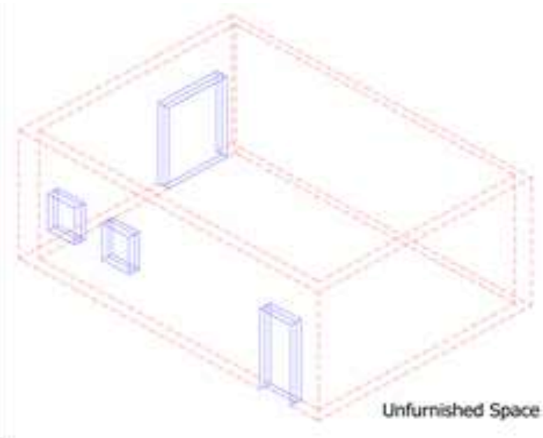

Fig. 3: Unfurnished Room

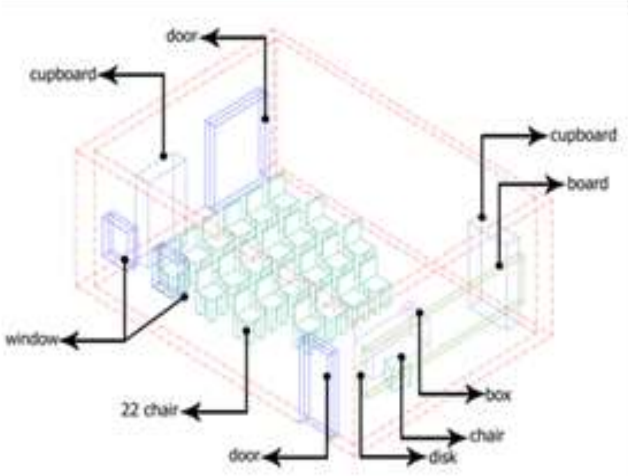

Fig. 4: Transverse Furniture (Case A)

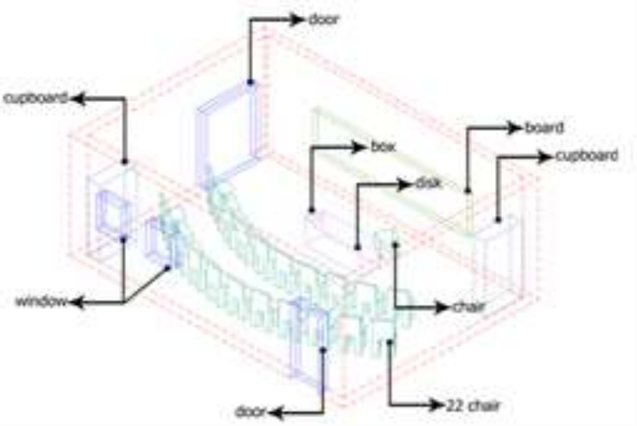

Fig. 5: Longitudinal Furniture (Case B)

IV. BOUNDARY CONDITIONS

Boundary conditions are required along all domain boundaries for all dependent variables in order to complete system equations. The air is introduced through the supply of each air conditioning unit and outlet is the return and exhaust of the unit. Two main furniture layouts were investigated architecturally, namely; "A" and "B". "Furniture Layout A" is a transverse furniture arrangement, on the other hand; "Furniture Layout B" is a longitudinal furniture arrangement. For each layout, the air velocity at inlet is assumed to be uniform. Five HVAC engineers were requested to provide alternate configurations for supply and return locations. Each HVAC designer proposed a solution for each furniture configuration, all five designers recommended changing return location in both directions transverse and longitudinal, horizontal and vertical with different heights by keeping supply at constant location to decrease changing system cost. (Fig. 6, Fig. 7, and Fig. 8)

A comparison between comfort area versus return location and furniture configuration was performed using Microsoft excel. For each case resulting in maximum comfort area, analysis of furniture configuration and the return location and orientation were applied. Using CFD, comfort area was calculated with respect to the different supply and return configurations.

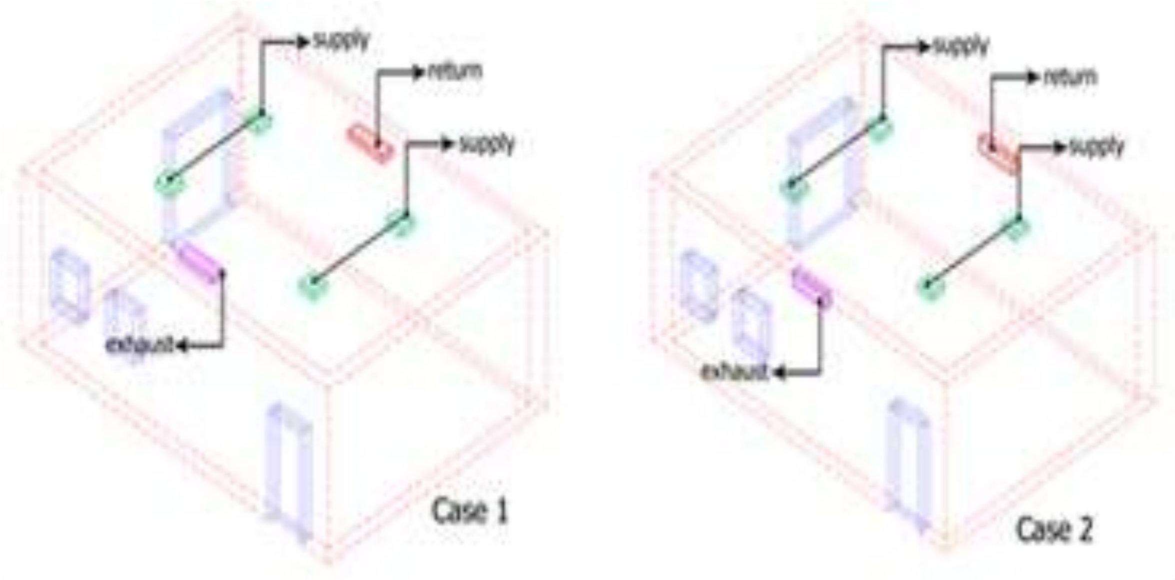

Fig. 6: Supply and Return locations in Proposal (1) and (2)

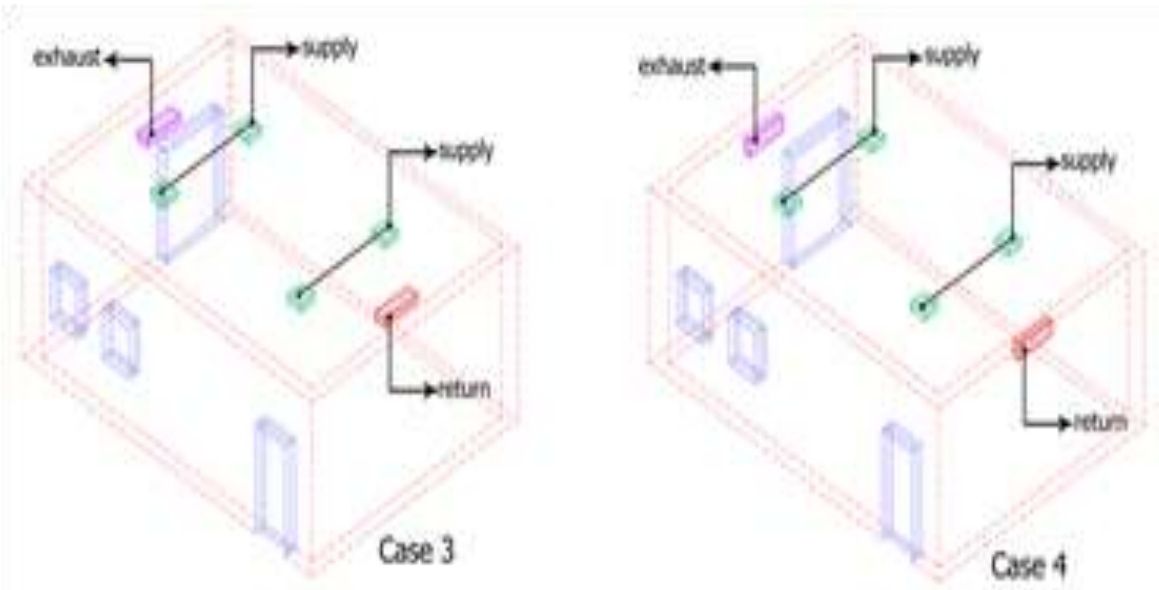

Fig. 7: Supply and Return Locations in Proposals (3) and (4)

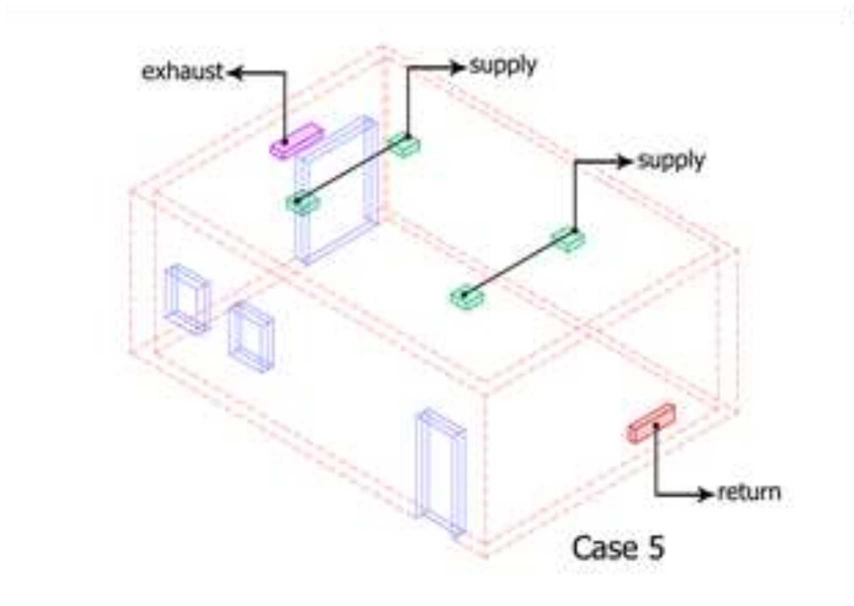

Fig. 8: Supply and Return locations in proposal (5)

V. RESULTS AND ANALYSIS

A numerical simulation was performed to investigate the optimal furniture and return locations that yield to the maximum possible comfort of occupants. Fig. (9) illustrates the decision tree followed within this study. Two main furniture layouts were investigated. “Furniture Layout A” is a transverse furniture arrangement, on the other hand; “Furniture Layout B” is a longitudinal furniture arrangement.

For each layout, different return locations were studied and illustrated. For a typical conference room, the location to study the air flow dynamics should be the location that is most occupied by the users, and at the elevation of the draft sensitive area of humans that is at the height of a seated person. Therefore, a horizontal section was taken at 0.8 m from the floor level.

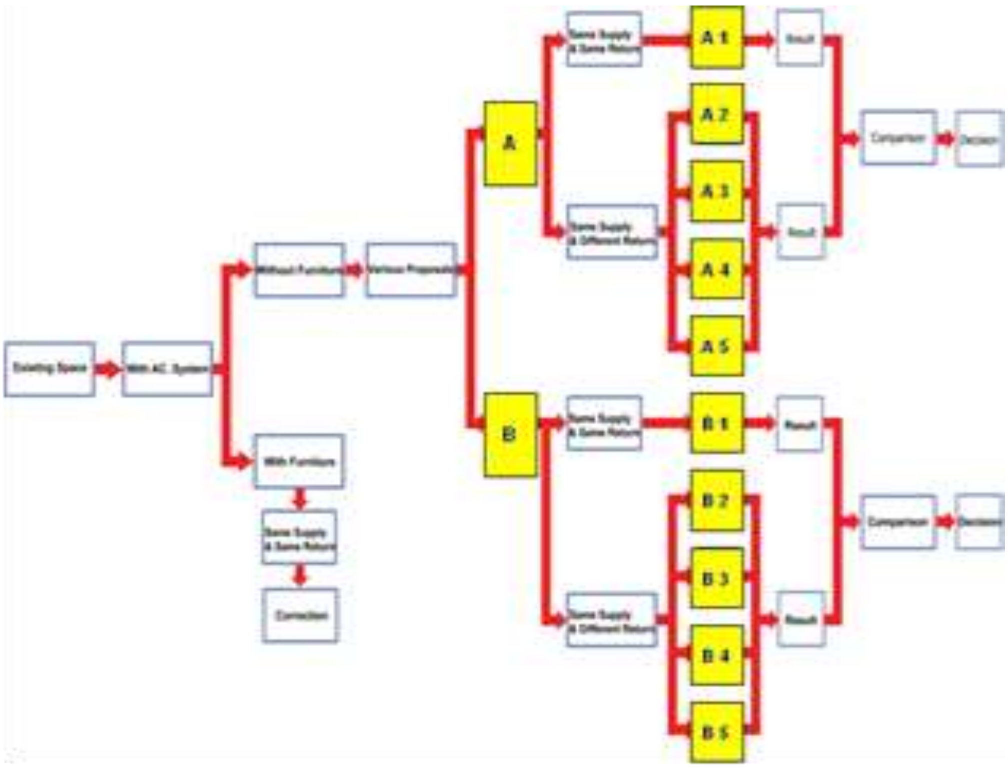

Fig. 9: Decision Tree Analysis

Case A-1

Furniture is placed in transverse direction where return and exhaust were located horizontally in a transverse direction. Four zones of discomfort were observed under the supplies, where the air velocities (shown in red and yellow colours) increased in the area between the discomfort zones and the walls at the back seats. Two of the discomfort zones were located in unfurnished areas presenting 7.5% of the total area while the numbers of occupants in discomfort zone were only four (Fig. 10).

Case A-2

Same configuration of Case A-1 was used, with a slight change that is returns were located at the walls (30cm from ceiling) instead of the ceiling. This altered configuration did not change the observations significantly, however, the discomfort area was reduced to 7 %, and number of occupants in discomfort zone was equal to two (Fig. 11).

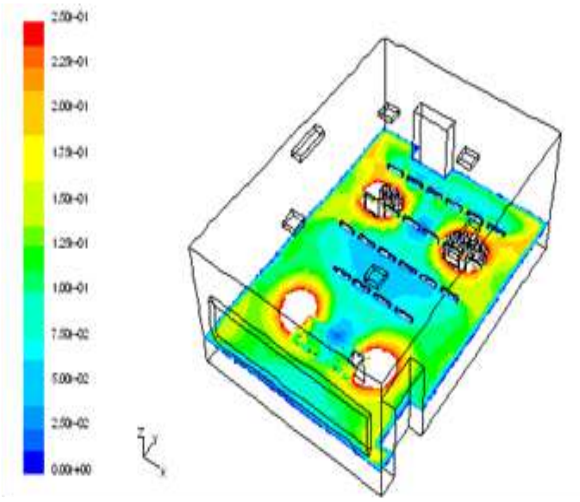

Fig. 10: Case A-1, Contours of Velocity Magnitude (m/s)

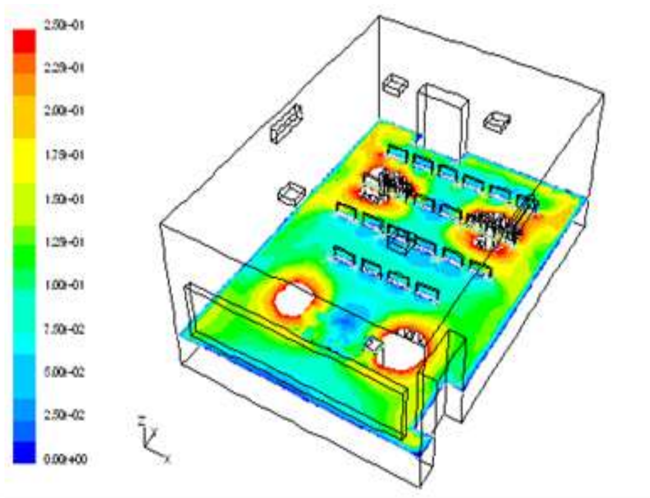

Fig. 11: Case A-2, Contours of Velocity Magnitude (m/s)

Case A-3

Returns were configured to be in the longitudinal direction (i.e., in front of, and behind the seated occupant). In this configuration, the discomfort area was limited to four zones located directly under the supplies, and of a proportion of 6%, and the number of discomfort occupants was three (Fig. 12).

Case A-4

Return locations were changed to be on the wall (30cm from ceiling), as a result, the highest air velocities were observed under the supplies and extending to the nearest corresponding wall. The observed discomfort area was equal to 6.3 %, and the observed number of discomfort occupants was equal to one (Fig. 13).

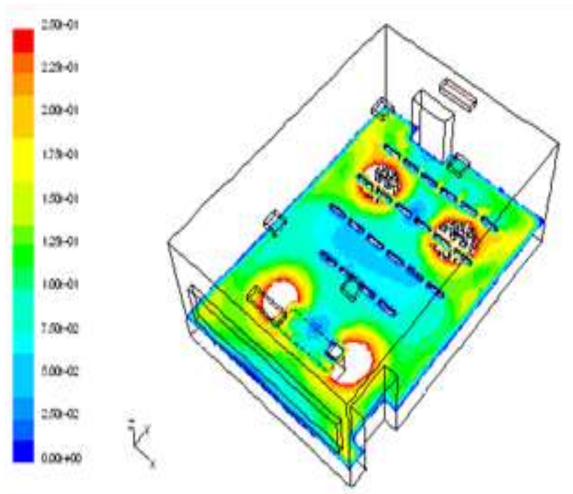

Fig. 12: Case A-3, Contours of Velocity Magnitude (m/s)

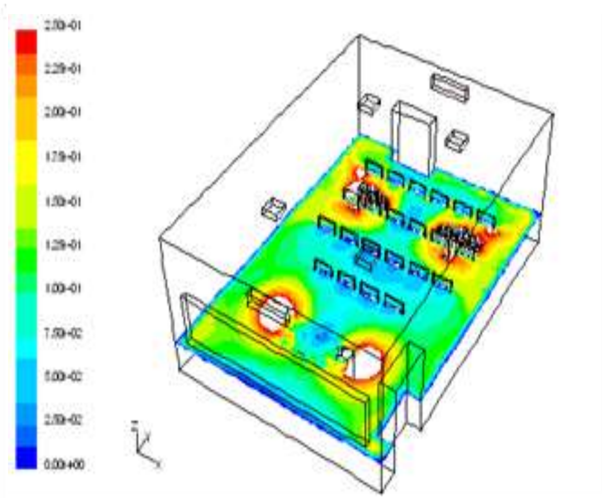

Fig. 13: Case A-4, Contours of Velocity Magnitude (m/s)

Case A-5

Returns were configured to be one on the wall (i.e., vertical), and the other one on the ceiling (i.e., horizontal). This configuration resulted in the highest discomfort area. Four zones of discomfort were observed; one of them reached the front board. The discomfort area was equal to 11.5 %, and number of discomfort occupants was equal to four (Fig. 14).

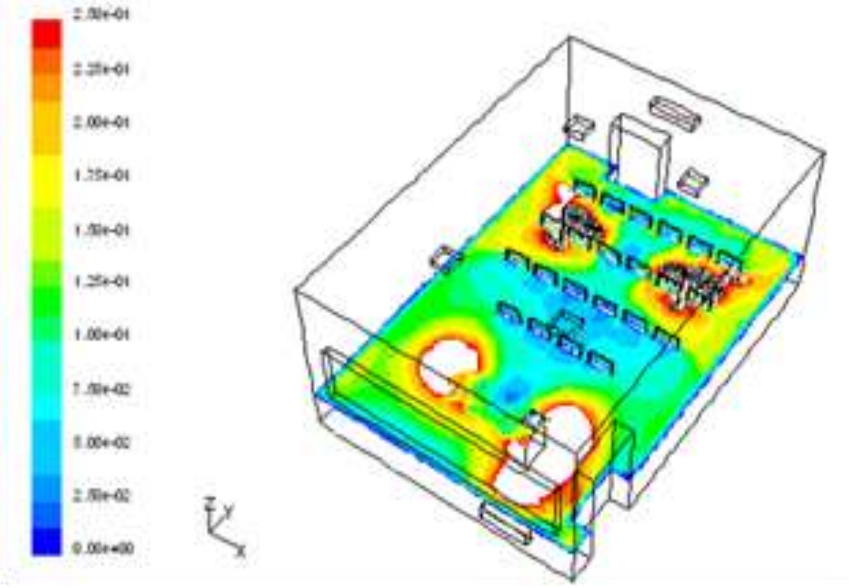

Fig. 14: Case A-5, Contours of Velocity Magnitude (m/s)

Case B-1

As shown in Fig. (15), air velocity is uniform all over the space and less than 0.25 m/sec, the discomfort area is equal to 0%, the number of discomfort occupants is equal to zero, and the highest air velocities are around the back rows of the space. Maximum air path velocities are from the front supplies; meanwhile, normal velocities appear through the back supplies.

Case B-2

Observed air velocity is greater than the comfort limit in three locations, between back wall and cupboard, between front wall and cupboard, and beside the board and front wall, the area of discomfort increased to 2.25%, the number of discomfort occupants is equal to zero (Fig. 16).

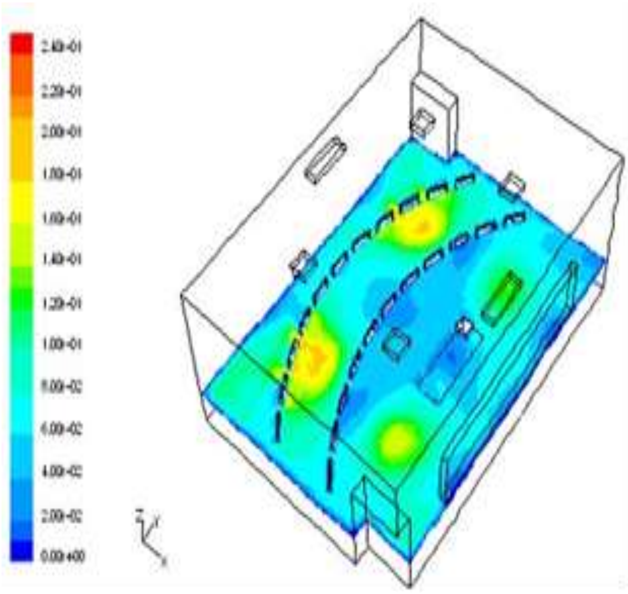

Fig. 15: Case B-1, Contours of Velocity Magnitude (m/s)

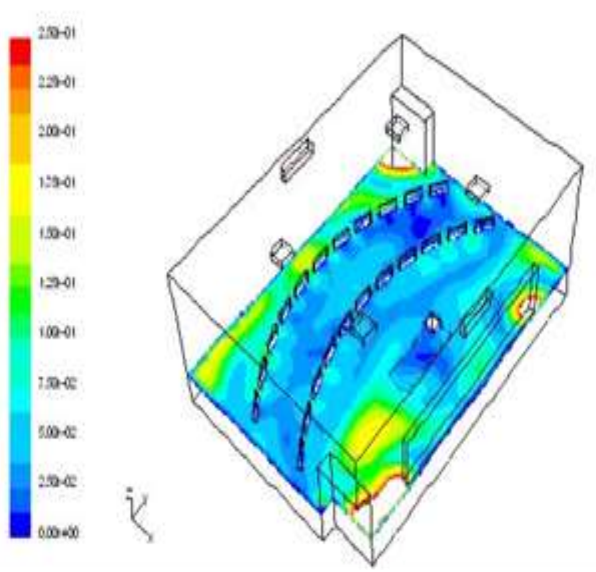

Fig. 16 : Case B-2, Contours of Velocity Magnitude (m/s)

Case B-3

The return locations were changed to be along the longitudinal direction. Due to such change, four locations of discomfort appeared. The discomfort locations were observed directly below the supplies, and increased around the seats locations. Therefore, the area of discomfort increased to 6%, and the corresponding number of discomfort occupants was three (Fig. 17).

Case B-4

In this configuration (Fig. 18), return locations were changed to be on the walls but the same as those of the previous case (Case B-3). Observed results of this case were similar to those of the previous one; discomfort area increased to 6.5 % and the number of discomfort occupants were four.

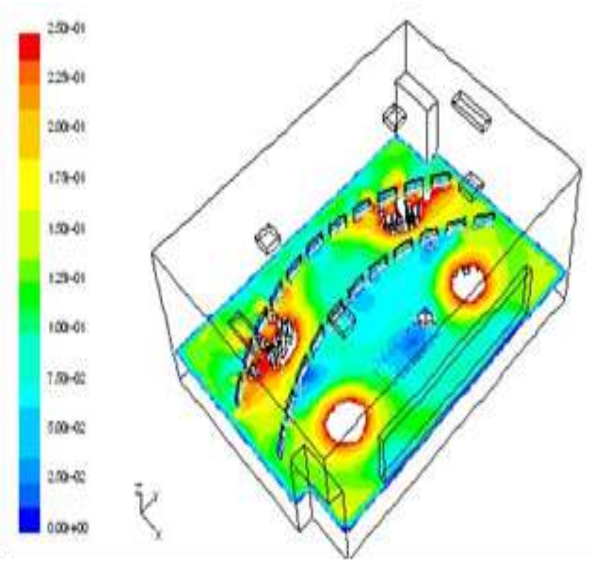

Fig. 17: Case B-3, Contours of Velocity Magnitude (m/s)

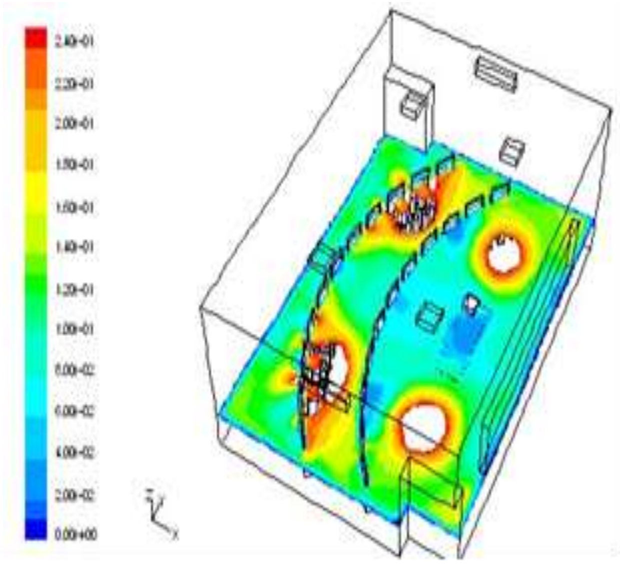

Fig. 18: Case B-4, Contours of Velocity Magnitude (m/s)

Case B-5

Returns were configured to one on the ceiling (i.e., horizontal) and the other on the wall (i.e., vertical) (Fig. 19). This configuration resulted in four large areas of discomfort under the supplies that extended to the front wall. The discomfort area reached 17.5%, and the numbers of discomfort occupants were seven.

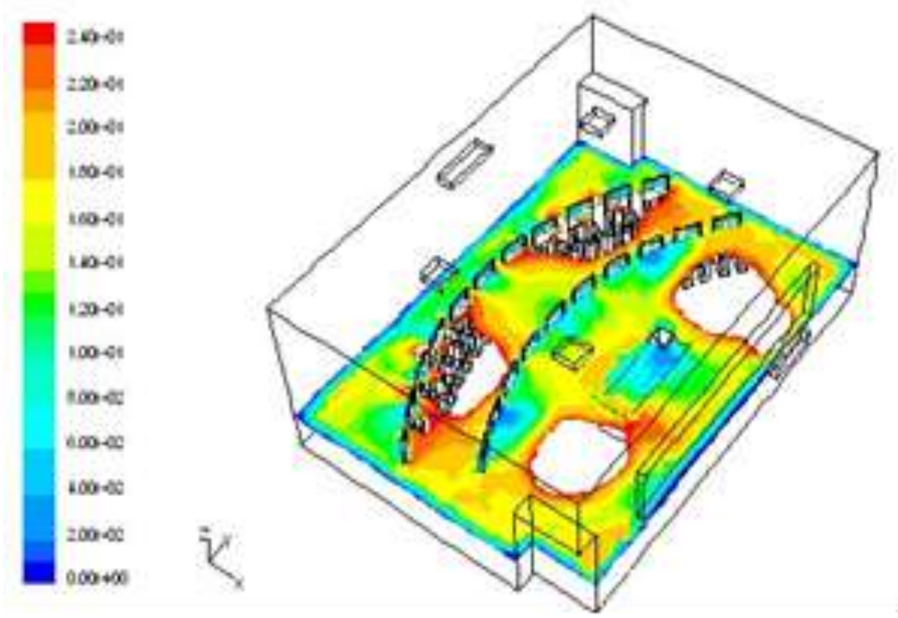

Fig. 19: Case B5, Contours of Velocity Magnitude (m/s)

VI. SUMMARY OF OBSERVATIONS

Furnished spaces have an air flow distribution and different velocities from unfurnished spaces where transverse and longitudinal furniture configurations have different air flow distribution. When studying a certain furniture configuration, changing the return locations dramatically affects the air flow distribution pattern. Within the presented case study, the horizontal returns produced more comfort zones than the vertical returns. It was observed that when the alignment of the returns and the furniture are the same, maximum possible comfort is achieved.

A combination of vertical and horizontal returns resulted in maximum discomfort for the occupants. Returns located at low elevations resulted in greater discomfort area than those located at higher elevations (Fig. 20, 21).

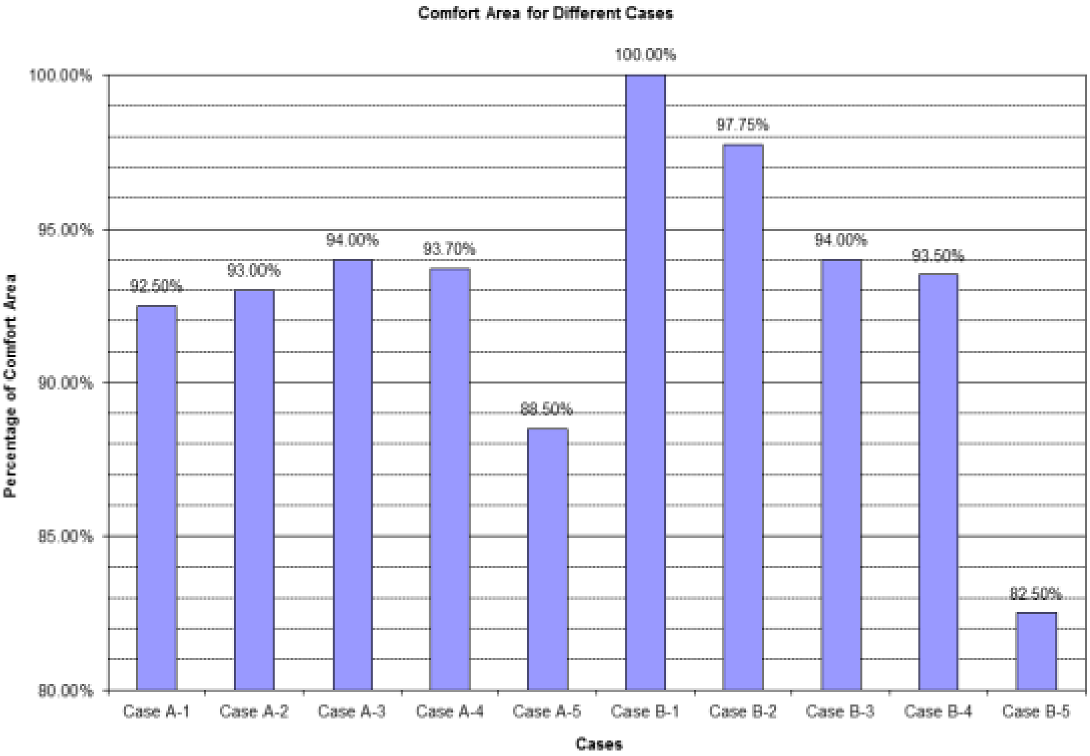

Fig. 20: Percentage of Comfort Areas for All Concepts

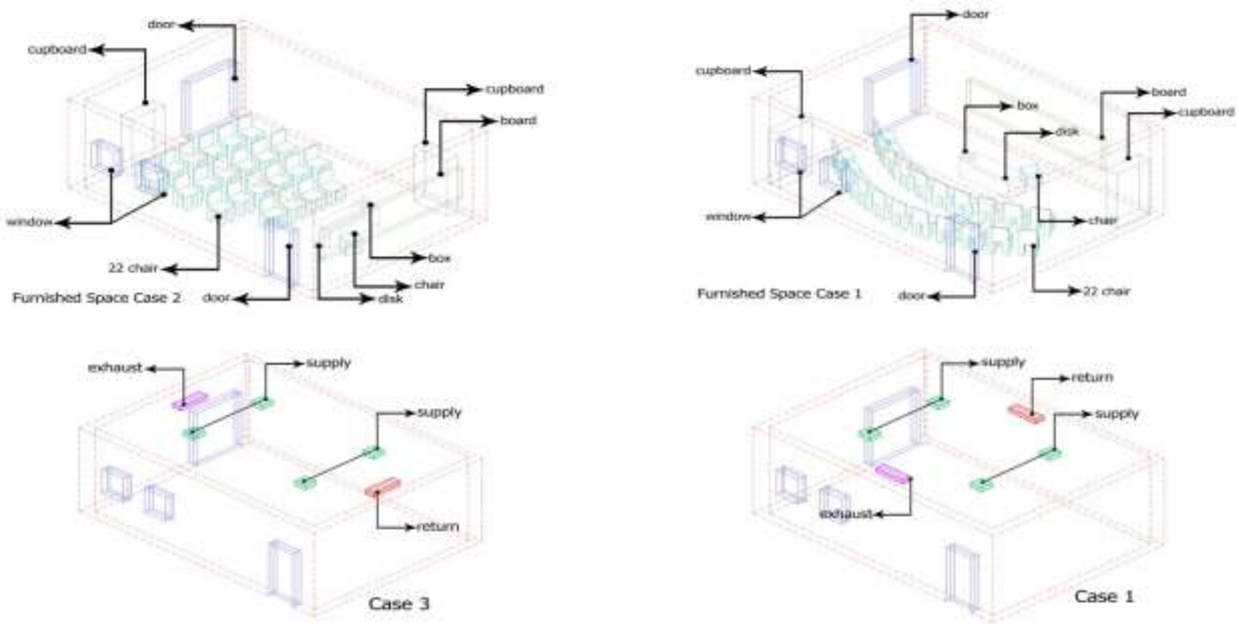

Fig. 21: Optimal Cases A-3 and B-1

VII. CONCLUSION AND RECOMMENDATIONS

CFD, an important tool in HVAC engineering, was used to analyse the data generated by models representing the complexity of the flow patterns that evolve inside the ventilated spaces of a seminar room. This CFD analysis allowed to predict air flow conditions and to estimate the indoor thermal comfort of the occupants in the seminar room. Furniture locations inside the room perturb the indoor air quantities causing the deviation of the air flow motion. The investigation shows that boundary conditions and inclusion of real-world geometries, like diffuser inlets, have a strong influence on overall fluid flow behaviour.

Furniture is powerful tool in location and orientation inside the architectural space. Comfort air velocity for occupants is related to their position. The location of supply, return and exhaust has a great effect on the airflow distribution inside the room. They should be located with respect to furniture location to avoid draft which affects comfort inside the room. In summary, it could be concluded that:

- For a space that has a fixed furniture configuration, manipulating the return location could enhance the observed comfort.

- Several models of return and exhaust have been used to achieve a better air velocity prediction with the numerical method. This is to emphasize the importance of detailed inlet supply specification (as part of the boundary conditions) in the accuracy of the prediction.

- Upon studying an existing place, for which changing the conditioning system peripherals is not feasible, manipulating the furniture configurations enhances the observed comfort.

It is recommended that the architect has to coordinate with all consultants at the beginning of any project. If a coasty Central air conditioning system already exists, the Architect and Engineer must cooperate to optimize the comfort needs by:

- Trying all accepted interior design furniture (Architect role).
- Changing positions of return and exhaust (Engineer role).

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