HVAC solution for shopping centers

Mustafa Muaxheri* and Januz Bunjaku

University of Prishtina, Faculty of Mechanical Engineering, Kosovo

*Corresponding email: muhxheri_m@yahoo.com

SUMMARY
Shopping center is a building or set of buildings that contain stores, with interconnecting walkways enabling visitors to easily walk from store to store and to allow shoppers to be as close as possible to the exposed products.

Realization of specific IAQ and hygienic conditions of ambient in shopping center has wide variety and depends from different indoor and outdoor factors, as type of building, technologies, outdoor temperature and humidity, level of occupancy etc. Each of these factors has to be treated carefully as a part final solution.

The paper will present impact of architecture and building design on technical solutions for shopping centers, design elements and criteria’s of HVAC for shopping centers, air conditioning principles, possibilities for saving of energy and recommendation for design approach.

KEYWORDS
Shopping centers, Technical solutions, Design elements, Energy saving

INTRODUCTION
Growing of life standard has impact in growing of spending power of people and their lust. They buy not only the basic products but also different products for decoration, jollity, amusement, comfortable life, easier homework etc. With the combination of fashion, food, entertainment and services, shopping centers have greatly expanded their role in the environments they serve.

Entertainment quickly became an industry buzzword in the late 1990s as technological advances allowed shopping center developments to foster the same magical experiences that were once only seen in national amusement parks. Since the start of the entertainment wave, retailers have focused on keeping their presentations exciting and shopping center owners have striven to obtain tenant mixes that draw traffic from the widest audience possible. Under one roof or in an outdoor retail format, consumers enjoy children’s plays capes, virtual reality games, live shows, movies in multiplex cinemas, a variety of food in either the food court or themed restaurants, carousel rides, visually stunning merchandising techniques, robotic animal displays, and interactive demonstrations. Many shopping centers are also focused on added service-oriented tenants, which offer today’s busy consumer an opportunity to complete weekly errands or to engage in a variety of other activities.

From the HVAC installation point of view shopping centers are buildings of special destination and requirements and in that way they have to be treated. Engineers and Designers, today, constantly face the challenge to conceptualize, design and specify best and cost-effective solutions for treating HVAC in shopping centers.
It means that from the concept, basic solutions till distribution elements and automatic the HVAC solution must be integral part of overall building solution.

ARCHITECTURE, BUILDING DESIGN AND HVAC INSTALLATIONS

Shopping centers distinguish based on their architectonic solution and diversity of the destination of different spaces inside center, and HVAC installation's depends from this diversity as well. The following design considerations have impact on both the appearance and the HVAC installation of a shopping center: Compactness (surface area- to- volume ratio), size and location of windows and the nature of the building materials. Thus, when architects start to design the appearance of the shopping center, they simultaneously start the design of HVAC installations. Because of this inseparable relationship between architectural features and HVAC of buildings, we can say that HVAC installations are formgivers in architecture of shopping centers.

The equipment required for HVAC is often quite bulky, and because it requires access to outside air, it’s frequently visible on the exterior. Thus HVAC is interconnected with Architecture, and as such, must be considered at earliest stage of the design process.

Architecture of today's shopping centers is very modern. In one place we have supermarkets with a variety of food, shops and garages, restaurants and cinema's with high level of occupancy etc., all needs large volumes of treated preconditioned air to satisfy needs for hygiene, energy efficiency and IAQ.

Cities shopping centers are often located close to the building complexes and usually with one or two free façades, toward the main road. But new bigger power centers are built as independent buildings outside the city centers with all free façades, big parking area and all facilities under one roof. Both solutions are challenges for architects because of diversity of requirements. In first case the building should be adapted to its environment, incorporated with ambient architecture and as independent building can be completely new attractive architecture but still in close interaction with HVAC equipment, thinking about users comfort, needs and behavior.

Ideal HVAC equipment should sanitize cool, heat, humidify, dehumidify, and be part of interior and exterior of building, evenly distribution air through the area and all cost effectively. That is the challenge, the designer face today.

High occupancy in the selling area is a major factor affecting HVAC system and IAQ as well, dictating the choice of a system for treating fresh air. Therefore is important to design accesses, entries and interconnecting walkways disabling high concentrations of consumers in certain area.

Interior of the shopping centers is usually very well organized and utilized as a selling space, without shelving but still representing a unique space whole. Floors of selling area are connected with electric mobile stairway or lifts, enabling continuous air intercourse of whole selling space.

Regarding of the interiors look-out there are significant differences between the centers, but still, the principals are the same. The cupboards, show cases and clothes press are usually installed beside the outside walls and inside the selling area as well.
Shopping centers windows and fronts are very often fixed, free standing and used as a shop-show and for natural illumination. A summer sun can provide as much as 1000 W/m² of radiation measured in a plane normal to the sun's direction. In that case thermal and insulation gains have to be treated very carefully. The interior temperature must be controlled to avoid the process of condensation during the winter period. In fully glazed buildings without efficient solar protection is at very large risk of overheating, and artificial cooling will be needed in all climates, even in cold ones.

For the external walls the insulating material must be placed on the external side of the internal wall. If it is placed on the internal side of the external wall it will provide almost no protection. The external wall structures can be thermally insulated on the external side, in the core of a double wall; and on the internal side. The method of the ventilated wall structure can also be implemented.

The protection of the exhibited products and wares against direct solar radiation can be realized using the different types of; parasols, shadow shading or protection device against solar radiance. The device is often equipped with solar sensor so can control the radiation.

To reduce solar heat glare, many passive envelopes use internal blinds. The effectiveness of internal blinds for heat reduction depends on their ability to reflect incoming solar radiation back through the glass before it can be absorbed and converted into "sensible" heat. Internal shading therefore has limited effectiveness since it allows heat to enter the room. The heat absorbed and re-radiated by the internal shade therefore contributes directly to the instantaneous cooling demand on the HVAC system.

The façade is important part of buildings envelope that protect centers occupant from the outdoor climate, noise and pollution. A large part of the solar radiation that contributes to the heating and cooling loads and lighting as well enters building through façade.

Extreme thermal insulation measures reduce the heat demand after working hours but increase the heat gains during working hours. Therefore, extreme insulation measures don’t mean always energy savings but reduction in the internal heat is energy saver. Today, shopping center’s building is airtight, which means that the quality of the indoor air depends by correct designed ventilation system (Abel and Elmroth, 2007).

Finally energy demands depend on the building envelope quality which is represented with the thermal characteristics of the energy efficient building envelope:

- \( U_{\text{Wall}} < 0.30 \text{ W/m}^2\text{K} \)
- \( U_{\text{Roof}} < 0.15 \text{ W/m}^2\text{K} \)
- \( U_{\text{Floor}} < 0.40 \text{ W/m}^2\text{K} \)
- \( U_{\text{Wind}} < 1.30 \text{ W/m}^2\text{K} \)

The most important strategy for HVAC optimal design of shopping centers and buildings in generally is to design and build according to the climate where the center is located. Geographically, the climatic conditions are diverse and hence the designer is required to describe and interpret climate in ways that are relevant to HVAC design (Abel and Elmroth, 2007).
DESIGN ELEMENTS OF HVAC FOR SHOPPING CENTERS

Functionally, shopping centers are divided into two main wholeselling spaces as main and secondary spaces like administration, storehouse, kitchen, workrooms etc. Each of these spaces has to be treated independently, because of different thermal and IAQ criteria's and requirements and should be designed for the health, productivity and comfort of employees and occupants.

Based on ASHRAE (1992) draught is defined as unwanted local cooling of the human body caused by air movement. The draught increases when the air temperature decreases and the air velocity increases. Even, combination of air velocity at 0.15m/s and air temperature at 22-24°C can cause draught complains. The expected percentage of dissatisfied persons with the draught, for different combination of mean air velocity, air temperature and turbulent flow intensity, can be 10, 15 and 20%. Higher air velocity, f.ex. 0.25 m/s cause more draught complains from slightly dressed saleswomen's. ASHRAE Standard 55 recommends elevated air speeds at elevated temperatures.

According some international experiences, indoor air temperature in selling areas of shopping centers should be in the winter period between 19-24°C and in summer 24-27°C. ASHRAE Standards and personal designing experience recommends 20-22°C for winter and 26°C for summer period at relative humidity up to 50%, and annotation for avoiding of the condensation on glass surfaces.

If the shop windows and show cases are built as a separated area, they have to be heated by detached system nor supplying conditioned air or installing the heaters. But, there are applied technical solutions with complete independent air conditioning system for such zones.

Largeness of shopping center and location as well, has significant impact on thermal loads through the occupancy, visitor’s frequency and the fluctuations of loads. If the shopping center is located in the city's center or is the only shopping mall in the certain periphery settlement, the level of occupancy will be higher and approximately constant during the day, opposite to the periphery shopping centers with vastly variation of the occupancy, during working hours. Recently, 190,000 visitors come to the Istanbul Cevahir Shopping centre daily. The internal heat generated from occupants is often greater than the heat loss through the building envelope, even when the outdoor temperature falls far below 0°C.

As its mention above, architectural solution of the building, prerogatively of the façade, show cases and windows, their number, dimensions, type and orientation has significant impact on heating and cooling loads. Type of the window, shape of the show case and largeness of the glass surface are in the direct proportion with the heat load from the solar radiation. The outdoor conditions influencing the buildings indoor air can be divided in following groups: heat transmission, ventilation loss, infiltration and exfiltration, solar radiation, humidity transport and air pollution.

The interaction between the building structure and the IAQ is a complicated dynamic process that is today usually handled by using calculation or simulation programs commercially available.

The role of the HVAC system will be to supply or to remove as much heat as required, and to remove as much of the airborne pollutants as required, to achieve the desired indoor climate
in shopping center (Novak, 2002). Based on this there are established HVAC principles and
design criteria’s as follows:

a. **Heating principles**
   - floor heating (~ 50-70 W/m²)
   - four pipe fan coil system (with primary air for retail stores)
   - AHU with 50 - 70% heat recovery
   - air curtain without heating (using warm air from the top of the entry space)
   - radiant or cooling panels (in same cases)
   - radiators for auxiliary rooms

b. **Cooling principles**
   - floor cooling (~ 50 W/m²)
   - four pipe fan coils system (tv1 > 12°C)
   - AHU with adiabatic cooling and/or build in auxiliary cooling system
     (heat pump heat recovery system)
   - free cooling, using fire shafts or fire openings

c. **Air conditioning principles**
   - Indoor temperature: 22-24°C (according to ISO 7730 and EN CR 1752)
   - indoor humidity: 35-55%- recommended 50%
   - air velocity: 0.2 – 0.3 m/s
   - lighting load 10 - 15 W/m2 or less
   - Maximum pressure difference cca. 800 Pa
   - Thermal insulation of distribution ducts
   - Waste air from the space with intensive odour- directly outside
   - Ventilation rate: CO₂ controlled; “The solution to air pollution is dilution”
   - Fresh - outdoor air rate:
     - according to EN CR 1759, class B or C
     - according to VDI 2082 : 6-9 m³/h,m² of floor area for general stores,
       2 m³/h,m² of floor area for less occupied regions and 12 m³/h,m² of
       floor area for self-service market
     - according to general experience : 25-36 m³/h, person (7 - 10 l/s, person)
     - air cleaning : pre-filter G3-G4 ( EN 779) and fine-filter F7 - F8 (EN 779)

Air distribution systems, like other parts of HVAC systems, are intended to achieve required
thermal comfort and ventilation for space occupants and shopping activities. ASHRAE (2007)
defines four air distribution methods, but partially mixed systems (provide limited air mixing)
and task/ambient air distribution (personally controlled desk outlets, spot air conditioning
systems) are not treated here. Two extreme air distribution strategies for shopping centres area
are:
   - mixed air supply with low height, variable air volume diffusers
   - displacement air distribution

- **Mixed air distribution system**

In mixed air systems, high-velocity supply jets from air outlets maintain comfort by mixing
room air with supply air (dilution ventilation).
• Over floor displacement air distribution system

Displacement System discharge cool air at low locations with very little entrainment of room air create thermal stratification throughout the space.

Benefits and limitations

Benefits include the following:
- Complete mixing of Supply and Room Air
- Temperature and Contaminant Levels Similar Throughout Room (Vent. Eff. ~100%)
- Return Air Temperature ~ Room Air Temperature
- Overhead Heat Gains Mixed with Room Air
- Supply air with lower moisture content
- Most common for designers and installers

Limitations include the following:
- Partial load operation can reduce air velocities, reducing room air mixing and compromising thermal comfort.
- Use of the same diffusers may cause inadequate performance in heating mode and/or excessive velocity in cooling mode.
- Shopping centers ceilings more than 4m high requires special design considerations to provide acceptable IAQ.
- Because of use of high velocity jets, obstructions in the shopping centers space (e.g. shelving’s, wall partitions, furniture) can reduce comfort.
- Lighter than air contaminants are uniformly mixed in the space and typically result in higher contaminant concentrations, which may compromise IAQ.

**Displacement Systems**

Benefits include the following:
- Minimal mixing of Supply and Room Air
- Removal of airborne contaminants more effective (Ez=1.2)
- Return Air Temperature > Room Air Temperature
- Overhead Heat Gains isolated from Room Air
- Diffuser noise level is lower
- Lower turbulence intensity can reduce draft-related complaints

Limitations include the following:
- Not applicable in spaces with ceiling heights less than 2.7 m
- Poor results in spaces with exceptionally high occupied zone heat loads
- Not recommended for applications where contaminants are heavier and/or colder than ambient air

Analyzing all benefits and limitations for both distribution systems, thermal displacement ventilation system is recommended for shopping centres HVAC systems with following application considerations:

- Use displacement ventilation in combination with heated floors and radiant panels
- Outlets should supply ventilation air about 2K lower than the desired room temperature
- Avoid using thermal displacement and mixing air systems in the same spaces

**WHERE CAN WE SAVE ENERGY?**

The resources that can be allocated to energy-saving measures must be used efficiently. The energy-saving solutions that are chosen must not require more energy than proposed savings. There are two recommended criteria’s for energy efficiency and both should be fulfilled.

- Measures taken to reduce energy demands must maintain or improve the function, indoor climate and technical quality of the shopping centers.
- The resources used for technical solutions or for measures taken to reduce energy demands must, at least, be balanced by the actual total energy savings.

Derived from recent experience of building, maintenance and use of HVAC installations for shopping centers there are following useful steps for energy savings:

- Installation of **Building Management Control System (BMCS)** to control both HVAC and Lighting. BMCS allows time schedules and control strategies to be programmed providing control to large chillers and boilers.
• Installation of **energy efficient lighting** using lower wattage lamps.

• Installation of **energy efficient devices** such as electronic expansion valves and variable speed devices for regulation of motor speeds according to the amount of work required. Reducing motor speed by 10% can cut consumption by 27%.

• **High efficiency motors** are good investment and they save energy from 2% to 8%.

CONCLUSIONS

• Shopping centres HVAC design needs an integrated approach and close collaboration with Architects and Building engineers in early faze of defining building construction, envelope and interior.

• Reducing of solar radiation that contributes to the heating and cooling loads and lighting as well enters building through façade and protection of centers occupant from the outdoor climate, noise and pollution.

• Respecting International norms and standards in designing HVAC systems in combination with energy efficiency. Energy efficient design can save up to 2/3 of energy used in standard design.

• Using of displacement ventilation, floor heating and cooling are energy saving technologies for Shopping centres.

• Using of all energy saving opportunities without compromising occupants comfort or HVAC equipment performance.

REFERENCES