

Designing Guidelines for Metro Stations in Developing Countries: The Case of Dubai

著者	Mushtaha Emad S., Nahle Ranime, Tahmaz Nour, AIKadry Mohammed
journal or publication title	IRSPSD International
volume	7
number	4
page range	83-96
year	2019-10-15
URL	http://doi.org/10.24517/00057218

doi: 10.14246/irspsd.7.4_83



Designing Guidelines for Metro Stations in Developing Countries: The Case of Dubai

Emad S. Mushtaha^{1*}, Ranime Nahlé¹, Nour Tahmaz¹, and Mohammed AlKadry¹

1 Dept. of Architectural Engineering, College of Engineering, University of Sharjah

** Corresponding Author, Email: emushtaha@sharjah.ac.ae*

Received: May 16, 2018; Accepted: November 15, 2018

Key words: IESVE, Mass Motion Oasys, Flow Design Autodesk, Wind Flow, Hot Climate Regions, LOS, Dubai.

Abstract: The aim of this study is to evaluate the effectiveness of Dubai metro stations, studying their external roof forms as well as their internal level of services (LOS). The first stage of the study generally studied the best roof form of metro station buildings suitable for Dubai in hot climate regions. Common shapes of roof surfaces of metro stations in hot climate regions such as curvilinear, rectilinear, and composite were studied. Several parameters such as solar radiation, wind pressure, and wind velocity were investigated using an Integrated Environmental Solution Virtual Environment (IESVE) and Flow Design Autodesk in order to select the best roof form suitable for Dubai. Secondly, after receiving the best roof form suitable for hot climate regions, the study was extended to investigate the (LOS) inside Dubai Metro Station using Mass Motion Oasys (MMO). As a result of the study, curvilinear roof forms were found to be more efficient for hot climate regions, matching with the existing roof form of Dubai Metro Stations. Additionally, the second stage of the study provided design guidelines for metro station buildings for hot climate regions.

1. INTRODUCTION

1.1 Background and Literature Review

A metro is an electric passenger railway in an urban area with a high capacity, frequency, and grade separation from other traffic. It is known as a rapid transit system, underground, subway, elevated railway, metro or metropolitan railway system ([American Public Transit Association, 1994](#)). According to [Sustainable Low Carbon Transport \(2018\)](#), metros are also defined as urban guided transport methods operated on their own right of way and separated from the road and pedestrian movement. They are designed for operations on surface level, in tunnel, and viaducts but with physical separation in such a way that unintentional access is not possible. The metro station is a site where passengers regularly board and alight from subways, light rail, and rapid transit systems in an urban network. Herein, when designing a metro station, it is important to assure that the building performs well thermally during peak hours as well as maintains an acceptable pedestrian

flow within the building. Therefore, many factors need to be considered when designing a metro station such as the flow design inside the building, the impact of sun radiation on the roof, which in return affects the interior spaces of the building thermally, thus altering the pedestrian comfort level and leading to increased use of air conditioning, and others like the effect of wind flow on the building, the building services, complex shapes and geological conditions ([Dunncliff, 1993](#)). [Takayanagi, Yamada, and Shibahara \(2015\)](#) stated that it is becoming more important to assess pedestrian flow today, where it has been used as the basic data for congestion and comfortable space planning for urban facilities and architecture. Herein, this research merges together thermal studies with the flow of people in Dubai metro stations because all the roof forms of metro stations are similar. One of the reasons for choosing a study in Dubai is the international role of Dubai as a major tourist attraction.

A study conducted by [Hoogendoorn, Hauser, and Rodrigues \(2004\)](#) recognised aspects that alter the pedestrian flow operations in the station designs. He found that many of the metro station design issues concern the access gates due to their abilities to impede a steady pedestrian flow. This is in regard to the congestion levels, levels of service (LOS), average walking times, delays incurred at gates, etc. The width of corridors in highly active buildings where congestion occurs has also a strong impact on pedestrian comfort level. A station's corridor width can also directly influence the pedestrian's average walking time and may also affect the level of service. Other relevant service facilities are also occasionally affected. [Jiang et al. \(2016\)](#) stated that simple design guidelines based on simulation models could always be used to set up design alternatives that contribute to a satisfying level of service. Researchers over the globe have published their studies on ways to measure pedestrian LOS in their regions focused on three primary areas: the characteristics of sidewalks, pedestrians and flow. This study uses Fruin level of service to analyse the flow characteristics and measure the density of people in the building. This study is completely comprehensive covering aspects of metro design from outside to inside, i.e. from roof form of the building to the flow characteristics inside the station.

1.2 Brief History of Metro Stations

The rapid transit system, which is an almost 150-year-old invention in Europe, and a little bit more than 80 years old in Japan, is one of the most popular and most efficient means of urban transportation. The following is a brief on metro stations through history.

1. The First Tunnel in London: The Metropolitan Railway is recorded as the world's first urban underground railway, which began its operations during January 10, 1863. The underground railway was built in shallow tunnels and is now considered part of the London underground. Despite the creation of numerous vents, smoke in the operating room caused discomfort towards the passengers in the operating of steam trains through tunnels, as well as limited the appeal of this mode of transport. Therefore, between 1863 and 1890, unfortunately, none proved successful in the numerous proposals that were set to build pneumatic or cable-hauled railways situated in London to overcome this problem. A new idea, proposed in the 1830s, linked London with some of the railway termini in its urban centre with the underground railway granting permission for the Metropolitan Railway, of such a line, to be built in 1854. Between Paddington and Farrington, it was opened in January 1863, carrying 38,000 passengers in gas-lit tunnels ([Telegraph, 2016](#)).

2. Turkey: The underground rapid transit system was constructed in the city of Istanbul, with it claiming to be the second city in Europe after London to have such a transit system. The construction was completed on December 5, 1874, and on its opening day, during 1874, it became known as “The Metropolitan Railway of Constantinople from Galata to Pera”. It is an impressive name for the shortest ‘metro line’ in the world: it has only one stop; it is not considered an actual metro but a funicular. In other words, it is regarded as a cable railway where a cable is attached to a pair of tram vehicles on rails. moving them up and down a steep slope; the ascending and descending vehicles counterbalance each other ([Guillet, 2019](#)).

3. United States: In the 1890s, the transportation infrastructure of downtown Boston, a labyrinth of limited roads laid out, along with Colonial cow ways – demonstrated total deficiencies for the necessities of a present day, clamouring city. Tremont Street, the city's Central Avenue, was consistently subject to gridlock from a meeting of pedestrian activity, horse-drawn transports, trolley lines, and electric streetcars. To correct the issue, the Boston Transit Commission, with Howard A. Carson as a lead architect, was made in 1894 to study fixes. A streetcar metro was chosen as the best arrangement and development started in March 1895. The finished project – the fifth on the planet, and the first in the United States – conveyed more than 100,000 riders on its opening day and more than 50 million travellers in its initial year ([Mathew, 2014](#)).

4. Spain: The primary line of the Madrid metro opened on 17 October 1919 under the guidance of the Compañía de Metro Alfonso XIII, consisting of eight stations and 3.5 km (2.2 mi). The Madrid Metro is the main metro framework in Spain and the second in the Spanish-speaking world after the Buenos Aires Underground. It was developed in a thin segment and the stations had 60 m stages. The broadening of this line and the development of two others occurred not long after 1919 ([Moya, 1990](#)).

5. Moscow: The USSR, in Moscow, developed its first underground metro in 1935. It is considered to be one of the most decorative undergrounds in the world with its stations known as underground palaces (Russell and Cohn (n.d.)).

6. Canada: Under the management of the Toronto Transit Commission (TTC), Toronto Subway is considered a large public transportation network, including light rapid transit, streetcars, and buses. Canada gained its first subway on 30 March 1954. It developed to be a single subway to expanding its stations, from 12 station lines running 7.4 km under the Yonge Street to a four line system consisting of 69 stations running 68.3 km ([Toronto Transit Commission, n.d.](#)).

7. Brazil: The largest metro system opened in 1974 was 74.3 km long, situated in Sao Paulo, the largest city in Brazil. The metro system is served by 64 stations consisting of five lines. Line 5 and Sao Paulo’s monorail of a 27km measured length remain under construction ([Revolvy, n.d.](#)).

8. Chile: Metro de Santiago is the metro framework serving Santiago in Chile. It is a system of five lines with a sum of 85 stations and is the main South American rubber-tyred metro. The thought to manufacture an underground railroad in Santiago goes back to 1944 when better approaches to enhance the turbulent transport framework were looked for after the fast population development the city was encountering from the mid-1930s. In any case, thoughts would start to come to shape in the 1960s, when the government moved for the improvement of an urban transport framework. On 24 October 1968, the administration of Eduardo Frei Montalva affirmed a draft put together by the Franco-Chilean consortium BCEOM SOFRETU CADE, and

on 29 May 1969, work started, building a system of five lines with an aggregate of 85 stations ([Mapa-metro, n.d.-a](#)).

9. Cairo: The biggest and most densely populated city in the Arab World and Africa is Cairo, where the population was recorded in 1987 to be 10 million residents, excluding the commuters who count two million that travel daily to Cairo for work. Cairo's public transport infrastructure welcomed 20,000 passengers/hour and, after the construction of the Metro, it increased to 60,000 passengers/hour. During 1982, after the French government's agreement on granting the necessary loan to Egypt, the construction of its metro began. On 27 September 1987, the opening of the first section took place and by 1989 the line reached its completion with a connection between Helwan and El Marg. It consists of 33 stations of 43 km in total length, in which 4.7 km is underground (Cairo (2016)).

10. China: In 1965, Beijing's metro was approved, motivated by military considerations, consisting of its first line with a length of 24 km. On 1 October 1969, the first line was opened in China. A rapid transit for a major city was a late comer considering China's condition as the largest population concentration in the national rail network; the local provision was out of step with the capital's standing ([Railway Technology, n.d.](#)).

11. South Korea: The combined urban rail transit system known as the Seoul Metropolitan Subway consists of twenty rapid transit, light metro, people mover lines, and commuter rail. Construction of the subway began in 1971 and publicly opened on 15 August 1974 ([Revolv, n.d.](#)).

12. Singapore: Based on a study conducted in 1967 by the United Nations Development Programme (UNDP), the Singapore State, and the City Planning Department, a concept plan was undertaken. This led to the concept for Singapore's MRT system. By 1922, Singapore projected a population of 3.4 million people which led to improving the metros' road infrastructure for the mass transit system to cope with the increasing number of travellers arriving in Singapore's central area. By the 1970s, traffic overcrowding in the city had also worsened, making it imperative for action to be taken to ease the overcrowding. Therefore, Singapore developed Mass Rapid Transit in 1987, and was the world's first heavy rail system to feature platform screen doors. The MRT network consists of 42 stations, among which are 27 above ground stations and 15 underground stations ([Chee-Meow, 1981](#)).

13. Taiwan: The Taipei Metro (MRT), which opened in 1996 serving the capital of Taiwan's 2.7 million inhabitants, was the first of its kind in Taiwan. It involves five lines serving 117 stations, plus two shuttles. The 'Taipei Rapid Transit Corporation (TRTC)' operates the metro system which has an overall length of 131.1 km. It tries to be environmentally friendly. It is a reliable and safe system. The system is underground with elevated sections ([Mapa-metro, n.d.-b](#)).

14. Japan: In the year 1872 Japan opened its first railway line between Shimbashi and Yokohama which contributed in boosting Japan's social, economic, and industrial aspects. The existing 17 private lines were later nationalized in 1906 and 1907. On 1st October 1964, the Tokaido Shinkansen became the first full-scale high-speed railway system in Japan, with a line connecting between Tokyo and Shin-Osaka and transporting 2,173 billion passenger-km at high speed. The Tokaido Shinkansen became the world benchmark promoting new means of travel and making a 1-day round trip possible.

In 1967, the construction of a new line, San'yo Shinkansen, began. In March 1972, the San'yo Shinkansen line opened linking Shin-Osaka and Okayama. The San'yo Shinkansen is a 553.7 km length, where half of the line

is in a tunnel under the Kammon Strait linking Honshu and Kyushu. Three years later, an extension was opened linking Okayama and Hakata. In June 1982, Japan opened the new Tohoku Shinkansen linking Omiya and Morioka. Following that month, two other lines were opened: Joetsu Shinkansen (Omiya to Niigata), and Tohoku Shinkansen (Ueno to Omiya). The Tsugaru-Kaikyo Line, along with the Seikan Tunnel, opened six years after the Tohoku Shinkansen extension was introduced. From 1991 up to 2004, various other lines were introduced and opened, such as Tohoku Shinkansen (Tokyo to Ueno), Hokuriku Shinkansen (Takasaki to Nagano), and Tohoku Shinkansen (Morioka to Hachinohe).

In March 2004, the Kyushu Shinkansen line was later opened linking Shin-Yatsushiro to Kagoshima-Chuao. Japan has been integrating such high-speed-railways in all Japanese cities and it is considered one of the most advanced in the world ([Takatsu, 2007](#)).

1.3 Research objectives

The purpose of the study is to: 1) Validate the existing roof form of Dubai Metro Stations by investigating different roof forms of metro station buildings in hot climate regions; 2) Evaluate and improve the Level of Service (LOS) of the Dubai Metro Station.

An understanding of the above issues would provide architects and planners with proper design guidelines for the design of Metro Stations in hot climates.

1.4 Research methodology

In this study, common roof forms of metro station buildings around the world, such as curvilinear, rectilinear, and composite, are selected. The forms have been simplified to the bare minimum relevant to this study. The effect of weather parameters on the metro station's roof forms in hot climate regions are investigated using (IESVE) and Flow Design Autodesk packages. The main body of the study uses Mass Motion Oasys (MMO) to evaluate and improve the LOS in the station. Further explanation and details on the used software packages are shown hereafter.

1.4.1 Integrated Building Performance Analysis

The Integrated Environmental Solutions Virtual Environment (IESVE) is a program to evaluate and improve buildings in terms of energy, light, ventilation, shade, carbon, lifecycle, costs, occupant safety, and economics ([Mushtaha et al., 2017](#)). The program was utilized to determine the thermal effect of solar radiation on roofs, both flat and curved. The buildings were drawn in 3D geometry with a different roof form. The city location was set from the IESVE database to consider the sun location during the simulation to determine which roof form had the least solar radiation incident on its surface.

1.4.2 Flow Design Autodesk

Flow Design is a program that demonstrates the airflow around the design model. According to [Pelletret and Khodr \(1989\)](#), these airflows led to an establishment of an important thermal linking between the building and the

outside as well as the different thermal zones. This program was utilized to assess the pressure and velocity of wind on both the flat and curved roof.

1.4.3 Mass Motion Oasys (MMO)

Mass Motion Oasys (MMO) is used for crowd simulation and pedestrian modelling. MMO is one of the most accurate and intuitive tools as it provides clear information regarding crowdedness, pattern of usage, and safety of the occupants in the facility. It leads to positive decision making in the early stages of the design process. The Dubai Metro Station is investigated using MMO, and accordingly, defects have been identified using this software.

2. SELECTED ROOF FORMS OF METRO STATIONS IN HOT CLIMATE

As per information availability on metro stations buildings of worldwide websites and online e-books, three main roof forms were recognised in hot climate regions such as curvilinear, rectilinear, and composite (*Figure 1*). These cases in hot climate regions will be compared with the existing case of Dubai Metro Stations. The study was simplified to consider only the curvilinear and rectilinear roof forms as the third roof form was composed of both. The authors have simplified the analysis of roof forms as this study mainly covers the level of service of Dubai Metro Stations. Regarding the climate in the UAE, it is considered one of the harshest on the globe, where temperature reaches up to 50°C and 23°C during summer and winter, respectively; therefore, the internal thermal comfort in winter is not of as much concern as that in summer.



1. Curvilinear; 2. Rectilinear, 3. Composite

Figure 1. Roof forms of buildings in hot climates (Source: Authors)

3. SIMULATION, ANALYSIS AND RESULTS

3.1 Solar Radiation Analysis

According to IESVE simulation, the solar radiation analysis showed the rectilinear flat roof received a large amount of incident solar radiation, covering the full area of the roof which is exposed directly to the sun throughout the day, as shown in *Figure 2*. The curved roof has shown much improvement on receiving incident solar radiation where a smaller area was exposed to the sun, which in turn results in a more efficient roof when compared with the flat roof. As per IESVE, the simulation was conducted for both roofs during August and January, as the hottest and coldest months of the year in Dubai, respectively. *Figure 2* shows the solar radiation of the flat and curved roofs during the hottest month of August. It is clearly shown that the

incident solar radiation was higher on the flat than the curved roof. The flat roof experienced a range of 92.85% to 100% of incident solar radiation on the entire surface area, while the curved roof experienced a range of 70% to 90% of incident solar radiation on a much smaller surface area.

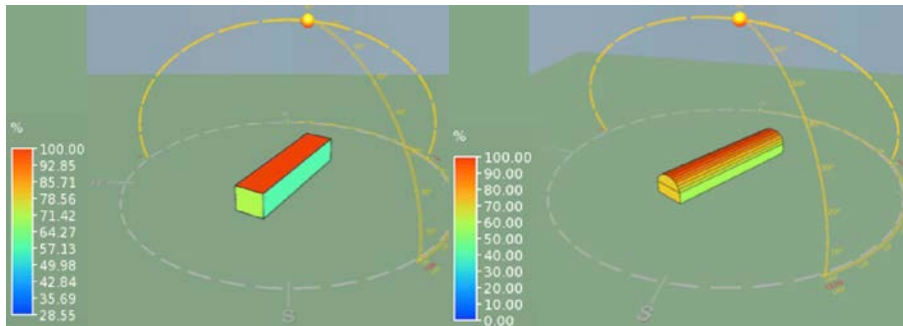


Figure 2. Solar radiation simulation on flat and curved roofs during the hottest month of August 1st at 12:00pm (Source: Authors)

Figure 3 shows that during the coolest month of January at 12:00 P.M., the flat roof had its entire surface area exposed to 92.8% to 100% of the incident solar radiation, while for the curved roof a range of 70% to 90% of incident solar radiation was covering a smaller surface area.

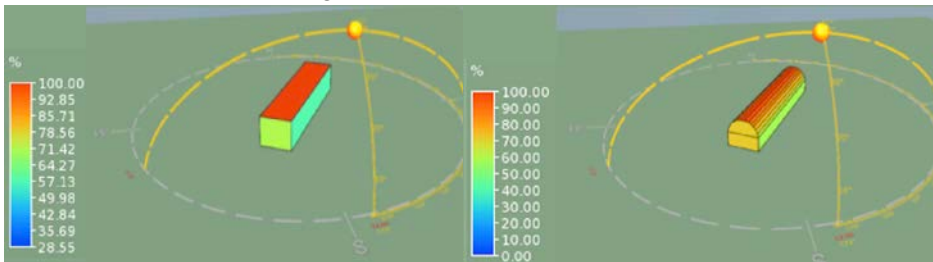


Figure 3. Solar radiation simulation on flat and curved roof during the coolest month January 1st at 12:00pm (Source: Authors)

3.2 Wind simulation

Using Flow Design Autodesk, the two different roof forms were exposed in a wind tunnel model to the maximum predicted flow of wind of 10 m/s which resembles the worst-case scenario that might occur in the UAE (Figure 4). The analysis was performed on curved and flat roofs to study the flow pattern and separation on each roof. The results of the flow pattern show that some recirculation and vortices occurred at edges and curves. However, the speed of wind did not exceed 5 m/s around either building form. For the separation of the curved roof, the separation starts on the curved part at the top, whereas for the flat roof the separation takes place on the edge of the roof. Also, the velocity of the air turbulence on the top of the curved roof was higher, which probably causes more roof cooling compared to a flat roof.

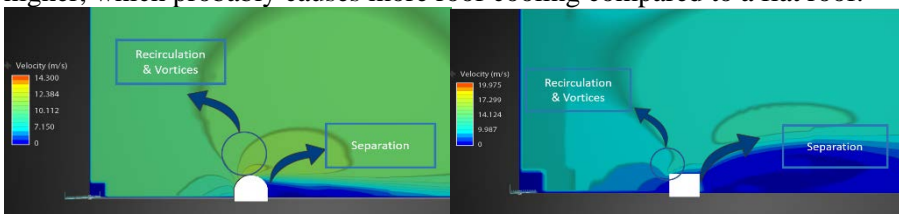


Figure 4. Velocity path passing through the curved and flat roof samples (Source: Authors)

Figure 5 clearly shows that pressure on the curved roof is higher than the pressure on the flat roof. Therefore, the difference of pressure on the curved

roof causes a higher speed of turbulence flow. So, placing openings on the roof of the curved form would allow larger airflow. Consequently, it would increase the coolness of the roof and reduce the indoor temperature of the building.

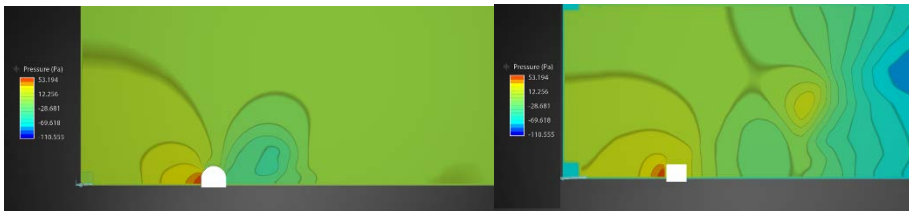


Figure 5. Pressure path passing through curved and flat roofs (Source: Authors)

3.3 Flow of people

After realizing the existing roof form of Dubai Metro Station is just a perfect roof form to consider for hot climate regions, the study was extended to include the flow of people analysis inside the metro using Mass Motion Oasys (MMO) software to improve the congestion of people that occurs during peak hours at morning and evening when workers return homes. The busiest station selected for the study was (Burj Khalifa/Dubai mall Metro Station,). The number of passengers from 17:00-19:00 in the peak hours was counted using counters by two researches waited beside the vertical circulations in the paid and transportation zone (B) at the arrival and departure zones of the ground floor level (Figure 7). The counting was conducted to validate the simulation.

3.3.1 Fruin Level of Service (LOS)

Table 1 is a qualitative measure based on levels and is used to measure the quality of traffic. According to Still (2018), the levels are represented as: level of service A in which people can move freely, level B where pedestrians respond to the presence of others, level C where passing is possible in a unidirectional stream and there is a minor probability of conflict creating reverse or cross movement, level of service D in which the passing of others is restricted and there is a high probability of conflict creating reverse or cross movement, level of service E where the walking speed and passing ability is restricted and cross movement is possible but with extreme difficulty, and lastly, level of service F where walking speed is severely restricted, and reverses or cross movement is virtually impossible.

3.3.2 Dubai Metro Peak Hours

After conducting a site visit and comparing the results with the simulation (Figure 6), it was noticed that Dubai Metro Station is congested for 20 hours a day. Usually, the peak hours were before and after working hours in the morning from (5:30 - 8:30), where the number of people arriving to the station reached to approximately of 3,200 people per hour, and the number of people leaving the station reached approximately 3,000 people per hour. However, from 17:30 till 20:00, the number of people arriving to the station was approximately of 1,900 people per hour. However, the number of people leaving the station during that time reached approximately 4,100 people per hour. Although there was a difference in the number of people leaving and arriving to the station in both timings during the rush hours, the number of

people during the day reached to approximately 6,000 people per hour (Figure 6).

Table 1. Fruin Level of Service (LOS)

LOS	Space (Ped/m ²)	Definition
LOS A	>3.24	People can move freely
LOS B	2.32 to 3.24	Pedestrian responses to presence of others
LOS C	1.39 to 2.34	Passing is possible in unidirectional stream
LOS D	0.93 to 1.39	Passing of others is restricted, and there is a high probability of conflict for reverse or cross movement
LOS E	0.46 to 1.39	Walking speed and passing ability is restricted, cross movements are possible but with extreme difficulty
LOS F	<0.46	Walking speed is severely restricted, and reverse or cross movements are virtually impossible.

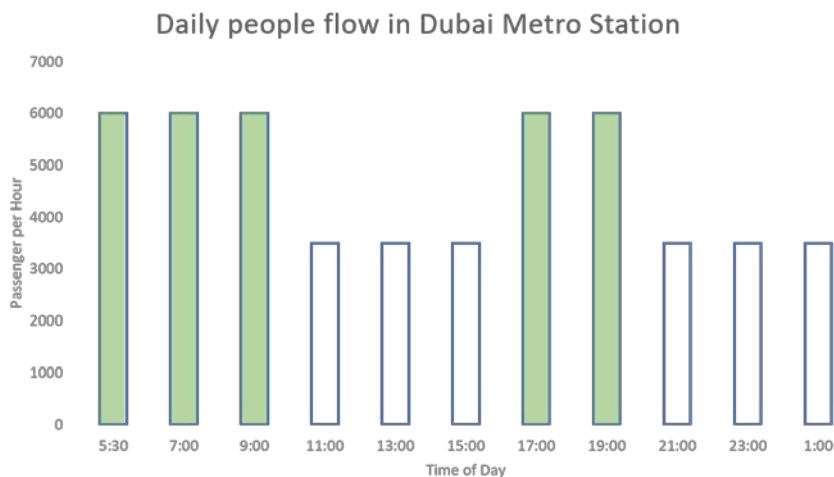


Figure 6. Simulated daily flow of people in Burj Khalifa Metro Station (Source: Authors)

3.4 Traffic Simulation

Traffic simulation was conducted to estimate the flow of people in the building in order to achieve an adequate number of transportation facilities. Using Mass Motion Oasis (MMO), a passenger's journey comfortability and waiting time, as well as the passenger queue lengths and congestion at different locations were studied, as shown in Figures 8, 9, 10 and 11. The simulation clarified the building interior layout of Burj Khalifa Metro Station, as well as how the flow of people interacted with the distribution of escalators, elevators, and stairs considering the way the internal zones were being treated. Every station consisted of a journey that was connected through three main areas starting from the ticketing area followed by the turnstiles (A) to enter the paid zone and transportation devices (B), ending with the upper platforms (C) Figure 7.

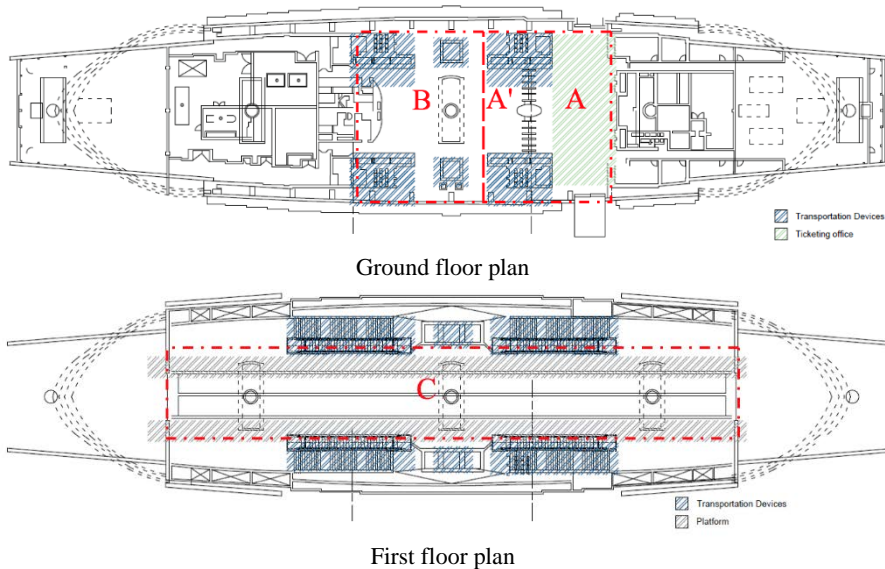


Figure 7. First floor plan of Dubai Metro Station (Source: Authors)

3.4.1 Ticketing Area (A)

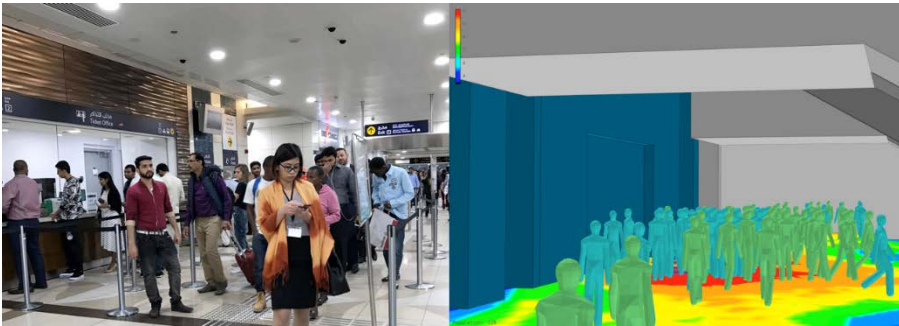


Figure 8. Ticketing area (Zone: A) (Source: Authors)

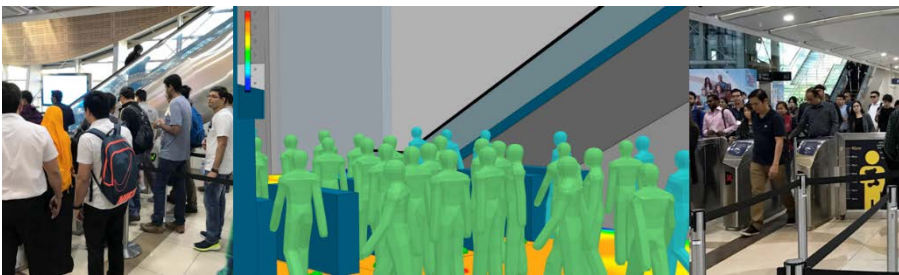


Figure 9. Ticketing gate (Zone: A) (Source: Authors)

After entering the station, people gather in the unpaid zone (A), which is the ticketing area so that they can collect their tickets to enter the paid zone through barriers known as turnstiles (A'). In the station, the path from the unpaid area to the turnstiles is clear in layout and guides people to the correct route. Overcrowding occurs in areas (A) due to narrow width (Figure 8), which makes walking speed severely restricted. Reverse or cross movements are virtually impossible, and flow is unstable according to the Fruin LOS. In the turnstile area, where people enter individually to the paid zone, the area is classified as LOS E, where the walking speed and passing ability is restricted, cross movements are possible but with extreme difficulty, and in certain places the LOS is F, where walking speed is severely restricted and reverse or cross movements are virtually impossible, as shown in Figure 9. The station is shown to lack sufficient time separation between the moments a pedestrian

reaches and passes through the ticketing gate followed by the next pedestrian, and the process is repeated.

3.4.2 Transportation Devices

Figure 11 shows two stairs in zone (B), located on opposite sides of the platform parallel to the escalators placed on both sides as one-way transportation devices. The stairs are classified as level C, where passing is possible in unidirectional streams and there is a minor probability of conflict for reverse or cross movements and, at some points, is considered as LOS D, where the passage of others is restricted and there is a high probability of conflict for reverse or cross movements which makes people feel less comfortable while using the escalators. For the area near the elevator in zone (B), it is classified as LOS F, where walking speed is severely restricted and reverse or cross movements are virtually impossible. As the station is surrounded by shopping areas, escalators and elevators are heavily used as people carry heavy luggage. However, people using stairs leave the platform smoothly. In order to improve the station, more elevators and escalators are needed to be provided in order to shift the LOS from F to B.

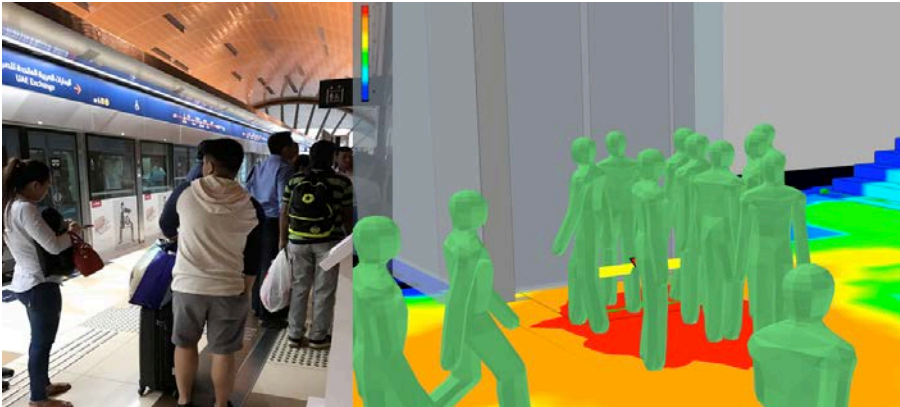


Figure 10. Dubai Metro Station – elevators in Zone: C (Source: Authors)

3.4.3 Platform

Regarding the platform, Figure 12 illustrates a side platform for either destination required by the passengers, handling a great capacity of the station. Furthermore, since it is a one-side platform and there are different options for vertical transportation devices, the queues to the trains did not mix and the main traffic flows were more separate, which in turn did not create heavy crowding. The platform is designed in a way so that people can see the space clearly, and so that they can start to queue immediately after reaching the platform. However, the area of a one-side platform in the station is about 400m², and in addition, the number of passengers reaches approximately 6,000 during rush hour, which causes heavy crowding in the platform zone. According to the Fruin LOS, the area of the platform is mostly classified as LOS C, where pedestrian passing is possible in a unidirectional stream, and there is a minor probability of conflict for reverse or cross movements, followed by LOS D, in which the passing of other pedestrians is restricted and there is a high probability of conflict for reverse or cross movements, and at some points it reaches LOS E, where the walking speed and passing ability is restricted, and cross movements are possible, but with extreme difficulty.

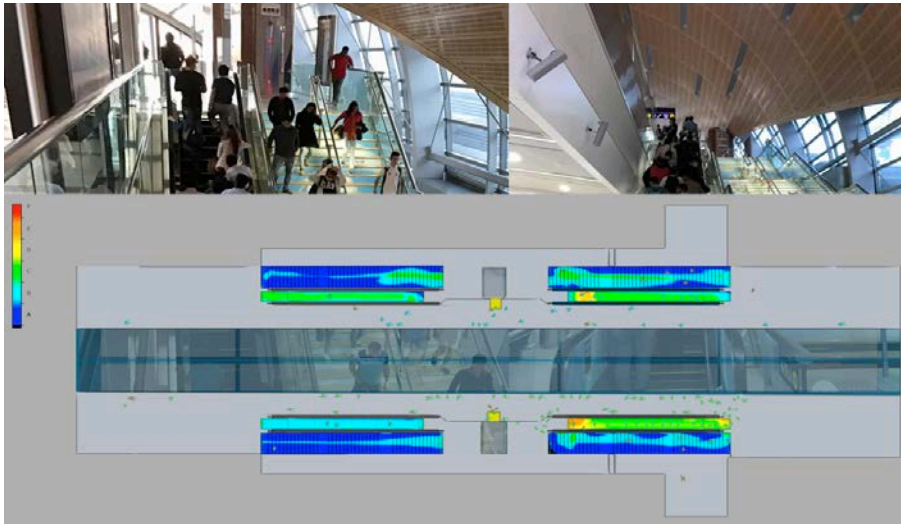


Figure 11. Dubai Metro Station – escalators and stairs (Source: Authors)

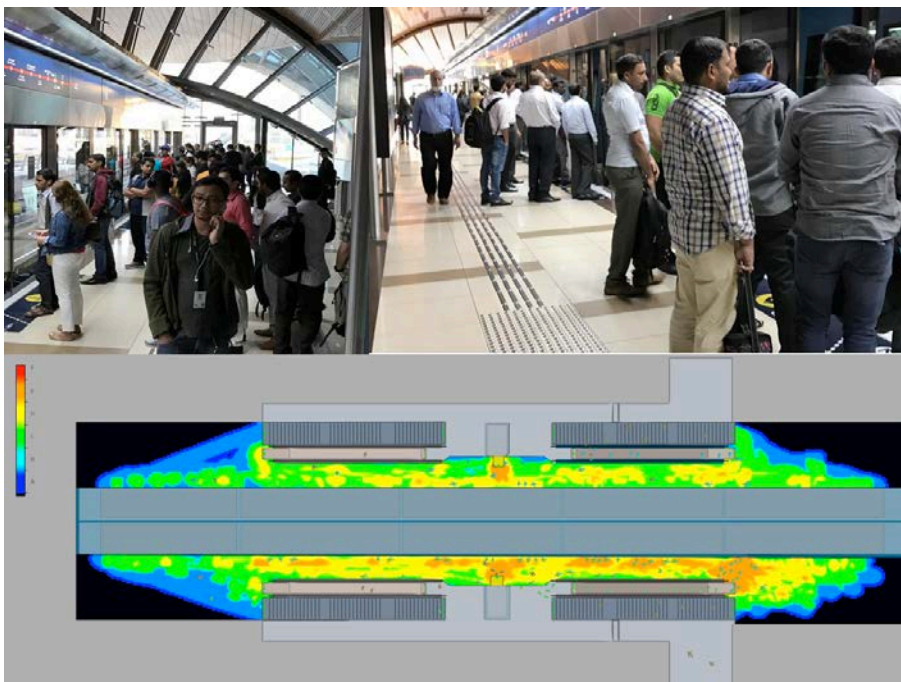


Figure 12. Dubai Metro Station – platform (Source: Authors)

4. CONCLUSION

To design an effective metro station for hot climate regions with a comfortable indoor environment, the curved roof form performed best in the case of Dubai Metro Station. On the level of service, the relationships between ticketing, transportation zones and platforms are very important to consider during the design process in order to achieve clear and strongly connected pathways when entering the station through until reaching the platform. Further recommendations are listed hereafter:

1. Design a clear pathway easily connecting the entrance with the ticketing offices, followed by the ticketing gates with a clear pathway leading to the transportation devices, and ending with the platform.
2. Separating the ticketing area from the pathways enhances pedestrian circulation and reduces congestion inside the ticketing and turnstile zones.

Additionally, providing clear separated spaces for people beside the main entrance to collect their tickets would reduce congestion.

3. Provide a sufficient number of escalators and elevators for metro stations placed near shopping areas because people tend to use the transportation devices to transport their heavy luggage. Moreover, providing one-side platforms is more preferable to avoid heavy crowding during peak hours.
4. Manage the platform in such a way that people can see spaces and signs clearly, so that they can start their queuing immediately after reaching the platform.

REFERENCES

- American Public Transit Association. (1994). *Glossary of Transit Terminology*. Washington, DC: American Public Transit Association. Retrieved from <https://www4.uwm.edu/cuts/utp/glossary.pdf>.
- Chee-Meow, S. (1981). "The Mrt Debate in Singapore: To Do or Not to Do?". *Southeast Asian Affairs*, 290-306.
- Dunnicliff, J. (1993). *Geotechnical Instrumentation for Monitoring Field Performance*. John Wiley & Sons.
- Guillet, M. (2019). "Shortest 'Metro' Line in the World: Tünel". Retrieved from <https://www.enjoy-istanbul.com/history/shortest-metro-line-in-the-world-tunel/>.
- Hoogendoorn, S. P., Hauser, M., & Rodrigues, N. (2004). "Applying Microscopic Pedestrian Flow Simulation to Railway Station Design Evaluation in Lisbon, Portugal". *Transportation Research Record*, 1878(1), 83-94.
- Jiang, Y., Zhu, J., Hu, L., Lin, X., & Khattak, A. (2016). "Ag/G (N)/C/C State-Dependent Simulation Model for Metro Station Corridor Width Design". *Journal of advanced transportation*, 50(3), 273-295.
- Mapa-metro. (n.d.-a). "Santiago Metro Map, Chile". Retrieved from <http://mapa-metro.com/en/Chile/Santiago/Santiago-Metro-map.htm>.
- Mapa-metro. (n.d.-b). "Taipei Metro Map, Taiwan.". Retrieved from <http://mapa-metro.com/en/Taiwan/Taipei/Taipei-MRT-map.htm>.
- Mathew, J. (2014). "Metro Rail: Facts and History". Employees News Weekly. Retrieved from <http://employmentnews.gov.in/writereaddata/METRO%20RAIL%20FACTS%20AND%20HISTORY.pdf>.
- Moya, A. (1990). "Metro De Madrid 1919-1989". In Moya, A. (Ed.), *Sesenta Años De Historia*. Madrid: Galapagar.
- Mushtaha, E., Ayssar Nahlé, R., Bin Saifan, M., & Altan, H. (2017). "The Impact of Lighting on Vandalism in Hot Climates: The Case of the Abu Shagara Vandalised Corridor in Sharjah, United Arab Emirates". *Sustainability*, 9(11), 2040.
- Pelletret, R., & Khodr, H. (1989). "Transferts D'air Entre Pièces". *Revue générale de thermique*, 28(335-336), 657-662.
- Railway Technology. (n.d.). "Beijing's Metro, Beijing Subway Development". Retrieved from https://www.railway-technology.com/projects/beijing_subway/.
- Revolvy. (n.d.). "Rapid Transit in South Korea". Retrieved from <https://www.revolvy.com/main/index.php?s=Rapid%20transit%20in%20South%20Korea>.
- Still, G. K. (2018). "Fruin - Levels of Service". Retrieved from <http://www.oasys-software.com/products/engineering/massmotion.html>.
- Sustainable Low Carbon Transport. (2018). "International Association for Public Transport (Uitp)". Retrieved from <http://www.slocat.net/member/238>.
- Takatsu, T. (2007). "The History and Future of High-Speed Railways in Japan". *Japan Railway & Transport Review*, 48, 6-21.
- Takayanagi, H., Yamada, S., & Shibahara, H. (2015). "A Study on Understanding Pedestrian Flow Using Intermittent Recording Images (Piri)". *Journal of Asian Architecture and Building Engineering*, 14(3), 557-560.
- Telegraph. (2016). "Travel". Retrieved from <http://www.telegraph.co.uk/travel/destinations/europe/united-kingdom/england/london/galleries/The-history-of-the-Tube-in-pictures-150-years-of-London-Underground/>.

Toronto Transit Commission. (n.d.). "Section One". Retrieved from
https://www.ttc.ca/About_the_TTC/Operating_Statistics/2015/Section_One.jsp.