Illumination of the marmaray project

C Perdahci¹, D Yuce² and R. A. Aynaci³

¹ University of Kocaeli, Kocaeli, Turkey
² Litpa Lighting, Istanbul, Turkey
³ Litpa Lighting, Istanbul, Turkey

Abstract. The main objective of the underground railway stations lighting is to provide safe and comfortable conditions. This paper focuses on the illumination of Marmaray Project in order to shed light on long underground tunnel lighting design requirements and special railway tunnel environment. Moreover lighting of each Marmaray station and ticket hall were presented.

1. Introduction
With the increase in population (300,000 people) per year, Istanbul is the largest city in the Republic of Turkey. As the demand to the modern transportation systems increases in great cities like Istanbul, the fast growing and deepening problems in its transport infrastructure raise up. Because of the severe traffic in the morning and evening, the rush hours strings out which diminishes the options to increase the general capacity of the road systems. [1]

Istanbul is expanding its railway network to fulfill the needs of transportation. Therefore, The Marmaray Project can be considered as the corner stone of the transport system in Istanbul. There is going to be numerous transport facilities of the municipalities which will ease the transportation in the city. [1]

In the construction of The Marmaray Project, there are three bored tunnels and an immersed tunnel under the Istanbul Strait. The immersed tunnel is 1.4 km long, the connections between the immersed and adjacent tunnels included.
The most important lighting design factors for terminal and station lighting in public transport are: the appearance of space and lighting devices, the glare that the light from the source or reflection creates, security, field of view, horizontal and vertical lighting, integrated lighting and daylight control. [2]

Illumination of underground subway stations should allow safe circulation, provide user comfort, take into consideration the safety of the disabled, provide smooth transition from darker areas to bright areas. [2]

2. The marmaray project
Connecting the two banks of the Bosphorus has been a long term dream since 1502. It is rumored that the well-known artist Leonardo Da Vinci visited Istanbul as he had learned that Sultan Bayezid II had the idea for a bridge crossing the strait. The concept of a railway tunnel under the Bosphorus was first expressed by Sultan Abdülmecid in 1860s. American engineers studied the project in 1902 during the reign of Abdul Hamid and obtained a patent for Tünel-i Bahri.

A railway tunnel underneath the Bosphorus Strait has been opened in Turkey, connecting the Asian and European shores of Istanbul under the Marmara Sea. The Marmaray tunnel is the first tunnel connecting two continents in the world. The long desired dream to connect the two shores of Istanbul via an underwater tunnel came true with the help of this project.
The Marmaray Rail Tube Tunnel and Commuter Rail Mass Transit System project has started in the year 2004 in Istanbul.

A seamless high-capacity commuter rail system, an inter-city passenger service and a freight link between Europe and Asia were considered to be of utmost important characteristics of The Marmaray Project. The Gebze–Halkali section which is also a part of the Ankara–Istanbul corridor will meet the transport needs of the city of Istanbul as well as its hinterland.

The line goes underground at Yedikule, continues through Yenikapi and Sirkeci via new underground stations, passes under the Bosphorus, connects to the new Üsküdar underground station and emerges at the surface at Söğütlüçeşme. [3] The entire system will be 76 km long, 13.4 km of which will be underground.

The other constructions of The Marmaray Project will be three underground stations, as well as 37 surface stations (36 of which will be new), an operational control center, yards, workshops and maintenance facilities.

There will be 37 stations in the Marmaray project. Only one of these will be reused, and the remaining 36 stations will be new constructions. To put it in a different way, 18 listed historic stations (Sirkeci, Kumkapı, Yenikapi, Kocamustafapasa, Yedikule, Bakırköy, Yeşilköy, Haydarpaşa, Kızıltoprak, Feneryolu, Göztepe, Erenköy, Suadiye, Bostancı, Maltepe, Kartal, Pendik and Gebze), will be abandoned and lose their original function. [4]

The major objectives of the project are to:

a) find a long-term solutions to the present urban transport problems of Istanbul,
b) ease substantial operational problems on mainline railway services,
c) provide direct railway ties between Asia and Europe

d) increase capacity, reliability, accessibility, punctuality and safety on the commuter rail services,
e) decrease journey time and increase comfort for majority of commuter rail passangers,
f) provide uninterrupted passenger and freight transportation across the Istanbul Strait,
g) decrease air pollution which is caused by exhaust gasses, which will improve the air quality of Istanbul as a consequence,
h) reduce noise pollution resulting from airborne traffic in the centre of Istanbul, and
i) decrease the negative effects of car transport on historical buildings and heritage sites by providing a new alternative in the historical centre of Istanbul. [1]

![Figure 1: The Marmaray Project Stations](image)

Because underground subway stations create different spaces within the urban fiction, artistic works are also included in the stationed areas in order to give identity to the stations or to establish relations with the city. [2] The Iznik Foundation Tiles have been used in this magnificent underground metro station that connects Asia and Europe.

3. Illumination

In underground subway stations; physical injuries such as injury to people, respiration, hearing and difficulty in seeing, as well as psychological stress, fear, anxiety and other negative effects are likely to occur. For this reason, it is important to provide visual comfort in underground metro stations. [2]
In such structures, the psychological pressure and fear experienced by the passengers can be reduced by the combination of light and color. A refreshing effect was observed at stations where the cool white or warm white light with a color temperature of 500 Kelvin was used for general illumination. In addition, red, yellow colors may be preferred in regional lighting to enhance attention. [2]

![Figure 2: Üsküdar Station](image1)

![Figure 3: Üsküdar Station](image2)

Reducing energy consumption while increasing profitability and improving visibility as well as safety were the main goals of the project. All luminaires should meet the photometric and electrical performance requirements and also they should be aesthetically appropriate to their intended location. These considerations are all taken into consideration while designing the luminaires. Indirect lighting should be preferred in underground stations. It is possible to cause eye irritation if proper lighting is not attained. Eye dazzle, contrast can be avoided and comfortable vision can be achieved with proper lighting. From this point of view, the eye adaptation from the dark places to the bright places or from the bright places to the dark places can be obtained if the light transitions between different locations are not sharp.

### 3.1. Tunnels

Tunnel lighting should maintain required lighting level at the evacuation and maintenance walkway so that passengers can see the direction of escape and recognize the risk of tripping along the walkway edge. [5]

The main purposes of tunnel lighting can be listed as:

- Dropping off passengers safely and helping them walk along the tunnel.
- Helping maintenance personnel perform routine checks throughout the tunnel
- Guide train personnel and improve road visibility [6]

The system design where tunnel lighting is installed should provide the following:

- A luminous level of at least 10 Lux by considering the maintenance factor on the horizontal level on the rail level and a level of 2 Lux on the vertical level if it is 1 m above the rail level.
- The accountability of the signaling.
- A high level of lighting uniformity that facilitates adaptation.
- A precise smoke, fire alarm system in the tunnel for emergencies.
- A spare supply source for safety in the event of a failure of the normal supply source.
- A minimum of 10 Lux horizontal lighting on the emergency walkways along the route even when the maintenance factor is added. [6]
- The general illumination of the Marmaray tunnel is performed using LITPA FLP-TV waterproof luminaires with protection class IP66. Burning point of the luminaires, which are made of polycarbonate V2 rated material, is higher than 850°C. This material is shatterproof and can resist impacts up to 5J.
Table 1: Lighting Criteria for Station Areas

| Lighting Criteria for Station Areas According to National and International Standards | TS 12127 and DLH Criteria | GI/RT 7010 Railway Group Standard | EN 12464_1 |
|--------------------------------|-------------------|---------------------------------|-------------|
| | Em | Em > | Min. Em | Max. UGR | Min. Ra |
| **Traffic Zones** | | | | | |
| Circulation Areas and Corridors | 175-250 | 100 | 28 | 40 |
| Stairs, Escalators, Moving Tapes | 150-200 | 150 | 25 | 40 |
| **Railway Facilities** | | | | | |
| Closed Platforms and Passage Underpasses | 150-200 | 50 | 28 | 40 |
| Ticket Hall and Conkors Floor | 200-400 | 200 | 28 | 40 |
| Ticket And Luggage Offices And Turnstiles | | 300 | 19 | 80 |
| Waiting Rooms | | 200 | 22 | 80 |
| Platform Edge | | | | | |
| Platform Edge Zone, horizontal lighting | 250-300 | 10 | | |
| Platform Edge Area, vertical luminous level | | 2 | | |
| **Tunnel Lighting** | | | | | |
| Rail Upper Thick, horizontal plane | | 10 | | |
| Vertical plane 1m above Rail Top Coat | | 2 | | |
| **Authorized Walkway** | | 10 | | |
| **Emergency exit and escape routes, vertical lighting** | | 2 | | |
| **Emergency exit and escape routes, horizontal lighting** | | 10 | | |

A critical area to be lit along a metro route is the so-called yellow line that is used to regulate boarding and disembarking the trains. The international standard EN12464-1/8.2.1 requires that such places should have a minimum illumination level of 150 lux. Currently the illumination level is 400 lux. Taking into consideration the maintenance factors of long term operation, a minimum of 340 lux should be ensured.

The luminaires used along the tunnels of the Marmaray are resistant to salt and moisture of the sea as well as vibration and pressure effects. The luminaires in the tunnels are also designed to be resistant to 5J impacts. In order to prevent combustion of luminaires and the spread of fire, V2 polycarbonate material was used to manufacture the fixtures and the flash-point temperature was raised to 850°C.
236 FLP-TV fixtures are placed every 6 meters along the tunnel to obtain an illumination level of 50 lux throughout.

![Figure 4: The Marmaray Tunnel with LITPA FLP-TV Luminaires](image)

![Figure 5: Luminaires along Yellow Lines](image)

![Figure 6: Luminaire Layout in the Tunnel](image)

3.2. Ticket Halls
Ticket hall lighting should be bright and welcoming. Moreover, the key customer touch points such as; ticketing, information areas and gate lines should be highlighted. Orientation lighting to draw customers toward route ways for their onward journey is also essential. Applying ceiling recessed luminaires has helped to wash the key vertical surfaces of the space, define the space and make it feel bright and welcoming. The ticket halls and transit points have an illumination level of 310 lux, well in excess of the minimal level required by the international standard EN12464-1/8.2.2 which is 200 lux. For luminaires with protection class IP65, resistance to ambient conditions is increased so as to minimize potential lighting problems due to contamination of fittings over time. An illumination level of up to 400 lux is achieved near the stairs where pedestrian traffic is very heavy.

Figure 7: Ticket Halls

3.3. Stations

Lighting of each Marmaray station was handled separately. The types of luminaires used in each of the stations and tunnels were determined case by case.

Figure 8: Stations

The Marmaray includes five stations: Kazlıçeşme, Yenikapı, Sirkeci, Üsküdar and Ayrılıkçeşme. The luminaires used for lighting purposes were manufactured to resist all unfavorable conditions. They have been designed designed to go beyond the international standards for ambient lighting, light quality, and fixture quality levels.
4. Conclusion
In underground railway stations, lighting is one of the most significant properties to achieve and sustain safety. Compatible with the new emphasis in environmental concerns, a design approach which is highly energy saving and cost-effective is essential.
In the study, The Marmaray Project was selected as the sample underground railway station. First of all, The Marmaray Project is introduced and then lighting criteria for underground railway station areas according to national and international Standards are presented. Additionally, tunnel lighting and lighting of each Marmaray station and ticket hall were explained.

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