How an Intelligent Lighting System Transformed the Coexistence of Motorists, Pedestrians, and Cyclists in a Tunnel

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Abstract

The Cody Tunnel, located in Wyoming, serves as the state's only road access to Yellowstone National Park.
In recent years, the increasing number of pedestrians and cyclists using this narrow tunnel has posed significant safety challenges, particularly in ensuring smooth coexistence with motorists. When the Wyoming Department of Transportation (WYDOT) decided to upgrade the tunnel's outdated sodium lighting to modern LED fixtures, its engineers sought a fast and effective solution to enhance safety for all users.

At 975 meters (3,200 feet) long and carved directly into the rock, the bidirectional tunnel could not be easily expanded to accommodate a dedicated pedestrian and cyclist lane. Instead, a practical solution was implemented: a button installed at the tunnel entrance allows pedestrians and cyclists to activate the lighting system before entering, signaling motorists of their presence in the tunnel through a beacon luminaire. This feature is seamlessly integrated with the Supervisory Control and Data Acquisition (SCADA) system, which manages the tunnel's lighting.

This presentation highlights how Nyx Hemera Technologies' TLACS (Tunnel Lighting Addressable Control System) has significantly improved safety for pedestrians and cyclists. In addition to controlling the lighting, TLACS oversees critical systems such as carbon monoxide detection, ventilation, air conditioning, and uninterruptible power supplies (UPS), delivering a comprehensive safety solution for all tunnel users.

Introduction

This presentation, designed for a Canadian audience, aims to highlight an American project promoting coexistence between cars and bicycles in a road tunnel, to inspire and improve the cohabitation of these modes of transport in tunnels, viaducts and underpasses in Canada.

1- Some statistics

We couldn't find any specific statistics on bicycle accidents in tunnels, but according to a World Health Organization report on cyclist safety (1), poor visibility due to inadequate illumination during afternoon peak periods or at nighttime is a major risk factor associated with cyclist collisions. Therefore, the lighting of tunnels and underpasses becomes a safety issue—not only for drivers, but even more so for cyclists.

Now, considering that the number of Canadians who primarily travel by bicycle nearly doubled between 1996 and 2016 (2), and in light of several serious cyclist accidents in underpasses in recent years in Canada, it is time to address this issue.

Here are some interesting statistics on bicycle use and safety in Canada:

- In Canada, approximately 36% of the population owns a bicycle, slightly below the global average of 42%. With an estimated population of approximately 39 million in 2025, this represents nearly 14 million Canadians who own a bicycle. (3)
- In comparison, Quebec has a notable passion for cycling. In 2020, there were 7.2 million bicycles in Quebec, an increase of 20% from 2010. This corresponds to approximately 0.84 bicycles per capita, which is higher than the national average. (4,5)
- Most cycling injuries and deaths occur between 4 p.m. and 8 p.m., between rush hour and nightfall. (2)
- In Canada, there are an average of 74 fatal bicycle accidents each year, 73% of which involve a motor vehicle. (2)

2- Why are accidents involving cars, trucks, bicycles or any other vehicle in tunnels always more dangerous to human life? (6)

Accidents in tunnels present unique and heightened risks compared to those on open roads. The enclosed environment, limited escape options, and potential for cascading hazards mean that even minor incidents can quickly escalate into life-threatening situations. Below are some key factors that make tunnel accidents particularly dangerous:

- **Confined space**: Space is very limited in tunnels: there are no hard shoulders, no possibility of pulling over or escaping quickly. In the event of an accident, vehicles and people are trapped in an enclosed space, which complicates evacuation.
- **Increased risk of fire:** If an accident causes a fire, the heat, toxic smoke and lack of ventilation can quickly become deadly. Smoke builds up faster in a tunnel than on an open road, which can lead to suffocation or zero visibility.
- **Difficulty for emergency services to respond**: Access to the tunnel can be difficult for fire engines, ambulances or breakdown vehicles, especially if the accident blocks the only traffic lane. Response times are therefore often longer.
- Panic effect in a closed environment: People can panic more quickly, especially if there is smoke or a loss of lighting. This complicates evacuations and can cause dangerous behavior (disorganized flight, secondary collisions, etc.).
- **Ventilation and lighting problems**: An accident can damage ventilation systems or cut off electricity, further aggravating the situation. Without light or fresh air, conditions quickly become extreme.
- **Chain reaction**: On open roads, other vehicles can get around an accident. In a tunnel, traffic is often blocked behind. This can cause pileups or make evacuation very difficult.

3- So, what can be done to accommodate pedestrians and cyclists? (7)

Ensuring the safety and comfort of pedestrians and cyclists in tunnels requires thoughtful design and infrastructure improvements. Because these users are more vulnerable than motorists, specific measures must be taken to reduce risk, improve visibility, and create a sense of security. Below are several practical and effective strategies that cities and planners can implement to better accommodate non-motorized users in tunnels:

- **Separate users**: Create a dedicated lane for pedestrians and cyclists, physically separated from motorized traffic (barrier, low wall, railing). This prevents accidents and reassures vulnerable users.
- **Provide good lighting: Continuous, powerful lighting in the pedestrian/cycle area to improve safety, visibility and comfort. Use different colored lighting to clearly distinguish the non-motorized area.**
- **Ventilation and air quality:** Install an effective ventilation system, as pedestrians and cyclists are exposed to exhaust fumes for longer periods of time. Consider installing a noise and pollution barrier between lanes.
- **Sufficient width:** Provide a comfortable passage width, especially if there is two-way or mixed pedestrian/cycle traffic.
- **Safety and surveillance:** Surveillance cameras, emergency intercoms, and clear signage.
- **Warning or evacuation system** in case of danger (fire, power failure, etc.).
- **Well-designed access:** Gentle, accessible ramps for bikes, people with reduced mobility, pushchairs, etc., and signage at the tunnel entrance to guide each type of user.

4- How to properly light a tunnel

4.1 Challenges in tunnel lighting

Lighting is a safety feature in tunnels and underground passages for the following main reasons:

- **Visibility of hazards:** Good lighting allows users to see **obstacles**, other users or stationary vehicles and quickly locate **emergency exits**, signs or emergency equipment.
- **Safety of pedestrians and cyclists:** In low light, it is easy to trip, bump into a wall or another user. For cyclists, lighting allows them to anticipate turns, slow down and maintain control.
- **Reduction of stress and anxiety:** Dark, enclosed spaces can be frightening. Good lighting reassures people and **promotes calm and cautious behavior**.
- **Assistance in the event of evacuation:** In the event of an accident, fire or breakdown, **emergency lighting** makes it possible to find exits quickly, avoid panic, and facilitate emergency response.
- **Reduced risk of accidents:** Drivers need good lighting to judge distances and react in time. A poorly lit tunnel can cause a **black hole tunnel effect** at the entrance (figure 1), which temporarily blinds drivers. The same phenomenon can also occur at night when exiting a lit tunnel (figure 2).

Figure 1. Black hole effect at tunnel entrance

Credit: Created with AI

Figure 2. Tunnel exit black hole effect

Credit: Created with AI

In addition, since the adoption of LED lighting, drivers have also been confronted with glare, both when entering and exiting tunnels, when the brightness outside is greater than inside. This effect, which has become more frequent with the advent of LEDs, can also occur when it is dark outside, but the tunnel entrance or exit is brightly lit. To reduce this glare, specific lighting adjustments are necessary.

Figure 3. Glare effect when entering a tunnel

Credit: Created with AI

Figure 4. Tunnel exit glare effect

Credit: Created with AI

4.2 Recommendations for road tunnels and underpasses

According to the Illumination Engineering Society - IES-RP-8 recommendations for North America and CEI-88 for Europe, tunnels are divided into different zones (access, threshold, transition, interior and exit) depending on their length. Each zone has a specific lighting level, adapted to the size of the tunnel, to facilitate the human eye's adaptation to variations in brightness and ensure safe and comfortable transit for users.

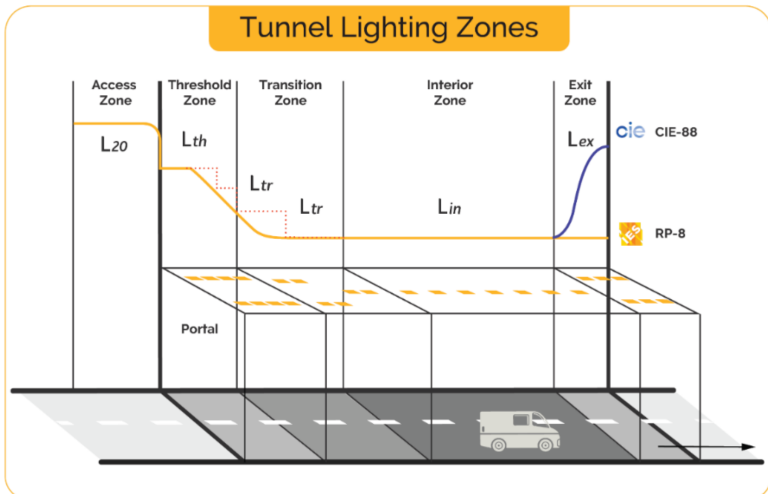
In daylight, road safety requires that drivers' eyes, which are adapted to outdoor lighting conditions, be able to adjust when entering the tunnel. An insufficiently lit tunnel can cause a ‘black hole’ effect at the entrance and glare at the exit, while an overly lit tunnel will cause glare at the entrance and a ‘black hole’ effect at the exit.

Once visual adaptation has begun and users are well into the tunnel, the luminance level can be gradually reduced to minimize energy consumption while maintaining adequate visual adaptation. This initial adjustment takes place in the threshold zone. The transition zone that follows allows for safe adaptation to the required brightness level in the interior zone.

The luminance level in the different zones is determined by several factors, including traffic speed and volume, tunnel length, geographical orientation and approach characteristics.
At night, as users' vision is already adapted to low light levels, no adjustment of the interior lighting level is generally necessary.

At tunnel exits, the North American RP-8 recommendation does not prescribe any adjustment of the luminance level in response to changes in external light (related to time of day, sunlight or urban lighting). However, the European recommendation does require this adjustment at tunnel exits, probably due to the greater length of European tunnels. That said, more North American tunnel operators are also requiring this adjustment at tunnel exits.

Figure 5. Lighting zones in a tunnel



Source: Nyx Hemera Technologies

5- The different types of lighting control systems

For safety reasons, the reliability of the control system is a major challenge for tunnel operators. The choice of communication technology for the control system is therefore crucial. Wi-Fi technologies are not suitable for tunnels, as materials such as concrete and rock block the signal. Radio frequency technologies also have disadvantages: lighting manufacturers cannot guarantee the waterproofing of the housing if they are pierced to integrate an antenna. Cable control, on the other hand, is time-consuming, expensive, polluting and unreliable, as it requires an average of six connectors per luminaire, which considerably complicates maintenance in the event of failure.

Most operators in North America now favor a lighting control system that uses power line communication. The control signal is injected into the bandwidth of the cables that supply the luminaires with electricity.

Powerline communication lighting control systems offer several advantages:

- As an addressable system, it allows individual control of luminaires, opening a virtually unlimited number of scenarios, as well as dimming.

- It reduces energy consumption by adjusting the lighting to actual needs, depending on the outside brightness.
- It ensures lighting complies with current technical recommendations

6- Solution for the Cody Tunnel

In 2023, the Wyoming Department of Transportation (WYDOT) launched a $ 4.5 million project to modernize the lighting system in a tunnel.

Taking advantage of the opportunity to replace the old equipment with LED luminaires and given the length of the tunnel (nearly one kilometer), the installation of a lighting control system was deemed necessary to ensure user safety. Although no official statistics are available on the number of cyclists using the tunnel, the Wyoming Department of Transportation estimated that the growth in bicycle traffic also justified specific measures to improve their safety.

It was therefore decided to:

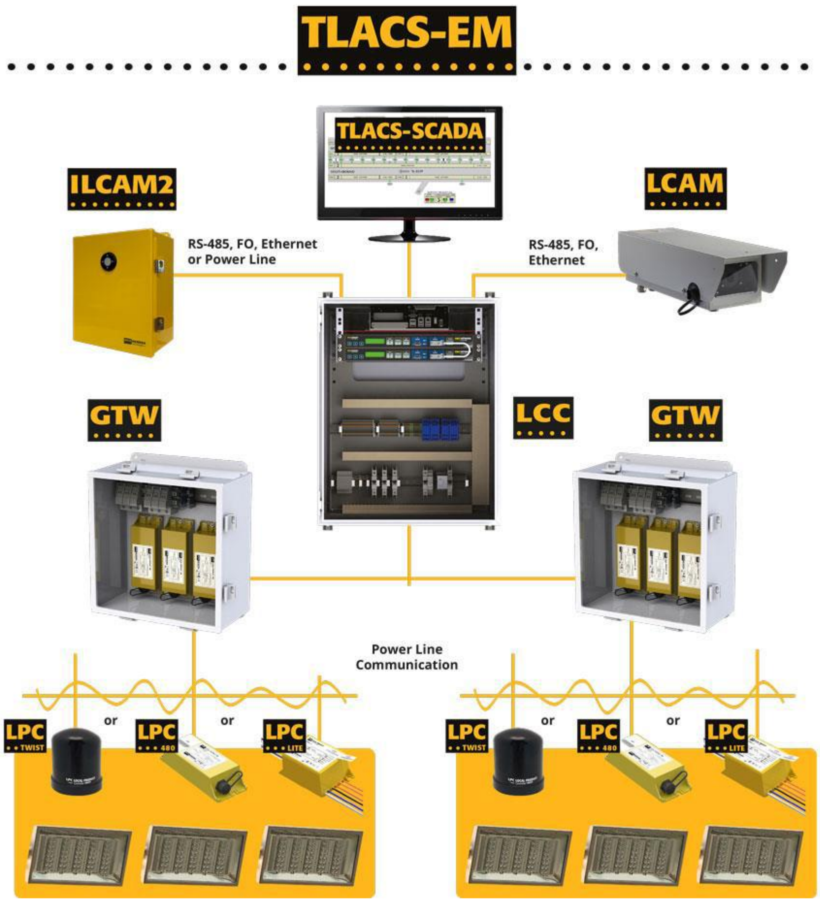
- Install a lighting control system capable of dynamically adjusting the lighting according to external conditions
- Install a warning system to alert motorists to the presence of pedestrians or cyclists, signaling greater awareness of non-motorized traffic in the tunnel
- Modernize the carbon monoxide (CO) detection system.
- Replace the ventilation system motors.
- Integrate the control and supervision of these four subsystems into a supervisory control and data acquisition (SCADA) system.

The modernization work began in April 2023 and was completed in October of the same year.

6.1 The lighting control system

The lighting control system installed in Cody Tunnel is broadly composed of the following elements:

Figure 6. TLACS lighting control system



Source: Nyx Hemera Technologies

- **A luminance meter (LCAM)**, which measures the luminance at the tunnel entrance to adjust the lighting level in the different zones in accordance with standards.
- **A main controller (LCC),** responsible for managing the entire system.
- **Gateway controllers (GTW),** which translate the LCC's commands to the local controllers (LPC) via power line communication.
- **A local controller (LPC)**, installed directly in each luminaire, which controls and monitors the luminaire drivers. It manages the dimming, switching (ON) and switching off (OFF) functions according to the required lighting level, calculates the hours of use and performs a diagnosis of each luminaire to transmit the information to the LCC.

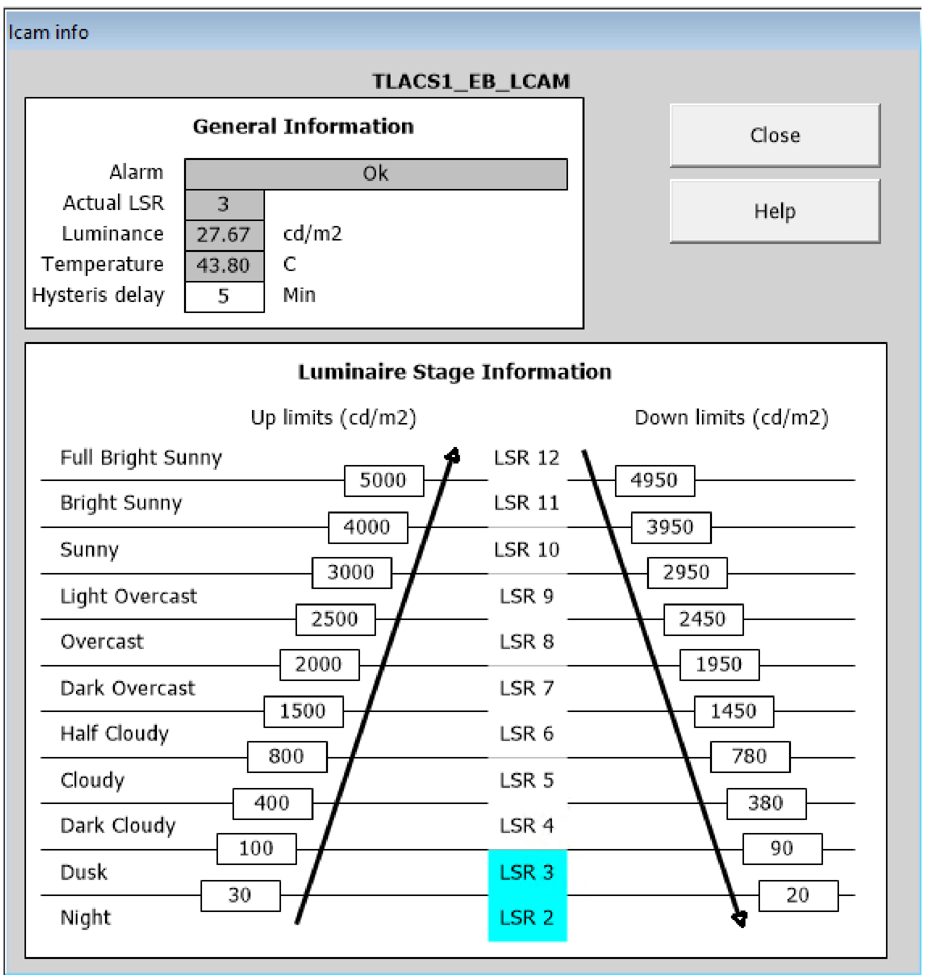
In the **Cody Tunnel** configuration, an illuminance meter (ILCAM2), designed to measure illuminance inside the tunnel based on luminaire fouling and ageing, was not installed.

Twelve lighting levels have been programmed into this system. These levels do not consider the time of day (although control based on a virtual clock is provided in case of TLACS system failure).

Lighting level adjustment (LSR) is performed dynamically based on the outdoor brightness measured by the LCAM luminance meter.

Finally, configurable hysteresis settings are provided to prevent lighting levels from changing every time a cloud passes or during brief periods of brightening.

Figure 7. The 12 lighting levels (LSR) in the Cody Tunnel



Source: Nyx Hemera Technologies

6.2 Enhancing Tunnel Safety and Comfort for Cyclists and Pedestrians

As part of a broader initiative to improve tunnel infrastructure for all users, several key systems have been upgraded or added to ensure the safety, comfort, and health of cyclists and pedestrians.

Recognizing that these users spend more time within the tunnel and have different needs than motorists, targeted adaptations were made to the warning, ventilation, and lighting systems:

- **The warning system is designed to alert motorists to the presence of pedestrians or cyclists**
  A button has now been installed at both entrances to the tunnel which, when pressed, alerts drivers to the presence of bicycles or pedestrians in the tunnel. Vehicle drivers are warned of the presence of cyclists by a flashing red light.

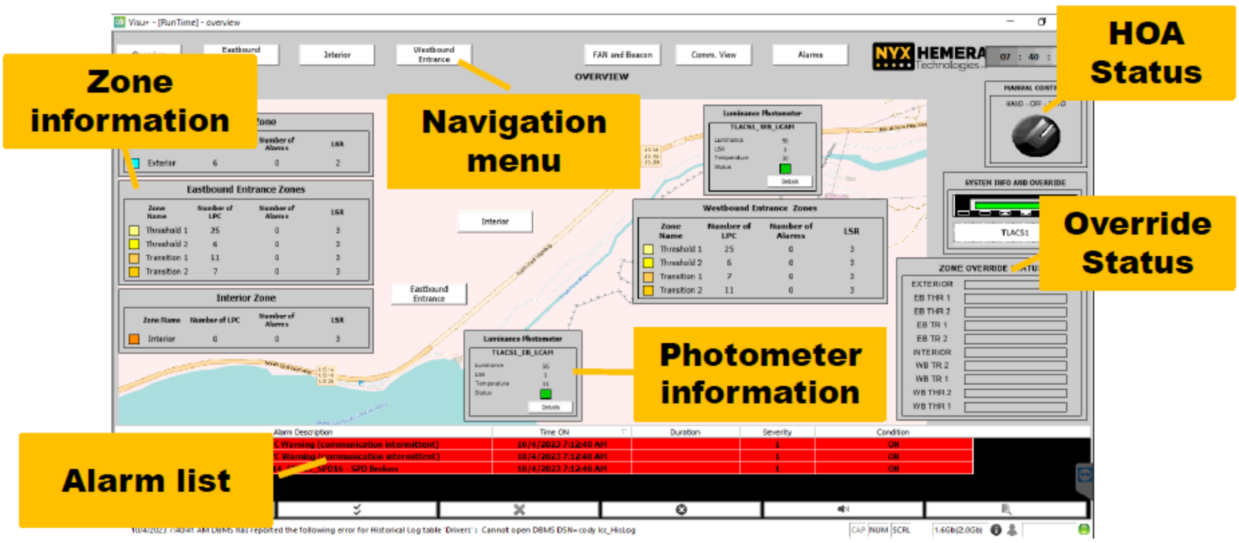
Figure 8. Flashing red light warning drivers of the presence of cyclists

Credit: Nyx Hemera Technologies

- **Carbon monoxide (CO) detection system and fan motor upgrade**
  To ensure good air quality for users spending more time in the tunnel (cyclists and pedestrians), the fan motors, which dated back to 1964, have been replaced. They are now controlled by programmable logic controllers installed in the LCC, based on data transmitted by six new CO detectors. Depending on the signal received, the two fans are activated to remove any gases present in the tunnel.

- **SCADA integration**
  The integration of the lighting system, the warning system for pedestrians and cyclists, the CO detection system and the ventilation system into a single SCADA interface enables intelligent interaction between these subsystems and simplified supervision for the operator responsible for remote tunnel management.

Figure 9. Cody Tunnel SCADA interface



Source: Nyx Hemera Technologies

7- What else can be done?

In addition to better lighting, more appropriate signage and an improved ventilation system, there is still room for improvement in protecting vulnerable users in tunnels. A case study of the Ecouges tunnel in Isère, an hour's drive from Grenoble in France (8), presented the same challenge as the Cody Tunnel, with an estimated 65 to 125 cyclists passing through each day.

The 491-metre-long Ecouges tunnel, which initially had no lighting system, was brought up to standard and equipped with thermal cameras installed at both entrances. The data collected by the cameras is processed by a programmable controller, which triggers the lighting at a variable level depending on the type of user detected (during the day: 150 lux for a cyclist, 50 lux for a car).

The lighting is switched off by a timer, but four infrared sensors inside the tunnel detect any users who are blocked.

Variable message signs display a bicycle symbol when cyclists are detected.

However, the implementation of this system remains partially limited: users already in the tunnel when a vehicle is detected approaching in the opposite direction cannot immediately benefit from the information transmitted by the variable message signs.

Figure 10. Limitations of the warning system in the Écouge tunnel

In addition to the solutions implemented in the Cody Tunnel and the Écouges Tunnel, it would also be possible to temporarily increase the light intensity when a cyclist is detected in the tunnel. This increase should be achieved without creating a 'black hole' effect at the entrance or exit of the tunnel, and in compliance with the recommendations of standards RP-8 and CIE-88.

Conclusion

With the growing number of cyclists in Canada and the increasing shift toward greener modes of transportation, ensuring cyclist safety in tunnels and underpasses—both in urban and rural areas—has become essential. Proper and dynamic lighting—adjusted to match ambient light at the tunnel entrance—is essential for driver safety and even more critical for cyclists and pedestrians, given their greater vulnerability.

Projects carried out in tunnels such as Cody in Wyoming and Les Écouges in France clearly demonstrate that the integration of intelligent and adaptive lighting systems is crucial to ensuring the safety of all road tunnel users, particularly the most vulnerable.

In these confined and shared environments, good lighting reduces the risk of accidents, facilitates visual adaptation for drivers and ensures optimal visibility for pedestrians and cyclists. The use of dynamic systems capable of adjusting to external light conditions or detecting non-motorized users is becoming essential for promoting safe and harmonious coexistence.

The experience of the Cody Tunnel, with the complete integration of lighting, CO detection, ventilation and warning systems into a centralized SCADA interface, shows that it is possible to effectively modernize our infrastructure while taking all types of users into account.