

Smart pedestrian crosswalk

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Abstract

Smart, intelligent pedestrian crossings are innovative technological solutions aimed at improving pedestrian safety. These crossings typically include sensors that detect the presence of pedestrians and automatically activate signals to alert drivers to their presence. Additionally, some smart pedestrian crossings may have additional features such as LED lights that adapt to traffic or audible signals for blind and visually impaired individuals. This technology has the potential to reduce the number of accidents and improve pedestrian safety when crossing the street. Increased mobility necessitates the continuous search for more efficient and effective solutions related to the safety of traffic participants. This paper will present the results of an analysis of pedestrian flow at a specific location, related to pedestrian crossing signaling and lighting that are economically justified, technologically efficient, and effective, contributing to pedestrian traffic safety. The paper will highlight the new evolution of technology that provides signaling and lighting for pedestrian crossings, making them interactive and safer. The installation needs to be adapted to the conditions at the intended site and determine the optimal solution in various situations.

Keywords: *Smart pedestrian crossing, pedestrian safety, technology, LED lights, traffic signaling, traffic safety*

1. Introduction

In urban infrastructure, pedestrian safety is an imperative that requires continuous improvement and innovation. In this context, smart pedestrian crossings represent a significant step towards enhancing pedestrian safety at intersections and crossings. This research paper is dedicated to studying the concept of "Smart Pedestrian Crossings," aiming to understand their applicability and benefits. The main focus of this work will be the analysis of technological aspects, design, implementation, and effectiveness of smart pedestrian crossings in various urban environments. Through a review of relevant literature, case studies, and analysis of examples of best practices, efforts will be made to identify key factors influencing the success of these innovative solutions and to propose guidelines for their implementation in the Canton of Sarajevo. Considering the increasing number of traffic

accidents involving pedestrians, it is important to explore new technological approaches that can contribute to reducing risks and improving traffic safety. Through this paper, we aim to provide a comprehensive overview of the concept of smart pedestrian crossings, highlight potential areas of application, and encourage further research towards the development of innovative solutions for a safer environment.

2. Smart pedestrian crosswalk

A smart pedestrian crossing is a type of pedestrian crossing that utilizes technology to enhance pedestrian safety. These crossings typically feature motion sensors, extra lighting, LED lights, monitoring cameras, sound signals and an anti-skidding system. When a pedestrian wants to cross the street, the driver gets warned with colour changing LED [10]. Additionally, they may have additional features such as auditory signals for blind or visually impaired

individuals and can be synchronized with vehicle traffic lights to ensure better traffic coordination. Smart crossings are pedestrian crossings which make the crosswalk safer by using smart electrical components. Most of these smart products can be implemented in already existing crosswalks [9]. Intelligent pedestrian systems are designed to reduce the number of traffic accidents that occur in traffic zones. This technical solution operates with a series of sensors that detect movement every time a pedestrian activates the sensor. LED lights on poles connected to the sensors immediately illuminate, aiding drivers in easily and quickly noticing pedestrians crossing the pedestrian crossing. In addition to the pedestrian crossing sign placed horizontally on the pole above the pedestrian crossing, two vertical panels, one on each side of the road, also light up. An additional feature that is not activated during the day is that the pedestrian crossing is fully illuminated at night with an LED panel located on the left and right poles, thus providing additional safety. [1]

SPC² monitors and detects all traffic participants using sensors and incorporates several safety and notification functions. The system alerts pedestrians with an audio signal and vehicle drivers with flashing LED lights. The system is adaptive and reacts according to the situation. The hardware is designed to be modular and can be retrofitted onto existing infrastructure. Smart Crosswalk can be activated in two ways [1]:

1. Manually pressing a button.

The push button is located on a pole or signpost near the crosswalk. This technology enabled pedestrians to press buttons installed on both sides of the road that allows pedestrians to signal their intention to cross the road [13].

2. Sensors detecting pedestrians.

Key functionalities include [1]:

- Notifying drivers about pedestrians
- Ensuring illuminated pedestrian crossing signs
- Active AI-based accident prevention system
- Data collection

- Connectivity with vehicles and other infrastructure
- Solar power system

3. Specifications and components of a smart pedestrian crosswalk

Over time, various solutions for pedestrian crossing signaling have evolved, including modern signaling and additional safety for pedestrians. Signaling at pedestrian crossings must be installed in accordance with prescribed standards. Modern signaling is developed to increase the safety of traffic participants [11].

SPC is the latest evolution of signaling and lighting systems for pedestrian crossings created to make pedestrian crossings more interactive and safer. The horizontal plane of the crossing is illuminated with a minimum recommended value of an average of 100 lux, as well as the vertical plane, illuminating pedestrians' bodies, making them visible from a sufficient distance, necessary to prevent accidents at pedestrian crossings. Light output is measured in lumens and represents the amount of light produced by the luminaire. For quality distribution of light output, an optical lens system is used, which also affects the value of the light output coming from the luminaire. For example, if a luminaire has a light source of 15,000 lm, that light output can be reduced to 12,000 lm after passing through the optics [1].

Lighting is the amount of measurable light at a point on a horizontal or vertical plane. It is measured in lux, and in most cases, it is important to meet the requirements for average plane illumination and overall uniformity (the ratio between minimum and average illumination). Horizontal lighting E_h [lux] represent the amount of light on the horizontal plane of the pedestrian crossing. The task is to achieve a high level of super-concentrated radiation, ensuring maximum visibility and detectability of the crossing from a great distance. [1] Vertical lighting E_v [lux] represents the amount of light on the vertical plane of the pedestrian crossing. High levels of lighting create strong contrast between pedestrians and the surroundings, guaranteeing clear visibility of pedestrians from a safe distance [1].

² SPC - Smart Pedestrian Crosswalk

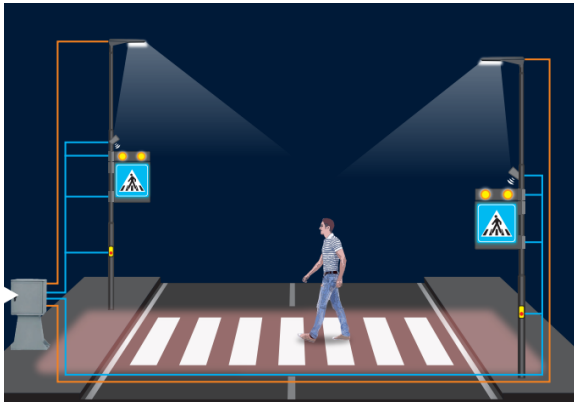


Fig. 1. Display of the smart pedestrian crossing

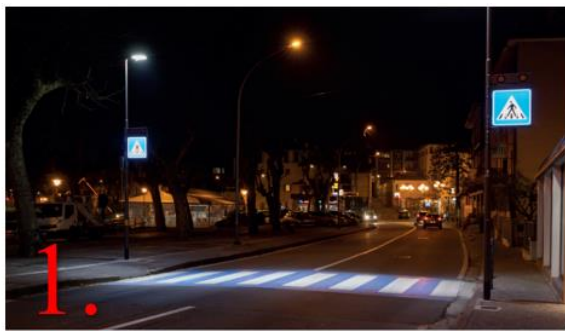


Fig. 2. Operation of the SPC in nighttime conditions

(<https://pjesackiprijelazi.com/>)

1. The system is activated by push buttons or sensors.

2 The lighting level at the pedestrian crossing ranges from 40% (standby mode) to 100% (active mode) thanks to intelligent dimming. It starts flashing LED signals. (Figure 2)

4. The possibility of introducing smart pedestrian crossings

As an introduction to the pedestrian traffic counting research, we can highlight the importance of monitoring and analyzing pedestrian movements in urban areas such as Sarajevo. Pedestrian traffic plays a crucial role in shaping urban space and planning measures to improve traffic safety and efficiency. Properly collected pedestrian data enables a better understanding of movement patterns, resulting in infrastructure improvements and adjustments of urban spaces to meet community needs. Pedestrian counting provides insights for further research and implementation of measures aimed at enhancing the urban environment.

Accordingly, we conducted pedestrian traffic counting at the following locations:

- Location number one: Marijin Dvor Marshal Tito 1, Sarajevo 71000 (Tram station heading towards Ilidža)
COORDINATES: 43°51'21.9"N
18°24'29.5"E

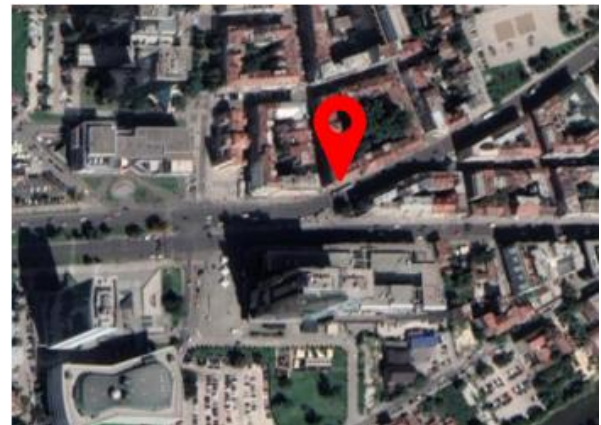


Fig. 3. Location number one

(<https://www.google.com/maps>)

- Location number two: Bus station - UNSA³ Campus, Put života, Sarajevo 71000 COORDINATES: 43°51'30.0"N
18°23'51.4"E

³ UNSA - University of Sarajevo



Fig. 4. Location number two
<https://www.google.com/maps>

Pedestrian traffic counting at the locations was conducted over three working days - Monday, Wednesday, and Friday, within the time interval from 11 am to 1 pm. When selecting the counting locations, determining factors included traffic density at those sites, the presence of pedestrian crossings, and whether the pedestrian crossing was regulated by adequate traffic signaling, proximity to the University of Sarajevo Campus, and the Bus station, which serves as a connection point for passengers arriving in or departing from Sarajevo. The results of the counting are provided in the Table 1.

Table 1: Presentation of pedestrian traffic counting results at locations

Location 1: Traffic Count - Marijin Dvor (11:00 - 13:00)							
	Total	Gender	Crossing on red light	Looking left/ right	Using a mobile phone	Direction towards SCC ⁴	Direction from SCC
Male	1317	1317	371	371	215	714	603
Female	1553	1553	486	486	304	688	865
Σ	2870		857	857	519	1402	1468
Location 2: Traffic Count - Bus Station / Campus (11:00 - 13:00)							
	Total	Gender	Crossing on red light	Looking left/ right	Using a mobile phone	Direction towards Campus	Direction towards Bus Station
Male	372	372	360	360	84	194	214
Female	473	473	454	454	95	162	275
Σ	845		814	814	179	356	489

⁴ SCC – Sarajevo City Center

After analyzing the collected data, we have chosen location number 2, the pedestrian crossing from the UNSA Campus to the Bus Station, as the priority location for installing a smart pedestrian crossing. The research results showed that out of the total number of pedestrians (845 in total), 814 crossed the pedestrian crossing while the pedestrian signal was red, meaning that only 31 pedestrians crossed during the green signal. These results highlight the importance of proper intersection design, traffic regulation, and signal setup to increase pedestrian safety and safety for other traffic participants at the given location.

In addition to ensuring pedestrian safety, our observation of pedestrian traffic included monitoring the operational intervals of traffic signals. On average, the red signal for drivers activates every 8 minutes. During the period when the red signal is activated for vehicles, the green signal for pedestrians remains active for 8 seconds. Taking into account all the relevant data available to us, analyzing the Location Campus of the University of Sarajevo – Sarajevo Bus Station, we conclude that this is a favorable location for the installation of a smart pedestrian crossing. This decision is based on several factors.

First, we consider the frequency of pedestrians crossing the street at this location. Analysis shows that this bus station is a central hub for students, staff, and visitors of the University of Sarajevo, resulting in a high flow of pedestrians throughout the day. Second, the location is of paramount importance due to its proximity to the campus and bus station. Many pedestrians use this intersection to reach their destinations or connect to public transportation, further increasing the frequency of pedestrian crossings. Third, the environment at this location plays a significant role. With a significant presence of pedestrian traffic, there is a high level of awareness of the need for safe street crossing. Installing a smart pedestrian crossing at this location would provide additional safety and facilitate pedestrian movement.

Finally, the importance of this location cannot be overstated. The University of Sarajevo is a vital center of education and culture in the city, and the bus station is a key point for public transportation. A smart pedestrian crossing at this location would not only improve pedestrian safety but also contribute to the enhancement of infrastructure

and quality of life in this vital part of the city. Therefore, considering the number of pedestrians crossing the street, the location, environment, and importance, we believe that the Location Campus of the University of Sarajevo – Sarajevo Bus Station is an optimal site for the implementation of a smart pedestrian crossing

4.1. Solving problems by introducing smart pedestrian crossings

Approximately 1.19 million people die each year as a result of road traffic crashes. Road traffic injuries are the leading cause of death for children and young adults aged 5–29 years. More than half of all road traffic deaths occur among vulnerable road users: pedestrians, cyclists, and motorcyclists. Road traffic crashes cost most countries 3% of their gross domestic product. [3]. At signalized pedestrian crossings, the probability of an accident occurring when a pedestrian crosses on a red light immediately before the green light turns on is up to 8 times higher compared to the probability of an accident occurring when crossing during the green light [14] SPC is an innovative product to reduce these risks. Here are some of the problems that can be solved by implementing a smart pedestrian crossing:

1. **Pedestrian Safety:** Traditional pedestrian crossings may lack visibility, leading to accidents and injuries. Smart pedestrian crossings equipped with features like automated signal timing, sensors, LED lights and warning systems can significantly enhance pedestrian safety by reducing the risk of accidents with vehicles. According to a studies, smart pedestrian crossings have shown to reduce pedestrian-vehicle conflicts and improve safety outcomes in urban environments [5].
2. **Accessibility of Smart Pedestrian Crosswalks:** Smart pedestrian crossings play a crucial role in ensuring accessibility for all individuals, including those with disabilities or limited mobility. These crossings can incorporate various features and technologies to cater to diverse user needs, promoting inclusivity in urban environments [8].

3. **Data Collection and Analysis:** Smart pedestrian crossings can serve as valuable data collection points for monitoring pedestrian and vehicle traffic patterns, identifying high-risk zones, and informing urban planning decisions. By leveraging technologies like video analytics and wireless communication, these systems can provide real-time data insights to transportation authorities and city planners. [7] The much-needed information today comes from traffic cameras, inductive loop sensors, and radar vehicle counters [10]



Fig. 5. Operation of the smart pedestrian crossing in reduced visibility conditions

5. Economic and environmental justification

Economic Aspects:

1. **Reduction of Accident Costs:** Smart pedestrian crossings can reduce the number of accidents at pedestrian crossings, resulting in lower costs for treating injuries and property damage, as well as legal expenses.
2. **Improvement of Traffic Flow:** Countries around the world have implemented many Intelligent Transportation Systems (ITS) solutions that significantly improved traffic flow [10]. The main goal of ITS is to solve the daily problems caused by traffic. ITS solutions offer many benefits, and the implementation of ITS improves the performance, efficiency and security of the transport system as a whole [12]. Traditional pedestrian crossings often cause traffic congestion and delays,

especially during peak hours. Implementing smart pedestrian crossings with features such as dynamic signal control and real-time pedestrian detection can help optimize traffic flow by efficiently managing the movement of both pedestrians and vehicles. [6]





Environmental Aspects:



1. **Reduction of CO2 Emissions:** Reducing CO2 emissions is currently a key policy in most developed countries. Studies show that deploying smart traffic lights at a single intersection can reduce CO2 emissions by 32% to 40%. [4] Using solar panels to power smart pedestrian crossings reduces the need for traditional energy sources. Among all the benefits of solar panels, the most important thing is that solar energy is a truly renewable energy source. It can be harnessed in all areas of the world and is available every day. We cannot run out of solar energy, unlike some of the other sources of energy. Solar energy will be accessible as long as we have the sun, therefore sunlight will be available to us for at least 5 billion years when according to scientists[15].
2. **Promotion of Sustainable Mobility:** Smart pedestrian crossings promote walking as an environmentally friendly mode of transportation. Improved pedestrian safety and better access to pedestrian crossings can encourage people to use pedestrian routes more often than personal vehicles, reducing emissions and promoting a healthier lifestyle.

6. Components of smart pedestrian crosswalk

The components of the smart pedestrian crossing encompass a range of technological elements that contribute to improving safety, efficiency, and functionality. Attached is a table detailing the components comprising the smart pedestrian crossing. The components are designed to be installed onto existing infrastructure (Table 2) [2]

Table 2: Components of a smart pedestrian system

	<p>LED lighting fixture with dedicated optics and dual asymmetry enabling achieving a high level of vertical illumination.</p>
	<p>Double-sided signs with LED backlighting - They assist drivers in easily detecting the presence of a pedestrian crossing, thanks to high brightness and excellent uniformity</p>
	<p>LED flashers - certified devices that are combined with signs with backlighting to increase the visibility of pedestrian crossings.</p>
	<p>Control module - A fiberglass housing with a holder for attachment to the pole. Inside the housing, there is a time module programmed with switching on and off times for the entire year, and it also serves as a power supply for the system."</p>

	<p>Activation devices - Sensors and switches make the system interactive and safer."</p>
	<p>Photovoltaic module with integrated battery charger.</p>

7. Conclusion

Referring to the section in the paper “The possibility of introducing smart pedestrian crossings” and analyzing the field counting data available for the location number two “University Campus in Sarajevo - Sarajevo Bus Station”, we conclude that this location is a priority for installing a smart pedestrian crosswalk. This decision is based on several factors. Firstly, we take into account the frequency of pedestrians crossing the street at this location. Analyses show that this bus station is a central point for the arrival and departure of students, staff, and visitors of the University of Sarajevo, resulting in high pedestrian traffic throughout the day.

Secondly, the location is crucial due to its proximity to the campus and the bus station. Many pedestrians use this intersection to reach their destinations or to connect to public transportation, further increasing the frequency of pedestrian crossings. With a significant presence of pedestrian traffic, there is a high level of awareness of the need for safe road crossing. Installing a smart pedestrian crosswalk at this location would provide additional safety and facilitate pedestrian movement.

The University of Sarajevo campus is an important educational center in the city, while the bus station is a key point of connection between pedestrians and public transport. A smart pedestrian crosswalk at this location would not only improve pedestrian safety but also contribute to the enhancement of infrastructure and quality of life in this vital part of the city.

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