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The "Engineer" publishes the most significant results of scientific and applied research carried out in universities of transport profile, as well as other higher educational institutions, research institutes, and centers of the Republic of Uzbekistan and foreign countries.

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Researching pedestrian movement in city streets

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Abstract: The article carefully analyzes the need for the study of pedestrian behaviour in the city streets, its determinants, and the methods of research. One of the major goals of planning within the city has been the improvement of pedestrian flows as well as the need to guarantee safety. A set of measures such as determining the parameters of pedestrian movement, obtaining data and applying statistical processes to it, and constructing movement models using new technologies were determined to be necessary. Thorough planning for urban structure provides opportunities for improvement of flows of pedestrian in the cities. The quality of urban infrastructure, the presence of safe sidewalks, crossing places, traffic lights, and other convenience features influence directly the effectiveness and safety of movement of pedestrians.

The research specifically focused on the necessity to factor the requirements of pedestrians under the design of the resultant infrastructure and the plans which endeavours to aid their mobility. It has also been noted the significance of studying pedestrian movements, analysing how this enables the recognition of activity patterns on streets, pedestrian traffic, and diagnosing certain issues. The analysis results support recommendations that seek to enhance urban infrastructure, pedestrian welfare, and urban mobility control. Moreover, the article gave comprehensive description about modeling techniques. It has extensively discussed the simulation of pedestrian activities in computer programs through modern technologies, predicting movement congestion for different scenarios, and evaluating the effectiveness of infrastructure. It was proposed that this modeling technique can be useful in the management of urban development and infrastructure planning because its outputs are useful in formulating different movement control strategies.

Keywords: urbanization, road infrastructure, pedestrian movement, optimization of transport vehicle movement, pedestrian flow, drones and cameras, traffic lights

1. Introduction

Cities around the globe are constantly rising in population and making strides economically, leading to rapid urbanization. Fueled by the growing demand for living spaces, the increase in transport vehicles and walking people directly affects road infrastructure. This further enhances the importance of urban infrastructure. Without a doubt, it is essential for modern day cities to focus on having efficient roads, safe areas for pedestrian movement, and the overall balance between traffic and public transport. This however is a much more complex problem in design and planning that needs to be addressed [1, 2, 20].

While past information is helpful, having a specific analysis of pedestrian movements and flows assists in developing infrastructure that pedestrians can find comfort in. This also allows the ability to make roads and crossing zones more safe, as well as effectively manage transport traffic systems [3, 4, 5, 21]. AI can further be utilized to create new strategies of enhancing pedestrian comfort and safety, while optimizing traffic flows to increase the overall effectiveness of a city's transport system.

The modernization of urban infrastructure facilitates more efficient management of traffic and contributes positively to city growth. A comfortable and safe infrastructure is a convenience to not only residents of the city but also tourists and other visitors [6, 7, 8, 22, 23] which, in turn, speeds up the economic and social growth. Therefore, there is an immediate need to formulate and execute these strategies during the urbanization process. The solutions should integrate new technology, effective resource management, and social considerations.

In any case, the urbanization phenomenon presents both opportunities and challenges when it comes to development and improvement of the urban infrastructure. These issues demand a strategic approach to urban infrastructure development that incorporates accurate predictive analysis. The increasing global attention towards sustainable development has created a need to rethink urban development planning strategies, especially those that include energy saving processes. Additionally, achieving a balance between the needs of pedestrians and motorists with respect to urban infrastructure improvement is also of critical importance. These, when combined with other various approaches, responses, and constructions, help in fostering the welfare of the urban populace [1, 9, 10] and in achieving the benefits of urbanisation.

2. Materials and method

The primary goal of the research is to analyze the features of pedestrian flows in urban street spaces in detail [11, 12, 13] and to formulate some practical tips for adequate infrastructure development in cities. To realize this goal, the following important tasks (Table 1) were set during the study:

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Table 1

Established Tasks	Main Objectives of the Research	Data
Studying the Characteristics of Pedestrian Flow	Analyzing the Movement Trends of Pedestrian Flow	Analyzing Movement Density and Pedestrian Flow Patterns, and Identifying Compatibility with Social Needs
Identifying Infrastructure Elements that Contribute to Providing a Comfortable and Safe Environment for Pedestrians	Creating a Safe and Comfortable Environment for Pedestrians	Analyzing Pedestrian Walkways, Traffic Lights, Crossing Points, Lighting Systems, and Other Infrastructure Elements
Applying Modern Technologies and Methods for Modeling Pedestrian Movement	Modeling and Analyzing Movement	Applying Simulation Software, Data Processing Tools, and Movement Tracking Technologies

As a result of implementing these tasks, scientifically-based recommendations aimed at improving urban infrastructure and creating a more comfortable, safe, and modern environment for pedestrians were developed. These recommendations serve as a foundation for formulating long-term strategic plans aimed at meeting societal needs and enhancing pedestrian safety.

During the research, the following methods were extensively employed, resulting in significant findings:

Observation. Special observation studies were conducted on major streets in the city center and in areas with high pedestrian permeability. Using this method, the characteristics of pedestrian flow movement, including pedestrian flow density, movement directions, and interactions with transport vehicles [14, 15, 20], were thoroughly examined. Activity patterns of pedestrian movements was analyzed in regards to various intervals of the day; morning, midday, and evening. This study provided insights into many existing issues pertaining to the city's infrastructure.

Interviews and Surveys. The research was done by asking pedestrians questions in which the responses provided information regarding their preferences and needs. To ease the collection of data, questionnaires were structured in a way that the most pertinent information regarding mobility and safety issues pedestrians encounter were gathered as shown in [16, 17]. Through interviews, pedestrians supplied very descriptive accounts of their preferences which made the target of the research more focused and accurate. This approach was especially important for assessing the degree of adequacy of urban infrastructure to people's needs.

Modeling. The studies use contemporary computer models for the equipment modern simulations to analyzing the movement's density will forecast possible issues within different scenarios. This specific method is beneficial to providing recommendations to increase safety of activities as well as movement s efficiency. In this case, the method which has the highest contribution is simulation software, thus making this method significantly contribute to the development recommendation designed to increase the safety and efficiency of movement.

Statistical Analysis. The analysis of documents received from the observations, interviews, and surveys was done with the help of statistical tools. This analysis, in addition to providing vital information about pedestrian flows, provided valuable insight regarding the infrastructure effectiveness. It allowed better understanding of the changes in the pedestrian flows, rent relations, and rational explanations of the research results.

The combination of techniques resulted in creation of a clear and concise document. This document proved that the steps taken towards resolving infrastructural urbanization issues are reasonable and can be implemented without any complication.

3. Result and Discussion

As a result of the research, the following main tasks were developed:

Variations Over Time and Density of Pedestrian Flow

The study shows that pedestrian commute during work hours is the most active. At these times, pedestrian flow significantly increases and it is necessary to manage the movement of other transport units and pedestrians on the streets. It was notably stated that the areas containing high density population zone are prone to having increased collisions between transport units and pedestrians which means there must be improved safety features.

Deficiencies in Infrastructure

During the course of the research, it was noticed that there is lack of proper infrastructure spaces dedicated for pedestrian use on the streets. Adequate provisions such as safe crossings and wide, well-lit sidewalks were not constructed. By the same token, it was observed that the placement of pedestrian lanes was either misplaced or inadequately used. Also, the placement of traffic signals was too low, which made it exceedingly difficult for pedestrians to cross the streets.

Technological Solutions Increased Efficiency

The study demonstrated that modern technological devices for analyzing and controlling pedestrian flow are effective. The condition of pedestrian flows was tracked in real-time with the help of drones and cameras which made it possible to collect accurate data and recognize movement patterns. In addition, computer models were used to study pedestrian flow patterns and to develop effective algorithms for flow direction optimization. All of these methods significantly aided in formulating important recommendations that help improve the safety of movements as well as enhance urban infrastructure.

These recommendations form the basis of the scientific data needed to improve urban infrastructure and provide pedestrians with a more friendly and safe environment.

4. Conclusion

The findings of the study recommend the effective management of pedestrian movement safety which is enabled by a number of developed suggestions. These recommendations are focused on the improvement of urban infrastructure, making it more convenient and safer for the pedestrians with the following: increasing the number of pedestrian crossing points with improved lighting on the streets, optimizing traffic signals for pedestrian purposes,

employing modern tools for monitoring and controlling pedestrian flow, enhancing infrastructure for pedestrians' safety, and modernizing innovation block projects.

These suggestions as in which infrastructure assumes a contemporary outlook with modern requirements, change in the management of pedestrian movement, and ensure safety when moving within urban areas makes a substantial difference towards the sustainable development of cities.

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