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Survey of Predictive Models for Safe Route Predicting Using Machine Learning Techniques

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Abstract

Safe route prediction is essential for the well-being and security of individuals in urban and rural environments. Machine learning techniques leverage historical data, real-time information, and algorithms to estimate the safety levels of different routes. The objective of safe route planning is to minimize risks, including crime-prone areas and accidents, reducing potential harm, property damage, and emotional distress. However, challenges arise from the complex and dynamic nature of urban environments, such as spatial and temporal variability, data availability and quality, and real-time considerations. Advanced machine learning techniques overcome these challenges by employing computational algorithms and statistical modeling. They analyze historical data, adapt to real-time information, and detect hidden relationships among factors to accurately predict safe routes. Machine learning models incorporate diverse data sources like crime records, accident reports, environmental factors, and social indicators to identify safety patterns. By capturing complex interactions and learning from past incidents, these models make informed predictions about route safety. Furthermore, machine learning algorithms continuously improve through feedback and the incorporation of new data, adapting to evolving safety patterns. Machine learning plays a crucial role in safe route planning by analyzing large volumes of data, extracting relevant features, and accurately predicting route safety. It provides an intelligent and data-driven approach to enhance safety while navigating through cities. Various computational algorithms, including decision trees, random forests, support vector machines, artificial neural networks, ensemble methods, and reinforcement learning, contribute to the analysis of data, extraction of patterns, and accurate predictions for safe route planning. The objective of the survey is to comprehensively explore predictive models for safe route planning using machine learning techniques.

Keywords: Spatial-temporal variability in safe route prediction, machine learning techniques for route safety, data-driven approaches for route safety, crime-prone area detection in route planning

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INTRODUCTION

Safe route prediction is a critical aspect of ensuring the well-being and security of individuals navigating through various environments. With the advent of machine learning techniques, there has been a significant advancement in predicting safe routes by leveraging historical data, real-time information, and sophisticated algorithms. These machine learning techniques offer promising solutions to estimate the safety levels of different routes, thereby minimizing the risks associated with potential hazards [1]. Machine learning techniques have revolutionized the field of safe route prediction by providing a data-driven approach to analyze and understand the factors that influence route safety. By harnessing the power of computational algorithms and statistical modeling, machine learning algorithms can effectively analyze vast amounts of historical data and adapt to real-time information. This enables them to detect hidden patterns, correlations, and relationships among various factors that contribute to the safety or danger of specific routes.

The objective of safe route prediction is to reduce the likelihood of encountering hazards such as crime-prone areas, accidents, or other dangerous situations. By guiding individuals towards safer routes, the potential for harm, property damage, and emotional distress can be significantly mitigated. Machine learning techniques play a crucial role in achieving this objective by accurately predicting the safety levels of different routes based on the analyzed data.

The complexity and dynamic nature of urban environments pose unique challenges to safe route prediction. These challenges include spatial [2, 3] and temporal variability [4], data availability and quality, and the need for real-time considerations. However, advanced machine learning techniques address these challenges by incorporating diverse data sources, such as crime records, accident reports, environmental factors, and social indicators. By considering these factors, machine learning models can identify safety patterns and capture the intricate interactions that influence route safety. Continuous improvement is a fundamental aspect of machine learning techniques in safe route prediction. As these algorithms receive feedback and new data, they adapt and evolve over time, enhancing their predictive capabilities. This adaptability ensures that the safe route prediction models remain effective in changing circumstances and can provide up-to-date recommendations for individuals navigating through various environments.

Figure 1 illustrates the architecture for predicting safe routes, incorporating data related to data location and route, crime factor data, pedestrian type, and step. The architecture encompasses data collection, data processing, and the utilization of machine learning algorithms to predict safe routes. This survey work is structured into several sections to provide a comprehensive understanding of the topic. First, it serves as an introduction, setting the stage for discussing safe route prediction using

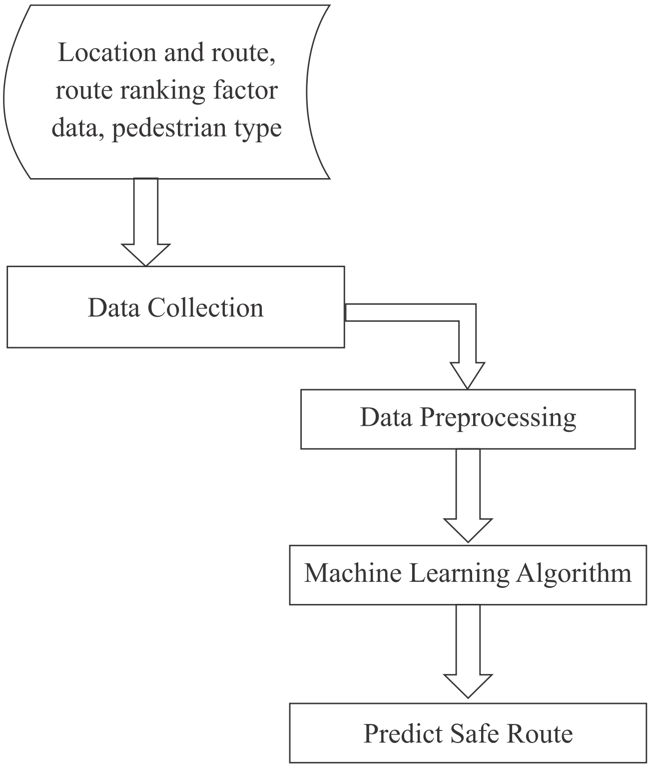

Figure 1. Architecture of safe route prediction.

machine learning techniques. Then, it delves into the concept of safe route prediction, highlighting its significance in enhancing individual safety and minimizing potential risks; explores the various machine learning techniques employed in this domain, showcasing their capabilities and applications in estimating route safety; and finally it concludes the survey, summarizing key findings and insights while highlighting future directions and potential advancements in the field of safe route prediction using machine learning techniques.

SAFE ROUTE PREDICTION

Safe route planning is to minimize the likelihood of encountering hazards such as crime-prone areas, accidents, or other dangerous situations during travel. By guiding individuals towards safer routes, the potential for harm, property damage, and emotional distress can be significantly mitigated. Machine learning techniques have revolutionized the field of safe route prediction by providing a data-driven approach to analyze and understand the factors that influence route safety. Safe route prediction encounters several challenges due to the complex and dynamic nature of urban environments. These challenges include spatial and temporal variability, data availability and quality, and the need for real-time considerations. Advanced machine learning techniques address these challenges by incorporating diverse data sources, such as crime records, accident reports, environmental factors, and social indicators. By considering these factors, machine learning models can identify safety patterns and capture the intricate interactions that influence route safety.

In the age of self-navigating ships, it is crucial for vessels to identify the most efficient route and precisely adhere to it through the implementation of route-following control technology. The research paper titled "Optimal Route Generation and Route-Following Control for Autonomous Vessel" by Kim *et al.* addresses the advancements in autonomous vessels and artificial intelligence in the context of safe route prediction [5]. The paper focuses on the generation of an optimal route and the development of a route-following control system for autonomous vessels. The paper emphasizes the importance of safety and fuel consumption reduction in generating the optimal route. Safety considerations include factors such as sea depth, under-keel clearance, and navigation charts, while fuel consumption reduction involves determining the most efficient route and eliminating unnecessary waypoints. The authors utilize a machine learning approach based on a reinforcement-learning algorithm to generate the best route, taking into account both sets of criteria.

Similarly, another research conducted Chen *et al*. focuses on the analysis of human travel patterns and population distributions for urban transport planning using multisource data [6]. The research investigates the connection between license plate recognition (LPR) data and cellular signaling (CS) data by utilizing identification methods to identify residents' travel stay points. Through correlation analysis, the study reveals a noteworthy association between CS and LPR data concerning population distribution and traffic patterns. This study enhances the understanding of intricate travel patterns and behaviors, providing valuable insights for the refinement of travel demand modeling and urban transport planning.

Another work in the safe route prediction titled "Object Identification and Safe Route Recommendation Based on Human Flow for the Visually Impaired" by Kajiwara and Kimura, focuses on addressing the challenges faced by visually impaired individuals in navigating unfamiliar environments [7]. The research aims to develop a system that can identify objects and recommend safe routes by leveraging human flow data. The study proposes a solution that utilizes computer vision techniques for object identification. By analyzing visual data from cameras or wearable devices, the system can recognize and categorize various objects in real-time. This capability assists visually impaired individuals in better understanding their surroundings and identifying obstacles or important landmarks. The results demonstrated that steps concealed by pedestrians could be accurately identified from the gait and route information, achieving an average accuracy of 0.92. Furthermore, the avoidance of "under construction" areas reached a 100% success rate. The research highlighted the potential of achieving 100% accuracy in route recommendations by leveraging human flow data.

Similar to work cited above, in the research by Fu *et al.* "TREADS: A Safe Route Recommender Using Social Media Mining and Text Summarization", the authors address the need for accurate and real-time information in safe route recommendations [8]. The study proposes an innovative approach that leverages social media mining and text summarization techniques to enhance the effectiveness and reliability of the recommendations. By mining social media platforms, such as Twitter or Facebook, TREADS gathers user-generated content related to safety incidents, crime reports, and real-time updates about various locations. The system then applies natural language processing and text summarization algorithms to extract relevant information and summarize it into concise and informative summaries.

The web-based geographic application "Be-safe travel" developed by Utamima and Djunaidy focuses on providing users with the ability to explore safe routes in a specific area [9]. The application aims to enhance personal safety and assist users in navigating unfamiliar locations by offering reliable route recommendations. Through the use of geospatial data and advanced algorithms, Be-safe travel analyzes various factors that contribute to safety, such as crime rates, accident statistics, and infrastructure conditions. By aggregating and processing this data, the application generates a comprehensive safety profile for different routes within the specified area. Users can interact with the application by inputting their starting point and destination, after which 'Be-safe travel' suggests multiple route options. Each route is evaluated based on the safety profile and presented to the user along with relevant information, including potential risks and safety features along the way. In addition to route recommendations, 'Be-safe travel' also provides real-time updates and alerts related to safety concerns in the selected area.

One another research work by Asawa *et al.* focuses on developing a user-specific safe route recommendation system [10]. The system aims to provide personalized recommendations for safe routes based on individual user preferences and requirements. By considering factors such as crime rates, traffic conditions, pedestrian safety, and user preferences, the system analyzes and evaluates different route options. It takes into account the user's desired mode of transportation, time of travel, and specific concerns related to safety. The system utilizes data from various sources, including historical crime data, real-time traffic updates, and user feedback, to generate route recommendations tailored to each user. Advanced algorithms and machine learning techniques are employed to process and analyze the data, enabling the system to provide accurate and context-aware recommendations. Through a user-friendly interface, the system presents the recommended routes to the user.

Mata *et al*. concentrate their research on creating a mobile information system that leverages crowd-sensed data and official crime data to aid users in identifying secure routes [11]. The study includes a case study conducted in Mexico City. The study aims to address the safety concerns of individuals navigating through urban environments, particularly in areas with high crime rates. By integrating crowd-sensed data, which is generated by users through mobile applications, and official crime data provided by relevant authorities, the system creates a comprehensive understanding of the safety landscape in Mexico City. Through the mobile information system, users can access real-time information about crime incidents, including their locations and types. This data is collected both from official sources and from reports submitted by the crowd-sensed data platform. By combining and analyzing these datasets, the system generates safety profiles for different routes and areas within Mexico City.

Continuous improvement is a fundamental aspect of machine learning techniques in safe route prediction. As these algorithms receive feedback and new data, they adapt and evolve over time, enhancing their predictive capabilities. This adaptability ensures that the safe route prediction models remain effective in changing circumstances and can provide up-to-date recommendations for individuals navigating through various environments.

MACHINE LEARNING TECHNIQUES

Machine learning techniques have revolutionized the field of safe route prediction by providing an intelligent and data-driven approach to estimate the safety levels of different routes. Given the wealth of historical data and real-time information, machine learning algorithms possess the capability to scrutinize intricate patterns and correlations among diverse factors, enabling them to produce precise predictions regarding route safety [12]. By leveraging computational algorithms and statistical modeling, machine learning models can incorporate diverse data sources, such as crime records, accident reports, environmental factors, and social indicators, to identify safety patterns and interactions. These models continually adapt and improve over time, considering changing circumstances and evolving safety patterns in urban environments.

Safe route prediction faces challenges due to the complex and dynamic nature of urban environments, including spatial and temporal variability, data availability and quality, and the need for real-time considerations [13]. Machine learning techniques address these challenges by efficiently processing large volumes of data, extracting relevant features, and making informed predictions about the safety levels of different routes. Diverse computational algorithms, including decision trees, random forests, support vector machines, artificial neural networks, ensemble methods, and reinforcement learning, are pivotal in the analysis of data, pattern extraction, and the generation of accurate predictions for the purpose of safe route planning.

A work on safe route prediction using machine learning by Huang *et al.* discusses on "A evacuation route recommendation using auto-encoder and Markov decision process" [14]. The research paper introduces an approach for suggesting evacuation routes during emergency situations by leveraging auto-encoder and Markov decision process (MDP). The proposed method is rooted in machine learning, utilizing MDP to model the evacuation problem as a sequential decision-making challenge in the face of uncertainty. The primary goal is to recommend optimal evacuation routes through the integration of these computational techniques. The MDP is a mathematical framework that describes the state, action, reward, and transition probabilities of a system. The paper uses a reinforcement learning algorithm called Q-learning to learn the optimal policy for each agent, which is a function that maps each state to an action.

The paper authored by Meng and Zheng focuses on the development of a personalized bikeability-based cycling route recommendation method using machine learning [15]. The main objective is to create a method that takes into account the quality of the urban built environment along the travel route when providing personalized recommendations for cycling routes. The work claims that most existing cycling route recommendation methods ignore the visual attributes of the built environment, such as greenery, landmarks, or aesthetics. The paper introduces a personalized bikeability-based cycling route recommendation (PBCRR) method, employing machine learning techniques to integrate built environment features into route planning. A weighted road impedance calculation function is applied to determine route recommendation indicators for each road segment, taking into account user preferences and constraints. This method aims to offer personalized and optimized cycling route suggestions by considering the specific features of the built environment along the route.

A similar work on this field was presented by Lv *et al*. 'Deep learning for autonomous vehicle and pedestrian interaction safety [16]'. Their paper proposes a deep learning framework for autonomous vehicle and pedestrian interaction safety, which consists of three modules: pedestrian detection, network (CNN) based model called Scale Invariant Faster Region-based Convolutional Neural Network (SIFRCNN) for pedestrian detection, which can handle different scales and orientations of pedestrians. The paper uses a Kalman filter-based model for pedestrian tracking, which can estimate the state and location of pedestrians. The paper uses a recurrent neural network (RNN) based model for pedestrian intention estimation, which can predict the future trajectory and crossing behavior of pedestrians.

A congruent work in this domain is by Li *et al*. 'Occlusion-Aware R-CNN: Detecting Pedestrians in a Crowd' [17]. The paper proposes a new occlusion-aware R-CNN (OR-CNN) for pedestrian detection in crowded scenes. The paper uses a new aggregation loss to make the proposals compact and close to the objects, and a new part occlusion-aware region of interest (PORoI) pooling unit to handle occlusion based on human body structure and visibility prediction. The paper assesses the effectiveness of the proposed method by conducting evaluations on four pedestrian detection datasets, achieving state-of-the-art results.

A related work in the same domain is presented by Adam *et al*. in their paper "MobileNets: Efficient Convolutional Neural Networks for Mobile Vision Applications" [18]. This work introduces a category of efficient models known as MobileNets, designed for mobile and embedded vision applications. It employs depth-wise separable convolutions to decrease computation and model size in convolutional neural networks. Additionally, the paper introduces two hyper-parameters, namely width multiplier and resolution multiplier, which allow for a trade-off between latency and accuracy in the models. The paper shows that MobileNets can achieve comparable or better accuracy than other models on various vision tasks, such as object detection, face recognition, and landmark recognition, while being much faster and smaller.

An analogous work in this field is Deep Residual Learning for Image Recognition by Sun *et al*. [19]. The paper proposes a deep convolutional neural network architecture called ResNet that can learn very deep networks with hundreds or thousands of layers. The paper introduces residual learning to ease the training of such deep networks and shows that ResNets can achieve state-of-the-art results on ImageNet and other datasets. The paper also demonstrates the importance of depth for visual recognition tasks and shows that ResNets can improve the performance of object detection, localization, and segmentation.

A related work to the previously mentioned papers is presented by Nama *et al.* in the paper titled "Machine learning-based traffic scheduling techniques for intelligent transportation system: Opportunities and challenges" [20]. This study reviews various machine learning-based traffic scheduling techniques employed in Intelligent Transportation Systems (ITS). The paper explores both the opportunities and challenges associated with the application of machine learning in enhancing traffic scheduling within ITS. The paper discusses the benefits and challenges of applying machine learning to optimize traffic flow, reduce congestion, and improve safety. The paper also surveys the existing machine learning methods for traffic scheduling, such as reinforcement learning, deep learning, genetic algorithm, and swarm intelligence. The paper provides a comparative analysis and future research directions for machine learning-based traffic scheduling techniques for ITS.

The work by Kaur *et al*. titled "Hybrid optimization enabled trust-based secure routing with deep learning-based attack detection in VANET" aligns with the discussed themes [21]. The paper introduces a hybrid optimization-enabled trust-based secure routing protocol for Vehicular Ad Hoc Networks (VANETs), incorporating deep learning-based attack detection mechanisms. This research aims to enhance the security of communication within VANETs by combining trust-based routing strategies with the detection capabilities of deep learning for identifying potential attacks. The paper uses a skill optimization technique to cluster the vehicles and assign cluster heads. The paper uses a deep Q-learning technique to compute the direct and indirect trust of the vehicles and select the trustworthy routes. The paper uses a diffusion convolutional neural network to detect and mitigate routing attacks such as black hole, gray hole, and wormhole. The paper evaluates the proposed protocol on various performance metrics and compares it with existing protocols.

In similar work by Zhang *et al*., 'How far are we from solving pedestrian detection?', the authors evaluate the state-of-the-art methods for pedestrian detection on various datasets and metrics [22]. This work proposes a new dataset called CityPersons that contains diverse urban scenes with many pedestrians. The paper compares the human performance and the detector performance on the Caltech dataset and shows that there is still a large gap to be closed.

Driving Safety Prediction and Safe Route Mapping Using In-vehicle and Roadside Data by Huang *et al*. proposes a methodology for developing dynamic risk heat maps of roadways, considering driver behaviors, traffic situations, and historical crash data. It uses facial recognition, video analytics, LightGBM model, and fuzzy logic to predict conflict indices and risk scores for road segments [23]. comprehensive overview of predictive models for safe route planning using machine learning techniques, showcasing their capabilities, applications, and advancements in enhancing safety and efficiency while navigating through cities.

Table 1 provides a comprehensive summary of the survey findings in this work, focusing on safety route prediction using machine learning techniques. The table reveals that a wide array of methods and techniques have been developed in this domain. These approaches leverage the power of machine learning to predict safe routes for various applications. The survey findings demonstrate the diversity of the methods employed, highlighting the versatility of machine learning in safety route prediction. The techniques encompass a range of algorithms. Furthermore, the table indicates that various data sources are utilized for training and prediction purposes. These sources include historical accident data, road infrastructure information, weather conditions, and real-time traffic data. By integrating these diverse data sets, machine learning models can capture complex patterns and make accurate predictions about safe routes.

Table 1. Information of survey findings.

Author/Article name	Data set used	Technique used	Result
Kim *et al.* Optimal Route Generation and Route-Following Control for Autonomous Vessel [5]	The sea depth data	Reinforcement learning-based optimal route generation algorithm	The proposed method accurately follows the designated route, even in the presence of environmental disturbances
Chen *et al*. Research on Human Travel Correlation for Urban Transport Planning Based on Multisource Data [6]	LPR data and cellular signaling (CS) data	Spatiotemporal clustering algorithm using time allocation	The research demonstrates a significant correlation between CS and LPR data for population distribution and traffic patterns
Kajiwara *et al*. Object Identification and Safe Route Recommendation Based on Human Flow for the Visually Impaired [7]	Pedestrian data obtained from sensors	Brute-force	100% accuracy in route recommendations by leveraging human flow data
Fu *et al.* TREADS: a safe route recommender using social media mining and text summarization [8]	Social media data	user interest extraction algorithm, TREADS	User to schedule safer route based on TREADS
Utamima and Djunaidy. Be-safe travel, a web-based geographic application to explore safe-route in an area [9]	WAYPOINTS	Haversine Formula and Google Maps API	Predicts one or multiple safe routes based on the google API and Haversine distance calculation formula
Asawa *et al.* User Specific Safe Route Recommendation System [10]	FBI UCR database contains curated crime records of San Francisco city data	Decision network	Calculates the safest route
Mata *et al*. A Mobile Information System Based on Crowd-Sensed and Official Crime Data for Finding Safe Routes: A Case Study of Mexico City [11]	Corpus of tweets and government official reports	Hybrid of Dijkstra algorithm bayes algorithm for safe route and	75% accuracy for all sort of data

Author/Article name	Data set used	Technique used	Result
Bi *et al*. Evacuation route recommendation using auto-encoder and Markov decision process [14]	Synthetic and real-world	Auto-encoder and Q-learning	Average satisfaction of building and campus evacuations 100%
Meng and Zheng. A personalized bike ability-based cycling route recommendation method with machine learning [15]	Bike sharing data and geospatial data	Deep neural network, convolutional neural network.	Beijing: 0.76 Shanghai: 0.74 average bikeability score
Lv *et al*. Deep learning for autonomous vehicle and pedestrian interaction safety [16]	KITTI benchmark	SIFRCNN, Kalman filter, and RNN	87.9% accuracy
Zhang *et al.* Occlusion-aware R-CNN: Detecting pedestrians in a crowd [17]	CityPersons 1 ETH 2 INRIA 3 Caltech	Scale Invariant Faster Region-based Convolutional Neural Network (SIFRCNN) Kalman filter Recurrent neural network (RNN)	Average precision CityPersons 15.7 ETH 54.0 INRIA 96.0 Caltech 10.8
Howard *et al.* Mobilenets: Efficient convolutional neural networks for mobile vision applications [18]	ImageNet COCO PASCAL VOC	Depth-wise separable convolution Width multiplier Resolution multiplier	70.6 Accuracy
Sun *et al.* Deep residual learning for image recognition [19]	ImageNet CIFAR-10 COCO PASCAL VOC	Residual learning	6.0% increase in coco standard data set
Sadoun *et al*. Machine learning-based traffic scheduling techniques for intelligent transportation system [20]	SUMO VISSIM TRAFVU	Reinforcement learning Deep learning Genetic algorithm Swarm intelligence	Deep learning 7.2 average waiting time
Kaur *et al.* Hybrid optimization enabled trust-based secure routing with deep learning-based attack detection in VANET [21]	SUMO NS	Skill optimization technique Deep Q-learning technique Diffusion convolutional neural network	98.7 PDR, 5.6 Mbps through put
Zhang *et al.* How far are we from solving pedestrian detection? [22]	Caltech INRIA ETH TUD-Brussels CityPersons	Checkerboards SquaresChnFtrs InformedHaar HOG LDCF ACF ACF-Caltech+ TA-CNN CompACT-Deep Checkerboards+	For Caltech Has long average miss rate of 47.8%
Huang *et al.* Driving Safety Prediction and Safe Route Mapping Using In-vehicle and Roadside Data [23]	Drivers information, traffic and historical crash data	LightGBM and fuzzy model	Simulated data has two case next 1 sec with accuracy of 0.948 and next 2 sec with 0.914

Moreover, the table suggests that researchers have examined different evaluation metrics to assess the performance of safety route prediction models. Common metrics include accuracy, precision. This review work emphasizes the abundance of machine learning methods and techniques employed for safety route prediction. These approaches leverage various algorithms, data sources, and evaluation metrics to develop accurate and robust models. The continuous advancements in this field offer promising prospects for enhancing road safety and optimizing route planning in transportation systems.

CONCLUSION

This work discusses how machine learning algorithms analyze diverse data sources, including crime records, accident reports, environmental factors, and social indicators, to identify safety patterns and make informed predictions about route safety. These models capture complex interactions and continuously improve through feedback and the incorporation of new data, adapting to evolving safety patterns over time.

Various computational algorithms are explored in the paper. These algorithms play a crucial role in the analysis of data, extraction of relevant features, and accurate predictions for safe route planning. In general, this survey work offers an all-encompassing summary of predictive models applied in secure route planning through the utilization of machine learning techniques. It highlights the potential of these models to minimize risks, reduce harm, property damage, and emotional distress. By incorporating historical data and real-time information, machine learning enables individuals to navigate cities with improved safety and security. The findings of this survey contribute to the advancement of safe route planning methodologies and encourage further research in this important domain.

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