Review on Parking Demand Estimation Based on Crowdsourced Data

S.M.M.H Samarakoon
Department of Interdisciplinary Studies
Faculty of Engineering, University of Sri Jayewardenepura
Colombo, Sri Lanka
smmhsamarakoon@sjp.ac.lk

A.H.T. Shyam Kularathna
Department of Interdisciplinary Studies
Faculty of Engineering, University of Sri Jayewardenepura
Colombo, Sri Lanka
shyamkularathna@sjp.ac.lk

Nadika Jayasooriya
Department of Interdisciplinary Studies
Faculty of Engineering, University of Sri Jayewardenepura
Colombo, Sri Lanka
nadika@sjp.ac.lk

Abstract

With the increase in urbanization and the growth of the economy, car ownership increases significantly, and at the same time demand for parking increases causing several issues like traffic congestion and resource wastage. There's a critical significance of accurate parking demand estimation in the context of urban planning, addressing those issues. It emphasizes the emerging role of crowdsourced data as a novel solution for more efficient and cost-effective parking demand estimation. This review discusses the benefits of crowdsourcing, including real-time data and minimal infrastructure requirements, while acknowledging challenges like data accuracy, user privacy, and potential biases. Furthermore, it provides a comprehensive overview of the subject matter and it suggests future directions for improvement, proposing the integration of advanced technologies like Google APIs and IoT to augment parking demand estimation models and address the limitations associated with crowdsourced data.

Key words: Parking demand estimation, crowdsourcing, ITS, Google API

I. INTRODUCTION

As the world moves deeper into the 21st century, industrialization is taking place worldwide, leading to high economic growth and urbanization. This causes higher incomes, growth of population, and an increase in the living standards of people [1]. Rapid urbanization led to many challenges and it mainly impacted the economy, social, and cultural aspects [2]. With the higher growth of population and the growth of incomes, people are led to spend on a quality lifestyle and due to that, there's a continuous growth in private vehicle ownership [3]. With the adoption of the urban environment, most people are willing to travel using private vehicles instead of public transit considering their comfort. Daily entering a higher number of vehicles into the road system causes many challenges in the transportation sector.

High demand for parking spaces is one of the major challenges in transportation which led to a negative impact on the traffic in urban areas [1]. Managing parking demand with the available spaces has become a critical challenge in urban areas worldwide due to the higher number of vehicles on the roads.

Previous findings have illustrated that the mean time duration for locating an available parking space was approximated to be 8.1 minutes and 7.8 minutes [4]. In the context of typical parking behaviors, drivers spend 3 to 10 minutes usually to locate a parking space; nevertheless, more than 50% of drivers express an unwillingness to allocate more than 5 minutes for this purpose [5]. Furthermore, a significant proportion, specifically 25% of the total average travel time within urban locales, is expended in the pursuit of suitable parking spaces. Cruising traffic poses a noteworthy parking-related challenge, constituting a substantial portion of the total traffic in urban areas [5][6]. Numerous studies have approximated that approximately 30% of the existing traffic is dedicated to seeking parking spaces, with this percentage escalating to as much as 40% or even 50% during peak rush hours [6].

Improper parking utilization not only contributes to traffic congestion and waste of time but also results in a waste of fuel while struggling to find available parking spaces. Researchers are trying to find solutions using technologies such as different sensors, image capture methods [7], video capture methods [8], and autonomous vehicles [9], to overcome these issues. These methods are not feasible to implement in every country as they require a high initial investment to install the necessary equipment such as sensors, and cameras in every parking area, and have a higher maintenance cost for better outcomes. Because of that, those available methods have proven to be inadequate to meet the evolving needs of every city [10]. As a result, there is an urgent requirement for a more efficient and effective approach to estimating and managing parking demand accurately.

By incorporating modern technologies, a more accurate parking demand estimation method can be developed to address the complexity of urban parking problems. Crowdsourcing is one such emerging data collection approach that can be used to find proper solutions for managing the parking demand in the cities. Crowdsourcing is a method that involves assigning tasks to a large group of people (referred to as the crowd) with the aim of enhancing decision-making, accomplishing challenging tasks, or collaboratively creating designs and various projects [11]. Compared to other methods, this approach is cost-effective. It relies on crowd-sourced data collection techniques, utilizing consumer services like phone calls, GPS navigation, and geotagged data transfer [12]. Crowdsourcing can be used to gather a vast collection of real-time data from a variety of sources, including smartphone applications, and social media platforms, and it can use for the decision-making processes.

II. Methodology

This review aims to address and elucidate the available parking demand estimation techniques, the use of crowdsourcing as a new-age solution, and the applications of crowdsourced data in vehicle parking.

A comprehensive literature review was undertaken by searching the literature through the Science Direct and google scholar databases considering the research papers published during the past 30 years period from 1993 to 2023 utilizing the keywords "Parking demand estimation", "crowdsourcing", "ITS" and "Google API". A total of forty papers were selected from the literature search and thoroughly examined within the framework of this review.

III. Available Parking Demand Estimation Techniques

Parking demand estimation is crucial in transportation engineering for urban planning and other transportation-related infrastructure developments. Parking demand estimation techniques can be broadly classified as traditional techniques and modern techniques. Traditional techniques mainly depend on direct observations, surveys, and the available standards set by transportation agencies. Manual counts, License plate surveys, questionnaire surveys, and land use-based estimation are such kind of traditional methods used for parking demand estimation. In those cases, individuals have to take records manually and should do a critical analysis to get an understanding of the parking demand.

Even though several modern techniques are available, traditional parking demand estimation techniques have several advantages for transportation planners. These methods are simple and straightforward without any complex methodologies, and also low-tech methods with direct human involvement. Because of that, they don't heavily depend on external factors such as electricity and the internet. The important thing is these methods are universally understood methods that can be used for every country in any region. Furthermore, these traditional techniques are with less technical failures because they depend on the minimum amount of technology and some of them are totally free from technology.

As well as advantages, traditional parking demand estimation methods have a considerable amount of disadvantages. When compared to modern, automated techniques, those traditional methods require more time for data collection, data process, and data analysis. Even though these techniques don't consume external factors such as electricity and the internet, they require more physical resources and more manpower. Due to most of these methods being based on human observation, there can be human errors that affect the precision of the data.

Other types of parking demand estimation techniques basically use modern technologies and tools for data collection and data analysis processes. Smart sensors such as in-ground sensors like embedded parking spots, camera-based systems, mobile applications, big data and analytic platforms, license plate recognition systems, connected vehicles, machine learning, and AI, are kind of modern technologies used for parking demand estimation.

Instead of using the traditional demand estimation techniques researchers currently focused on modern technologies to obtain better outcomes. Using vehicle sensors such as cameras, ultrasonic sensors, and radar sensors, is one method to determine free parking places in cities. The collected data through this method can be used to enrich the existing information about available parking places [9],[11]. Data gathering through smartphone-embedded sensors' (accelerometer/gyroscope), Bluetooth connectivity, and analysis to determine the automatic detection of parking actions performed by the user [12] is another area studied by the researchers.

Another technique is on-street parking detection based on image and video analysis methods. Images captured by event recorders integrated into vehicular systems were gathered and subjected to image analysis to discern the availability of parking spaces. Subsequently, the system locates the nearest parking space based on user requests, enabling the driver to navigate directly to the identified available parking spot [7]. In the video-based approach, cameras observe on-street parking spaces, continuously recording video. These video sequences are transmitted to a central processing unit, where the footage is subsequently analyzed to estimate the occupancy status of on-street parking spaces [13].

IV. Crowdsourcing: A New Age Solution

The idea of crowdsourcing was found by Howe in 2006 [14]. Crowdsourcing can be defined as a platform that contains ideas, services, or data from a large and diverse group of individuals from the public or an online community [15]. The usage of crowdsourcing spread expeditiously with the growth of the Internet and the widespread use of personal mobile devices [12]. It's become stronger with the increasing usage of mobile devices, augmented data bandwidth, and the advent of ultra-reliable and low latency communications [15].

Currently, crowdsourcing is used in various applications including research and innovations, data collection, and problem-solving, and also it has the power to collect a wide range of purposes. Also, the use of crowdsourcing can be found in every field including medicine, engineering, management, agriculture, and other fields. Under the public health context, crowdsourcing is used for problem identification purposes. Brabham has described four types of typologies suitable for crowdsourcing which are knowledge discovery and management, distributed human intelligence tasking, broadcast search, and peer-vetted creative production. These factors are used to identify cases for public health like accessible scarce public health resources at the community level, tracking and mapping illness trends and clusters, quality of food deserts in grocery stores, finding tobacco retailers without a license, and solving large-scale information management problems where human intelligence is more efficient and effective than computer analysis like

organizing information more efficiently and cost-effectivly, making data entry, cataloging, language translation for health camping, etc. Broadcast search is used to find novel solutions to sanitation in the developing world and peer-vetted creative production is used to get community input for design and aesthetic problems [16]. Furthermore, crowdsourcing has made a considerable contribution to tackling the COVID-19 crisis. There are several innovative solutions were developed by the involvement of different stakeholders in health care, industry, government, and academic sectors to fight against COVID-19[17]. TopCoder, Cal4Ideas COVID-19 Challenge, and InnoCentive[17] are such kinds of crowdsourcing online platforms developed by different parties.

In agriculture, crowdsourcing plays a significant role in extensive projects, including environmental monitoring and research and development initiatives. It involves collecting raw measurements of environmental variables, noting geographical features, and recording visual observations. This collaborative approach allows for the gathering of diverse data from a large number of contributors, contributing to a better understanding of agricultural and environmental conditions [18]. Several crowdsourcing-related agricultural applications have been developed and utilized in various countries. Notable examples include Pl@ntNet[19], a platform designed for plant identification through image analysis, PlantVillage Image[20], which focuses on identifying plant diseases using image analysis, and PocketLAI[21], a mobile application specifically designed for measuring leaf area index. These applications leverage the power of crowdsourcing to engage individuals in contributing to agricultural activities, such as identifying plants and diseases or measuring leaf area index. The utilization of these tools highlights the potential of crowdsourcing in addressing agricultural challenges through innovative and accessible technologies.

Crowdsourcing finds numerous applications across various engineering fields, leveraging the reach and scale of the internet, alongside the widespread use of computing devices such as desktop computers and smartphones by individuals constituting the crowd [22]. One such domain where its utilization has surged is Intelligent Transportation Systems in transportation engineering.

With the development of Intelligent Transportation Systems (ITS) which are developed using modern technologies such as wireless communications, electronics, and information processing to improve the safety, efficiency, and convenience of the overall surface transportation network [23], there's a rapid increase in use of crowdsourcing in the transportation engineering. The use of crowdsourcing in ITS can be categorized as applications in mobile, spatial, and passive sensing crowdsourcing [23].

In Mobile crowdsourcing, assigned tasks are performed by the users on mobile platforms (e.g.: smartphones). Waze and Uber are such kinds of applications used in transportation, and novel systems use social media data to predict different transportation incidents such as traffic congestion, car accidents, etc[24]. In Spatial crowdsourcing, it's considered a specified location while completing the task [25]. Parking location monitoring systems can be expressed as an example of spatial crowdsourcing. In this context, information is gathered about available parking spaces in specific areas. This data is then utilized to aid drivers in locating street parking efficiently, offering additional details related to their destination. The aim is to minimize the time spent fruitlessly searching for a parking spot [26]. Sensors embedded in smart vehicles are one way of using passive sensing crowdsourcing in ITS. This can be used to schedule the collection based on the vehicle trajectories [27] and track vehicle fleets in real time [28].

V. Application of Crowdsourced Data in vehicle Parking

As described in the previous section, crowdsourcing data can be used for parking location monitoring purposes. Mobile applications, social media platforms, connected vehicles, and Google APIs are sources used to collect crowdsourcing data in this context. There are studies on autonomous and connected vehicle-based parking and navigation models based on crowdsourcing. To support autonomous vehicle parking in urban environments, Crowd Parking schemes have been suggested. These schemes utilize crowdsourcing and vehicular fog computing to gather parking information from vehicles and identify available parking spaces through crowdsourced data [9][29].

Park Bid [30], Park Here [31], and Crowdparking [9] are crowdsourcing-based mobile applications used to find parking lots. Park Bid service was developed to circulate information about free parking places among interested users through a bidding process. This application uses time, location, reputation and urgency as primitives when providing the parking information. The mobile application depends on the parking bidders and the users. Parking bidders provide the details about the available parking slots and users are the persons who plan to take the service from ParkingBid. Even though the application was well planned using crowdsourcing which follows a bidding strategy, it faces several challenges because of the dishonesty of bidders who provide misleading information targeting to earn more money and the users who are dishonest in taking the service of the application.

The mobile application "Park Here" adopts a crowdsourcing approach, having an algorithm that automatically detects the users' parking actions through the analysis of smartphone-embedded sensors and Bluetooth connections. Crowdparking achieves parking reservations by crowdsourcing data that provide information on available parking resources, and use that available information to help other users to find parking spots.

ParkCrowd [32] is a parking system that utilizes crowd sensing to collect on-street and roadside parking space data consistently. The system is specifically designed to efficiently relay this information to drivers in a timely manner. Furthermore, Parker [33], ParkSense [34], Open Spot [35], and Park Me [36] are mobile phone-based applications that have been developed to find parking spaces

and pay for them through the application. Moreover, CRAWLING [37] introduces a Crowdsourcing Algorithm on WheeLs designed for smart parking within the context of in-car services for connected cars' routing. This innovative service leverages crowdsourced data from diverse sources such as other vehicles, pedestrians, smart sensors, and social media to effectively accomplish a designated routing task.

These applications emphasize that crowdsourcing is a very powerful technique that can be used for the parking demand analysis process because it allows contacting a wide range of participants to share the data. Also, it is a low-cost method compared to other modern technologies [38].

Additionally, it is noteworthy that crowdsourced data offers real-time information with enhanced speed. That is very important for planners to make decisions in urban planning processes [39]. Moreover, this technique is mainly based on cloud platforms, there's no requirement to install any physical devices in parking lots. Because of that, the cost-effectiveness is very high compared to the other modern technologies.

Even though crowdsourcing data offers many advantages, there are several challenges linked to gathering this type of information. Most of the above-mentioned applications are based on various technologies such as image and video capturing, different sensing elements and the data collected through the users. Installation of sensors is not feasible for every parking location and it's a costly method that needs more cost for installation and maintenance purposes. Since the information of many people contributes to the data, the accuracy of the crowdsourcing data is dependable and the data quality can vary [40]. The privacy of users is also a concerning challenge related to crowdsourced data. It's important to protect the personal information of individuals and ensure that data is not misused. It also should carefully manage potential biases introduced by the opinions or perspectives of the people.

VI. Conclusion

This review emphasizes the importance of parking demand estimation in the context of urban planning, to overcome the challenges manifest in the form of traffic congestion, long search time for parking, and wastage of resources. As a new solution, discussed the importance of utilizing crowdsourcing data for the parking demand estimation over traditional methods. Furthermore, advantages and the limitations of crowdsourced data were discussed. Integration with the latest technologies such as Google APIs, and IoT to develop parking demand estimation models to overcome the limitations of the crowdsourced data can be elaborated for future studies.

VII. References

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