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Urban Development Strategies to Enhance Traffic Flow in the Al-Midan Area: A Review

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ABSTRACT

Parking significantly influences urban traffic management, affecting congestion, traffic flow, and intersection performance. Off-street parking, in particular, can reduce on-street parking demand and enhance road capacity. Still, if poorly integrated, it may increase traffic volumes, congestion near access points, and delays at adjacent intersections. This study reviews existing literature on the relationship between parking and traffic conditions, emphasizing simulation-based approaches. It uses the SIDRA Intersection software to assess the impact of a proposed off-street parking facility within an urban network. The analysis includes both existing and projected traffic scenarios, evaluating key performance metrics such as delay, vehicle queuing, and level of service (LOS). Key considerations include access point design, signal coordination, and intersection control strategies to determine the facility's integration efficiency. The goal is to evaluate whether the new parking facility improves or worsens overall traffic performance and to suggest mitigation strategies for any negative impacts. Findings from this research will offer practical insights for urban planners and transportation engineers, supporting the development of parking solutions that enhance mobility and maintain efficient traffic operations in urban environments.

1. Introduction

Parking is vital in urban traffic management, influencing congestion, traffic flow, and intersection performance. It can also impact surrounding road networks by altering vehicle movement patterns. This chapter reviews existing studies on the relationship between parking and traffic conditions, focusing on research utilizing traffic simulation tools for traffic analysis. It also explores strategies to optimize parking integration and minimize negative effects. The findings from this review provide a foundation for the study, shaping its methodology and objectives.

2. Parking Facilities

Arriving at a place with delays or challenges in parking significantly reduces the utility of a car. For optimal efficiency, a transportation system must have sufficient parking facilities at all locations that generate trips [1]. Parking facilities are generally defined as any building, land, right of way, or structure used for the off-street parking of vehicles [2]. It can be public or private, and it has many types. Different vehicle types utilize various parking designs, each tailored to fulfill specific roles, locations, parking regulations, and traffic demands.

2.1 Off-Street Parking

Off-street parking refers to designated parking areas where vehicles can be parked

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away from public roads. Unlike on-street parking, which takes place along curbs and roadways, off-street parking provides a more organized and often safer alternative for vehicle storage. These parking areas can be found in various forms, including surface lots, parking garages, and other facilities specifically designed to accommodate vehicles [3].

Off-street parking facilities can be classified according to their ownership, geographical location, and intended use. They may be either outdoor or indoor, depending on their structural design. Outdoor parking areas, such as surface lots, are typically open-air and found in commercial centers, residential areas, and public spaces. Indoor parking, on the other hand, includes multi-story parking structures and underground garages that offer protection from weather conditions and often enhance security [4].

2.1.1 Types of Off-Street Parking

As follows, the main types of off-street parking [3].

2.1.1.1 By Ownership

- Public Parking: These facilities are owned and maintained by municipalities or government agencies. They are generally accessible to the public, sometimes free or available at a regulated fee. Public parking can be found near transportation hubs, commercial districts, and recreational areas.
- Private Parking: Owned by businesses, organizations, or individuals, private parking facilities are usually restricted to authorized users. These may include office building parking lots, apartment complex garages, and shopping center parking areas.

2.1.1.2 By Usage Duration

- Short-Stay Parking: Designed for brief visits, such as retail shopping or quick errands, these facilities often have higher hourly rates to encourage turnover.
- Long-Stay Parking: Typically found at airports, train stations, and business districts, long-term parking options allow vehicles to remain parked for extended periods at a lower daily or monthly rate.
- Contract Parking: Also known as leased parking, this arrangement allows individuals or businesses to rent parking spaces on a monthly or yearly basis, commonly used in business districts where demand for parking is high.

2.1.1.3 By Facility Type

- Surface Lots: Open parking areas without overhead structures, commonly found in commercial and residential areas.

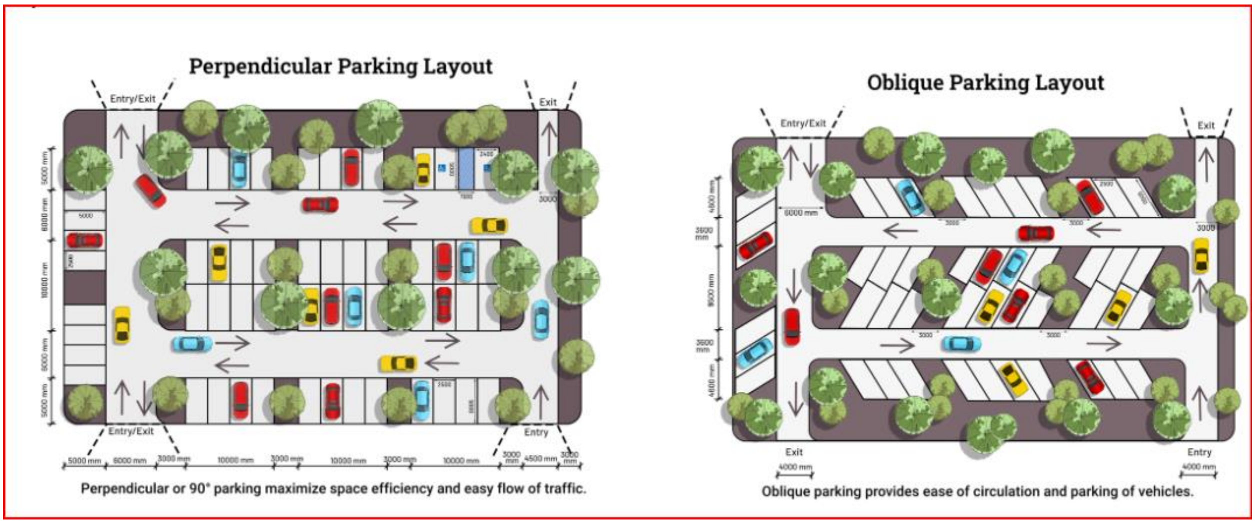

Figure 1: Surface parking

2.1.2 Parking Garages

Structures designed to maximize parking include vertical or multi-level parking spaces found in retail areas attached to shopping malls, restaurants, and entertainment centers, which accommodate customers. However, some of these parking lots serve as Park-and-Ride Facilities, designed to promote the use of public transportation. These lots are strategically located near transit hubs where commuters can leave their cars and continue their journey via buses or trains.

There are many types of parking garages, such as:

2.1.2.1 Multi-level parking, or vertical parking, is a parking complex designed to accommodate vehicles across numerous tiers, as shown in Figure 2. This facility can accept a greater volume of cars simultaneously and optimizes vertical space use. Multi-level parking is intended for residential buildings and business entities such as malls, retail centers, offices, and multiplexes.

Figure 2: Multi-level parking in Kuala Lumpur

2.1.2.2 Multi-story car parks: Public places with limited or inadequate space, such as city centers, business districts, and other high-traffic regions, might benefit from this form of parking, as seen in Figure 3 [5].

Figure 3: Al-Sinak multi-story car parks.

2.1.2.3 Underground car parks: Built under the ground level of the building, this kind of parking allows cars to access and leave the area by means of ramps, therefore connecting them to the ground. Figure 4 demonstrates its fit for usage in service buildings, business centers, and residential buildings [6].

Figure 4: Underground car parks.

2.1.3 Benefits of Off-Street Parking

There are many benefits in adopting off-street parking that can be listed as follows [7-8].

- Reduces Traffic Congestion, by providing dedicated parking spaces away from the road, off-street parking helps reduce the number of vehicles searching for spots along busy streets.
- Enhances Safety, off street facilities help minimize roadside hazards, such as sudden stops and obstructed visibility, which can lead to accidents.
- Maximizes Land Use Efficiency, multi-story garages and underground parking solutions enable better space utilization, particularly in densely populated urban areas.
- Improves Aesthetics and Organization, by keeping vehicles off main roads and sidewalks, off-street parking contributes to a cleaner and more organized cityscape.

2.1.4 Challenges of Off-Street Parking

There are many challenges in adopting off-street parking that can be listed as follows [9].

- High Construction and Maintenance Costs: Building parking garages and maintaining them can be expensive, particularly in urban centers with high land costs.
- Space Allocation Issues: Finding sufficient space for parking facilities in dense cities can be challenging, often requiring innovative solutions like automated parking systems.
- Environmental Concerns: Parking with large-sized lots contributes to stormwater runoff issues and urban heat islands, prompting the need for eco-friendly designs such as green roofs and permeable pavement.

Off-street parking is essential in urban design, facilitating effective vehicle management and alleviating congestion on public thoroughfares. As urban areas expand, contemporary parking solutions, like automated parking systems and intelligent parking technologies, are being devised to improve efficiency and sustainability.

2.2 On-Street Parking

Curb facilities are an alternative designation for them. These parking facilities often denote the parking of a vehicle on public roads or streets, at the curbside, along the edge of the carriageway, on lateral strips parallel to the roadway, or in designated locations such as squares or other surfaces. This facility is located in retail districts near the entrance of high-traffic shopping establishments, providing swift access for users. This type of garage is a prevalent method of parking in urban and suburban regions [5].

According to the operational and regulatory frameworks, there are three categories of on-street parking facilities:

- Long duration parking
- Restricted parking for a limited time with stringent regulations enforcement
- Payment Parking, which involves fees

2.2.1 Types of On-Street Parking

Figure 5 and the following table demonstrate the several forms of on-street parking that may be classified according to the angle of the road alignment [10]:

- Parallel parking is when cars are parked side by side with the road, as the name implies. As far as parking accidents are concerned, it's the safest option. One potential drawback is that it might use up all of the available curb space, limiting the number of cars that can fit along that stretch.
- 30° parking: Compared to parallel parking, the number of cars parked in this configuration is much higher. Its reduced traffic delays and enhanced maneuverability are two of its many benefits.
- 45° parking: As the parking angle is increased, the total number of cars that might be serviced also increases.
- 60° parking: In this instance, automobiles may be parked at a 60° angle relative to the orientation of the road. Consequently, an increased number of vehicles may be accommodated.
- 90° (right angle) parking: Cars have to engage in complicated maneuvers in this configuration, which may result in serious collisions. The possibility of it slowing down traffic is also directly proportional to the road's width.

However, curb parking has a significant effect on urban dynamic traffic, causing many problems such as congestion, accidents, delays, reduced levels of service, and traffic speed. Mainly, the inhabitants tend to curb parking because of their desire to be as close as feasible to their intended destination. The road capacity is most influenced by curb parking, where a single car can effectively close a lane and lose the capacity of the adjacent lane; sometimes, at small street widths, the entire capacity of the roadway is affected. The vehicle's starting, backing, and stopping during the parking maneuver are physically obstructing other traffic movements. The presence of vehicle occupants on the roadway, the opening of vehicle doors, or people emerging from between parked automobiles often disrupts the efficient flow of motor traffic [1,11].

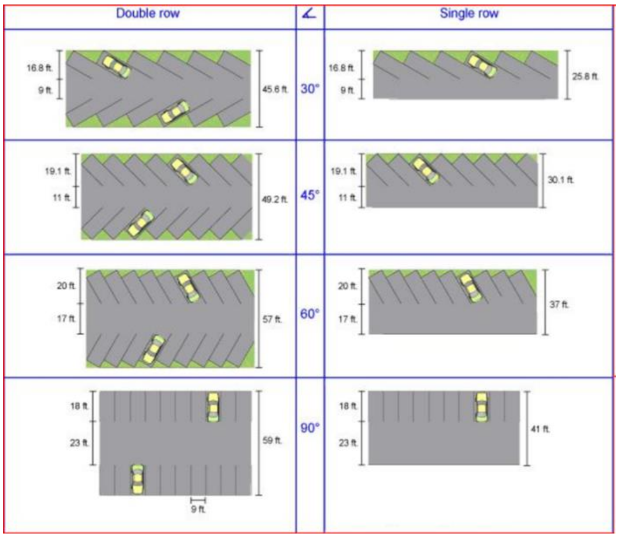

Figure 5: On-street parking Types [10]

On-street parking and accidents have a definite relationship; they are directly responsible for some of the 20 percent of urban street accidents, not just for cars but also pedestrian accidents, and cause one-half of school-age children killed in traffic. Local streets have more curb accidents than major and collector streets. Furthermore, curb parking causes more accidents on one-way streets. As for intersection curb parking, it is more hazardous as it restricts the traffic sight distance for drivers crossing or entering the major streets. Prohibition of curbside parking on major streets reduced the accident rate from 12 to 90%. Angle parking is more hazardous than parallel parking; it leads to a higher crash rate because of its challenging maneuvering and results in a greater reduction in road capacity. [12].

The research aims to provide a clearer understanding of the impact of curb parking on the width of the street. Table 1 shows how much the street width and capacity decrease with the number of stopped cars on the street side.

Table 1: The Impact of Parked Vehicle Quantity on Roadway Width and Capacity [13].

Capacity lost at 24 Km/hr. (PCU/hr.)	Vehicles parked per km (both sides, parallel parking)	Carriage way width effective loss of (M)
200	3	0.3
275	6	1.2
475	30	2.1
575	60	2.5
675	120	3
800	300	3.7

2.3 Parking Management

Among the most significant methods to make transportation more sustainable is to improve parking management. There are a lot of different ways to handle parking, but when done well, parking management may drastically cut down on the number of spots required in a given situation while also providing an extensive number of other advantages [14]:

- enhancing quality service of user.
- Making land-use patterns more accessible.
- Reducing automobile traffic.
- Reducing pollution, traffic, and accidents.
- Making communities more appealing.
- Enhancing mobility for non-drivers.

2.4 Parking Demand and Supply

The rule of supply and demand has a significant impact on the parking phenomena. The supply shows the amount of parking places that are available for a specific area. Generally, the curb parking problem is not constant; it varies depending on several factors such as the functional classification of the street system, land use type, the vehicle demand in the area, etc. Curb parking is essential, but we must restrict it to reduce congestion and associated accidents. In several cases, the financial losses resulting from accidents and congestion caused by curb parking would likely cover the cost of comparable space in off-street parking facilities. Side-impact or rear-end collisions are also a concern. [1].

The type of land use usually dictates the parking needs. For residential services, such as housing, communities generally set a minimum number of parking places per dwelling unit, bed, or room; for commercial uses, such as offices and stores, this is often expressed as a floor area unit. According to the increasing growth rate, these requirements have grown, and they fall between 3 and 4 spots per 1000 ft (0.3 km^2) of the building's floor area [15].

One of the two most important factors is the rise in the number of available parking spots. Every new construction project is required by law to include a certain minimum parking level. The second issue is that designers and innovators aren't always ready to provide enough parking to satisfy customer demand. To reduce parking congestion at nearby institutions, these requirements primarily aim to guarantee that suitable parking is accessible near destinations. There has been criticism of this technique due to the fact that meeting these criteria sometimes requires large amounts of land and significant investments in both capital and upkeep [16].

Parking demand is defined as the quantity of parking utilized at a certain time, place, and duration. Parking needs are affected by many things that are different in each area, including the type and amount of land use, cultural norms, the users' socioeconomic status, and the availability of other ways to get around. Moreover, these characteristics exhibit variability both within and across metropolitan regions, while they remain comparable [13].

The demand for urban parking escalated with the rise in vehicle ownership, resulting in a significant traffic problem in the central business districts of cities. Predicting parking demand is crucial for known parking planning as it provides critical data for establishing the appropriate size of the parking facility[17]. Parking needs tend to repeat themselves on a daily, monthly, or yearly basis. On weekdays, for example, parking demand in office-business zones rises.

However, weekends are when most people want to park, especially at popular venues like restaurants, theaters, and markets.

Moreover, parking demand may fluctuate due to alterations in transportation, land use, and demographic factors. Let's assume that a structure transitions from residential to industrial or commercial use. The density and configuration of the area may change, along with the quality of transportation services, all of which influence parking demand and duration. The duration of parking fluctuates based on the objective of the trip. Commuters require prolonged parking and exhibit more price sensitivity.

Existing parking space availability, high parking prices, below-capacity property use, and multi-purpose trips may all act as brakes on parking demand. The amount of available parking, on-site circulation, the required space for vehicles to maneuver, and the waiting time and congestion that come with it are all factors that are taken into account. The demand for parking at a certain place is affected by all of these variables. Finally, the current parking supply system determines the actual use of available parking spaces, making it tough to estimate parking demand when designing parking facilities [18].

2.5 Problems of Parking in The Central Business District (CBD)

Parking is a substantial problem in several urban areas. In densely populated regions, the central business center serves as a magnet for traffic, driven by heightened commercial and economic expansion, leading to a substantial rise in vehicular mobility [19].

Parking in the Central Business District is contentious owing to a disparity between demand and availability. When the demand for parking spots surpasses the available supply, the hunt for parking becomes imperative. Transportation planners have challenges in addressing parking problems, especially in commercial areas. Locating a parking place in the urban commercial district is laborious [20].

Owing to scarce and costly land resources, parking in the majority of urban areas is a challenge for drivers and traffic managers. Research indicates that more than 8% of all motorists in urban areas search for parking, with this figure escalating to 30% and an average duration of 8.1 minutes in central business districts (CBD) during peak hours [21]. Moreover, parking lots might adversely affect metropolitan areas [22].

A negative consequence of insufficient parking places to satisfy demand is "cruising for parking." Owing to a lack of suitable curb space, drivers use indirect routes to locate parking near their destinations. The waste of time and fuel significantly elevates travel expenses [21].

Conversely, despite being cognizant of the risks linked to prolonged cruising, individuals remain in search of on-street parking, incurring marginal fuel expenses to evade the exorbitant fees associated with off-street parking, thereby engaging in a trade-off between financial expenditure and time investment [21, 23].

Two scenarios happen as a result of parking cruising. First, cruisers suffer direct expenses due to the time wasted looking for parking, which could have been saved elsewhere. Second, this extra travel causes more traffic, air pollution, wasted time, and irritated drivers, which may raise the risk of accidents and hurt the economy in places with few parking spots, especially if there aren't many other ways to get there [24-25].

An increase in cars requiring parking may be mitigated by augmenting the availability of parking spots or managing demand using Transportation Demand Management (TDM) strategies [26].

Therefore, the creation of advanced technologies like Intelligent Parking Services (IPS) has eliminated the need to navigate urban parking spaces. With the use of real-time data collecting, IPS provides parking recommendations and reservation services to assist passengers in finding available parking places. But the cruise procedure is now much faster because of this new technology [27].

2.6 Negative Effects of Parking

Many road users, such as pedestrians, cyclists, and vehicles, are in densely populated places. The capacity of all road users to navigate efficiently and securely is essential in managing mixed-use transportation. The result is some of the detrimental implications for drivers:

2.6.1 Congestion: Parking is an essential consequence of the transportation of humans and goods into and within metropolitan regions. Parking contributes to traffic congestion when several cars seek to access certain sites concurrently, compounded by insufficient road and parking infrastructure to support them. Loss of street space and the resulting congestion are among the negative consequences of parking. There is less space on the streets, travel times are longer, and delays are more frequent. Consequently, the community suffers a substantial economic setback as car running expenditures rise. The capacity of traffic flow is reduced, and congestion worsens when vehicles park on carriageways. The path is effectively blocked from moving traffic when one vehicle stops in the middle of a curb lane. There are two ways in which curbside parking reduces available roadway space. To begin with, it obstructs the path of traffic. Additionally, it is common for nearby lanes to become inoperable due to parking and unparking activities [28].

2.6.2 Environmental pollution: Fewer vehicles are on the road, which means lengthier commutes and more frequent delays. The community's economy takes a significant blow as a result of the increase in automobile operating expenses. When cars pull over onto highways, it slows traffic and makes congestion worse. When one car pulls into the center of a curb lane, it blocks the way for all oncoming vehicles. Curbside parking limits the amount of road space that may be used for driving in two ways. To start with, it blocks the road. Furthermore, adjacent lanes often become impassable as a result of parking and unparking operations [29]. Road traffic contributes up to 70% of air pollution, while industrial pollution contributes 30%. Motorized vehicles are the primary source of air pollution because of their exponential growth resulting from technological advancements, particularly in transportation. The principal pollutants created by motorized vehicles are CO and SO_2 [30].

Sustainable transportation and smart cities aim to lessen the toll of human traffic on the environment without sacrificing efficiency. Restricting the availability of parking spaces is a common practice in many cities throughout the globe. Vehicles causing traffic jams are those that actively seek parking spots and utilize the parking strategy [31].

3. Car Ownership

The city of Baghdad has seen tremendous economic expansion, motorization, and urbanization from 1976 to 2022. World Population Review data shows that from 1976, when Baghdad's population was 2.5 million, it has increased by 7.2 million (2022). Urbanization, more frequent travel, and an increase in everyday activities are all outcomes of this population growth. With 2,479,898 vehicles and 28,351 motorbikes registered at the General Traffic Directorate till 2020, Baghdad governorate ranked sixth in Iraq for car and motorcycle usage. The increase in car imports and the high incomes of citizens, particularly employees, have contributed to this trend.

The current growth in these percentages is due to financial loans to everyone, yet the roads have been neglected and undermaintained, leading to traffic bottlenecks, unlawful parking, and distorted road designs.

Another transformation in Baghdad City is the fast spread of new retail centers (malls), which augments the workforce and enhances attraction activities, leading to congestion in the adjacent malls. Insufficient planning and research have resulted in several problems for shopping malls and its vicinity, including inadequate parking availability and strain on the transportation network, among others. Construction of new commercial malls, poor public transportation, a lack of other options for getting around town, a firm reliance on private cars, and extensive illegal parking on municipal streets contribute to the city of Baghdad’s current traffic issues [32].

4. Local Regulation

The Baghdad Mayoralty's design department issued various rules and regulations concerning the construction of Iraqi local units, including a parking ordinance disseminated to municipalities in 2012. The ordinance specifies the quantity of parking places mandated for various land use classifications, as seen in Table 2.

Table 2: Required Parking space for diverse land use types according to the mayoralty of Baghdad.

Type of land use	Parking places Requirements
local companies and government institutions	3 spaces per 100 m^2
supermarkets and malls	5 spaces for each 100 m^2
Universities	3 spaces per 100 m^2

5. Review of Parking Studies

Parking studies include a diverse array of subjects both domestically and internationally, and while each nation has unique characteristics, they all exhibit some similarities. This section comprises studies on parking, categorized into two classifications: local and international.

5.1 Previous International Studies of Parking.

Chawdhury [33] examined the availability and demand for parking spaces in the commercial area. A total of 280 vehicles per hour were available in the area. Nevertheless, 488 people used it over the week. There is a shortage of supply compared to the demand. Findings from the study indicate that problems can't be solved without first establishing a management structure.

Zhang and Zhu, [34] considered the issue of parking alternatives via the introduction of charge thresholds and proposed a plan for making reasonable adjustments to parking costs. They found that cars are more accommodating to parking on the curb than in designated off-street spaces. However, drivers' habits change when on-street parking becomes expensive. Additionally, it has been found that drivers with less driving experience and those who were older had a greater threshold for parking fees. Also found that drivers were willing to pay more to have shorter walks. For buildings that are difficult to reach on foot, the authors suggested raising the cost of parking on the street.

Mangiaracina et. al. [35] found in their study that motorists searching for free parking contribute to 30% of daily traffic congestion in major downtown areas. Researchers developed a model to simulate urban parking before and after implementing a Smart Parking system in Milan, Italy. The system uses sensors in pay-and-display parking spaces to show availability. The study revealed two key benefits: increased revenue for parking operators by reducing unpaid parking and reduced fuel consumption and emissions for drivers. The findings suggest that Smart Parking could save each driver 77.2 hours and €86.5 in fuel annually while reducing Milan's CO_2 emissions by 44,470 tons per year.

Yan et al. [36] demonstrated the parking strategy's influence on improving vehicle usage and parking demand. It was discovered that visitors respond to parking restrictions by moving to another parking facility rather than choosing an alternate mode of transportation. The writers came to the conclusion that putting together pricing and regulatory measures that shorten the time it takes to search for and leave a parking space has a bigger impact on demand than the sum of the effects of each measure when used alone.

Eka et al. [37] investigate the impact of parking on traffic performance along the Cisaat Sukamanah Highway near Cisaat Baru Market in Sukabumi, West Java. The highway's performance receives a B rating, yet parking demand remains high, particularly on Sundays. There were 4,709 motorcycles and 2,210 cars parked, with peak accumulations at specific times. The parking turnover rates indicate heavy usage, exceeding the capacity of available spaces. This inefficiency leads to congestion, negatively affecting traffic flow.

Gedefaye Geremew, [38] highlights the critical issue of insufficient parking in Debre Markos City, which is causing significant traffic congestion due to rising taxi demand and population growth. The inadequate road facilities, combined with on-street parking problems such as double parking and reduced vehicle maneuverability, result in narrow road widths and impaired traffic flow. On-street parking diminishes road capacity by 24.1% from legal parking and an extra 25.89% from unlawful double parking. Removing on-street parking may enhance road capacity by 49.9% and decrease travel time by 36%. The study also finds a direct correlation between increased parking occupancy and decreased vehicle speed. The findings suggest the need for proactive policies to manage parking, enforce regulations, and incorporate parking management into urban planning to improve traffic flow and reduce congestion.

The Previous international studies of parking are summarized in Table 3.

Table 3: The previous research of parking studies

	Author(s)	Year	Study Area	Type	Findings
1	Chawdhury [33]	2014	Business district parking supply/demand	Demand-Supply analysis	Parking demand (488) exceeded supply (280); a management system is needed.
2	Zhang and Zhu [34]	2016	Parking pricing strategies	Behavioral study	Drivers prefer curbside parking; high fees alter behavior; older drivers tolerate higher fees.
3	Mangiaracina et al. [35]	2017	Smart Parking in Milan, Italy	Simulation study	Smart Parking reduces unpaid parking, fuel use, and emissions; saves drivers 77.2 hours and €86.5 annually.
4	Yan et. al. [36].	2019	Parking strategy impact on demand	Policy evaluation	Pricing and regulations reduce search/egress time and influence parking demand.

5	Eka Gandara et. al. [37].	2021	Parking impact on Cisaat Sukamanah Highway	Traffic performance analysis	High demand causes congestion; heavy usage exceeds capacity, affecting flow.
6	Gedefaye [38]	2024	On-street parking in Debre Markos, Ethiopia	Traffic impact analysis	On-street parking reduces road capacity by 49.9%; travel time decreases by 36% if removed.

5.2 Previous Local Studies of Parking

A wide range of studies have examined parking issues and possible remedies in Iraq.

Previous research, like that of [39-40], examined university parking issues, emphasizing notable imbalances between parking availability and demand. This research highlighted the absence of comprehensive rules, legal frameworks, and strategic planning as key factors leading to inefficiencies in campus parking. Their results made it clear how important it is to have clear parking rules, improve existing facilities, and come up with organized ways to deal with the growing need for parking.

Al-Obaidi et al. [41] evaluated parking efficiency in Baghdad by examining critical metrics like the parking turnover, parking index, and parking duration. Their findings revealed that although some parking facilities functioned below capacity, others frequently encountered overcapacity owing to poor management and inadequacies in electronic gate control systems.

Al-Jameel [42] investigated significant parking deficiencies in core metropolitan areas, recommending the development of a multi-story parking facility and the use of intelligent parking systems integrated with sensors to improve efficiency.

Hassan Kadhim [43] introduced a smart parking system utilizing Arduino technology, allowing vehicles to identify and reserve vacant parking spaces through a smartphone application.

Alabassi and Al-Jameel [44] developed an ultrasonic sensor-based system aimed at mitigating parking constraints at universities by providing real-time availability information.

Sonya et al. [45] The study examines the impact of on-street parking on traffic congestion at Gajah Mada St., Rambipuji, and Jember. High parking demand reduces road width, disrupting traffic flow. It was noted that removing on-street parking increased road capacity by 25%, reduced saturation by 25%, and raised vehicle speeds by 11%. Parking data showed significant variations across vehicle types, with high turnover and occupancy rates indicating inadequate parking supply. The findings highlight the need for better parking management to improve traffic flow in commercial areas.

Rukaya and Hasan [46] The research investigates the influence of on-street parking on traffic congestion along Al-Rasheed Street in Baghdad. Limited space and increasing car ownership result in on-street parking that narrows lane width, causes bottlenecks, and exacerbates peak-hour congestion. The VISSIM simulation indicated that the elimination of on-street parking resulted in a 46.6% enhancement in traffic flow, a 38% decrease in travel time, and a 69% reduction in vehicle delays. The findings underscore the necessity for enhanced parking management to optimize urban traffic efficiency.

Al-Rikabi [47] devised an intelligent parking management system that governs vehicle access according to real-time space availability, hence minimizing search durations and enhancing overall efficiency.

Jony et al. [48] discovered a substantial deficiency of legal off-street parking spots in Al-Hilla, resulting in inefficiencies in parking usage.

Al-Tamimi and Asmael [49] researched Baghdad's Al-Mansour district, a prominent business center, and discovered that the current parking infrastructure was inadequate, exacerbating significant traffic congestion. Similarly, [50] examined on-street parking challenges in Al-Najaf, uncovering prevalent occurrences of unlawful parking, especially during peak hours. Their research advocated for regulatory measures, the growth of off-street parking facilities, and the use of smart parking technology to alleviate congestion.

Numerous research studies have concentrated on the utilization of new technology to enhance parking management.

Shnewer et al. [51] assessed parking configurations in Amara, highlighting the inefficiencies resulting from a lack of uniform design. Their studies indicated that a 90-degree parking arrangement would maximize space efficiency.

Allbadi et al. [52] further developed this concept by incorporating ultrasonic and infrared sensors with RFID technology to enhance parking operations and reduce congestion.

The Previous local studies of parking are summarized in Table 4.

Table 4: The Previous local studies of parking

	Author(s)	Year	Study Area	Type	Findings
1	Al-Harbawee [53]	1990	University parking in Iraq	Institutional parking study	Imbalance between demand and availability; need for regulations and strategic planning.
2	Kraidi [54]	2011			
3	Al-Obaidi et al. [41]	2018	Parking efficiency in Baghdad	Parking performance metrics analysis	Some lots are underutilized; others are overcapacity due to poor management.
4	Al-Jameel [42]	2018	Urban parking deficiencies	Infrastructure recommendation	Multi-story parking and smart parking are suggested to address deficits.
5	Hassan Kadhim [43]	2018	Smart parking using Arduino	Technology implementation study	A mobile-based reservation system was developed for efficient space usage.
6	Alabassi and Al-Jameel [44]	2018	University parking management	Sensor-based system	Ultrasonic sensors improve real-time availability tracking.
7	Sonya et al. [45]	2018	On-street parking in Gajah Mada St., Indonesia	Traffic congestion impact analysis	Removing parking increased road capacity by 25%, cut congestion, and improved speeds.
8	Rukaya and Hasan [46]	2023	On-street parking in Al-Rasheed St., Baghdad	VISSIM simulation study	Removing parking improved traffic flow (46.6%), reduced travel time (38%), and cut delays (69%).
9	Al-Rikabi [47]	2019	Intelligent parking management	Smart parking system development	Real-time availability tracking reduces search time and improves efficiency.
10	Jony et. al,[48].	2020	Off-street parking in Al-Hilla	Parking space deficiency study	Legal off-street parking is insufficient, leading to inefficient usage.
11	Al-Tamimi and Asmael [49]	2020	Parking in Al-Mansour, Baghdad	Parking infrastructure study	Inadequate facilities worsen congestion; need for expansion.
12	Al-Jameel and Muzhar [50]	2020	On-street parking in Al-Najaf	Regulatory and technology assessment	Illegal parking is prevalent; recommends off-street expansion and smart parking tech.
13	Shnewer et al. [51]	2021	Parking design in Amara	Configuration optimization study	90-degree parking maximizes space efficiency.
14	Allbadi et al. [52]	2021	Sensor-based parking management	Technology integration study	RFID, ultrasonic, and infrared sensors improve operations and reduce congestion.

6. Traffic Simulation

HCM advised the utilization of delay times for all intersection options, including signalized intersections. It suggested examining the capacity and delay to assess the overall functionality of the junction [55]. Therefore, we evaluated the operational efficacy of intersection alternatives using the mean control delay. When there is a stop, give way control, or opposing turns at signalized intersections, the gap acceptance parameter has a big effect on how well crossings work [56].

SIDRA Junction is a prevalent program utilized for traffic simulation and junction analysis among many analytic tools. It is especially efficacious for assessing the performance of diverse intersection types, including roundabouts, signalized intersections, and unsignalized intersections. Rasha and Irfan [57] stated that the SIDRA method uses an integrated modeling framework to show how capacity and performance analysis techniques for roundabouts, controlled signage, and signalized intersections are aligned.

According to the US Highway Capacity Manual and the Australian Road Research Board (ARRB), SIDRA has the same level of service (LOS) criteria for roundabouts and traffic signals. This is because roundabouts are thought to work about the same way as traffic signals in a wide range of flow conditions [58].

The Manual on Uniform Traffic Control Devices offers recommendations on the implementation of yield signs and stop signs at one or more approaches to an intersection. The instructions specified that a halt is mandatory under the following conditions [59]:

• Traffic levels on the thoroughfare surpass 6000 vehicles per day.

• There is a necessity to sufficiently monitor conflicting traffic on the thoroughfare.

• Based on accident records.

The yield sign is utilized in the following conditions:

• At a small road, yielding to the major road is required, but a complete stop is not mandated.

• At an entrance without an acceleration lane to a freeway. In the presence of a designated right-turn lane without an acceleration lane.

6.1 Sidra Intersection

SIDRA is a micro-analytical software commonly employed in traffic engineering to assess different types of intersections on a lane-by-lane basis. The Australian Road Research Board (ARRB) established SIDRA [60]. It evaluates efficacy metrics like junction capacity, queue lengths, total delays, and levels of pollution by integrating traffic models with a continuous approximation method. Most studies regarding the efficacy of intersection operations have employed SIDRA. SIDRA's methodologies demonstrate the uniformity of capacity and performance analysis [57].

6.2 Review of Traffic Simulation Studies

Numerous studies examine the effects of traffic congestion issues, including delays, travel expenses, and environmental damage. Congestion adversely impacts health in metropolitan settings due to its influence on a large population [61].

Zion et al. [62] examined field data at all-way-stop controlled crossings and discovered that junctions with balanced traffic levels have reduced delays. They determined that the proportion of left turns significantly impacts delay. Other efforts provide supplementary recommendations for the selection of traffic control devices at junctions.

Sisiopiku and Oh [63] examined various volumes, turning ratios, quantities, and lane widths. Roundabouts were better at handling traffic and took less time than other types of junctions when there were two-lane approaches and a lot of traffic or left turns.

McKinley [64] proposed the installation of a traffic control signal at an all-way-stop controlled (AWSC) junction that was experiencing heightened delay and congestion. He noted that the most secure junction control, contingent upon adherence to regulations, is the All-Way Stop Control (AWSC), despite it being the least efficient form of intersection management in many instances.

Polus and Vlahos [65] examined the operational efficiency of the junction, encompassing delay, capacity, and LOS. It was determined that TWSC junctions excelled at low main road volumes, roundabouts were most effective at major roads with mid-range volumes, and pre-timed signals functioned optimally.

Russell et al. [66] examined the performance efficacy of junctions before and after their transformation into contemporary roundabouts. They utilized the SIDRA program to deliver efficacy metrics for the comparison of junction types. Their results indicated that the average wait time went down by 65%, the 95% queue length went down by 44%, the degree of saturation went down by 53%, and the number of stopped cars went down by 52%.

We evaluated the effectiveness of roundabouts, yield junctions, two-way stop-controlled (TWSC) intersections, and signalized intersections using SIDRA.

The Insurance Institute for Highway Safety conducted a before-and-after analysis of 24 stop and signal-controlled junctions following their conversion to roundabouts. The findings indicated a 75% reduction in intersection time when roundabouts substituted stop or signal-controlled crossings.

Kyte et al. [67] examined the LOS and capacity at unsignalized junctions. The saturation headway at TWSC intersections is influenced by geometry, vehicle types, conflict levels, and the directional motions of interacting traffic. According to [67], these factors influence the saturation headway at TWSC intersections.

Kirk et al. [68] conducted research to ascertain the dimensions of junctions based on operational factors. They employed the critical lane analysis approach to compute size estimates for junctions. They created the Intersection Design Alternative Tool (IDAT), which was capable of simultaneously analyzing 13 possibilities. Their tool determines the most effective design that can achieve a certain operational level. This method allows a tailored design for every junction. When you use the HCM model in SIDRA to study the delay of junctions, you get values that are similar to data from the field. The HCM model utilizing Highway Capacity Software (HCS) produced overestimated delay values.

Joni and Mohammed [69] employed SIDRA to evaluate traffic flow performance at the Al Masbah Intersection. Their conclusion indicated that SIDRA shows realistic results in the analysis of flow, capacity, queue, and delay.

Ali et al. [70] emulated traffic performance at the Jordan crossroads in Baghdad, Iraq, utilizing Sidra software. Traffic data was gathered over four days from 7 AM to 3 PM. Based on the simulations, the junction has a Level of Service (LOS) of D, which means that there is an average delay of 35 seconds per vehicle and a saturation degree of 0.996 vehicles per cycle. The research proposes enhancements such as Intelligent Transportation Systems (ITS) and CCTV to optimize traffic flow and mitigate congestion.

Aboud et al. [71] used SIDRA software to assess costs, travel time delays, and carbon dioxide emissions. The researchers found that the Level of Service (LOS) goes up from E and F to C. They also found that travel time, cost, and pollution emissions go down by 16%, 25%, and 29%, respectively, when gas-powered vehicles, modern private cars, and different types of public transportation vehicles are used. This has been regarded as a progression towards additional research on sustainable transportation.

Zubaidi et al. [72] examined the determinants that may affect collisions at roundabouts. They determined that the majority of injury collisions are associated with driver attributes and conduct. This finding has been corroborated by several investigations.

Ibrahim et al. [58] investigate junction planning in Egypt by looking at signalized intersections, roundabouts, and two-way stop controls at Level of Service (LOS) D. The study gives charts that can be used to find the best junction designs. The study evaluates capacity and delays by analyzing traffic patterns, turning distribution, the proportion of heavy vehicles, and control type. Research indicates that roundabouts are optimal for moderate traffic, but signalized junctions excel in scenarios of high traffic density with significant left-turn flows.

Jameel [73], Omar, and Hussein [74] utilized HCS and SIDRA software to improve the efficiency of signalized crossings in Baghdad and Erbil, respectively. The study revealed a 21% decrease in the average delay value using the STDRA delay model, whereas the HCS model resulted in a 29% reduction. The results indicated that the SIDRA model had a shorter optimal cycle time in comparison to HCS.

Adeleke et al. [75] condition Using SIDRA Intersection software and the intersection's highest average passenger car unit, the best cycle length and signal configuration have been found.

Ahmida et al. [76] conducted an improvement to five junctions following an assessment of their performance utilizing SIDRA software. The findings indicated that a decrease in average time delay might improve traffic flow, shorten travel time, and elevate speed, hence diminishing fuel consumption and CO_2 emissions.

Rasha and Irfan [57] evaluate traffic congestion at the Al-Husainea crossroads in proximity to Karbala, Iraq, with SIDRA software. This three-way junction has significant congestion, resulting in prolonged delays, diminished capacity, and an inadequate level of service (LOS). Traffic data was gathered over seven days, indicating LOS of F, with an average delay of 52 sec/veh and a saturation level of 0.86 vehicles per capacity (v/c). The results underscore the necessity for enhancements at intersections, and the research proposes options to increase traffic flow and efficiency.

Sidra intersection software is summarized in Table 5.

Table 5: The previous research of traffic simulation

	Author(s)	Year	Study Area	Type	Findings
1	Zion et al. [62]	1989	All-way-stop controlled crossings	Field data analysis	Balanced traffic reduces delays; left-turn proportion impacts delay.
2	Sisiopiku and Oh [63]	2001	Various junction types	Simulation study	Roundabouts have superior capacity and lower delay for two-lane, high-volume intersections.
3	McKinley [64]	2001	AWSC junction efficiency	Proposal study	AWSC is safest but least efficient; traffic signals can reduce congestion.
4	Polus and Vlahos [65]	2005	Junction operational efficiency	Performance analysis	TWSC is best at low volumes, roundabouts at mid-volumes, and signals for optimization.
5	Russell et al. [66]	2005	Roundabout conversion impact	SIDRA-based analysis	65% reduction in wait time, 44% decrease in queue length, 52% fewer stopped cars.
6	Kyte et al. [67]	2007	LOS and capacity at unsignalized junctions	Empirical study	Saturation headway is influenced by geometry, vehicle type, and conflicts.
7	Kirk et al. [68]	2011	Intersection design using IDAT	Design optimization study	IDAT tool identifies optimal junction design, HCM model overestimates delay.
8	Joni and Mohammed [69]	2016	Al Masbah Intersection	SIDRA traffic analysis	SIDRA provides realistic results for flow, capacity, and delay.
9	Ali et al. [70]	2018	Jordan Crossroads, Baghdad	Simulation (SIDRA)	LOS D with 35s average delay; ITS & CCTV proposed for improvement.
10	Aboud et al. [71]	2019	LOS improvement using SIDRA	Traffic efficiency study	LOS improved from E/F to C; reduced journey time (16%), cost (25%), emissions (29%).
11	Zubaidi et al. [72]	2020	Collision factors at roundabouts	Safety study	Driver behavior is a major cause of injury collisions.
12	Ibrahim et. al. [58]	2022	Junction planning in Egypt	Traffic capacity & delay analysis	Roundabouts are best for moderate traffic; signals are best for high-density and left turns.
13	Omar and hussein Hussein [74]	2022	Signalized junctions in Baghdad & Erbil	Software comparison (HCS vs. SIDRA)	The SIDRA model showed a 21% delay reduction, and the HCS showed a 29%. SIDRA had a shorter cycle time.
14	Adeleke et al. [75]	2023	Signal cycle optimization	Simulation (SIDRA)	Determined optimal cycle time and signal configuration.
15	Ahmida et al. [76]	2023	Junction performance improvements	SIDRA-based study	Reduced delay improves traffic, travel time, speed, fuel efficiency, and emissions.
16	Rasha and Irfan [57]	2024	Al-Husainea crossroads, Iraq	Congestion study (SIDRA)	LOS F with 52s delay; study suggests an improvement option

7. Conclusions

The impact of off-street parking on urban traffic networks has been widely studied, with research highlighting both positive and negative effects. Several studies indicate that off-street parking can reduce on-street parking demand, improving roadway capacity and reducing conflicts caused by vehicles searching for parking spaces. However, other research suggests that introducing off-street parking may lead to increased vehicle trips, congestion near access points, and delays at adjacent intersections. The efficiency of off-street parking largely depends on factors such as location, design, accessibility, and integration with the surrounding traffic network.

Research has demonstrated that increased parking supply near busy intersections can alter traffic flow patterns, affecting queue lengths, travel times, and intersection delays. Another important thing to think about is how well the nearby signalized and unsignalized intersections work. This is because badly managed access points can slow down traffic and cause bottlenecks. Previous research has stressed how important it is to do a thorough traffic impact analysis before adding new parking lots. This is to make sure that measures to reduce the effects of traffic are in place, such as better signal timings, dedicated entry/exit lanes, and different routing strategies.

Building on these findings, this study aims to analyze the influence of adding off-street parking on the surrounding traffic network using the SIDRA Intersection software. The research will involve collecting traffic data, simulating both current and future scenarios, and assessing key performance metrics such as delays, level of service (LOS), and vehicle queuing.

The goal is to determine whether the new parking facility enhances or worsens traffic conditions and to identify strategies to mitigate potential negative impacts. The study's results will provide valuable insights for urban planners and transportation engineers, ensuring that off-street parking solutions contribute to improved mobility and efficient traffic management in urban areas.

References

[1] National Academy of Sciences, 'parking principles'. Highway Research Board Special Report No. 125, (1971).

[2] US. Legal, available on https://definitions.uslegal.com/p/parking-facility/. (6 June (2019).

[3] Jun Chen, Guang Yang, Off-Street Parking, International Encyclopedia of Transportation 2021, Pages 285-288.

[4] Garber, N. J., & Hoel, L. A. (2010). Traffic and highway engineering. Cengage Learning.

[5] Wolshon, B., & Pande, A. (2016). Traffic Engineering Handbook. 7th edition, USA. John Wiley & Sons.

[6] Khayal, O. (2017). STUDY OF MODERN VEHICLES PARKINGS . Nile Valley University, Atbara Sudan.

[7] Burris, V., Schenk, M., & Schaefer, J. (2012). Off-street parking and traffic safety: Assessing the effect of off-street parking on collision frequency in urban areas. Transportation Research Record, 2293, 87-95.

[8] De Salvo, D. (2017). The cost and benefits of off-street parking: A case study of construction and operational costs. Journal of Urban Economics, 46(2), 113-128.

[9] Harvey, J. R., Bass, R. F., & Wickham, L. P. (2016). Sustainable parking strategies: Environmental and economic challenges of parking lot construction. Journal of Environmental Planning and Management, 59(5), 1057-1074.

[10] Madhuri K. Rathi, Darshan V Patel (2022), Different types of Parking Spaces and Multiple Level Car Parking, *Department of Civil Engineering, Pune University, India* https://www.engineeringcivil.com/

[11] Cao, Y. yang, Z. Z. and Zuo, Z. Y. 'the effect of curb parking on road capacity and traffic safety', springer journal, DOI 10.1007/s12544-016-0219-3, (2017).

[12] Biswas, S. Chandra, S. and Ghosh, I.' effects of on-street parking in urban context: a critical review', transportation in developing economics, springer, No. DOI 10.1007/s40890-017-0040-2, India, (2017).

[13] Yi Cao, zhong zhen Yang, Z. Y. Zuo, (2017). The effect of curb parking on road capacity and traffic safety, European Transport Research Review 9 (1):4 DOI:10.1007/s12544-016-0219-3.

[14] Litman, T. (2020). Parking management best practices. Routledge. www.vtpi.org.

[15] Ferguson, E. (2004). Zoning for parking as policy process: A historical review. Transport Reviews, 24(2). https://doi.org/10.1080/0144164032000080485.

[16] McCahill, C., & Garrick, N. (2014). Parking supply and urban impacts. In Parking Issues and Policies. Emerald Group Publishing Limited.

[17] Cheng, T., Tai, M., & Ma, Z. (2011). The model of parking demand forecast for the urban CCD. Energy Procedia, 16(PART B), 1393–1400. https://doi.org/10.1016/j.egypro.2012.01.221.
[18] Douglass, M., & Abley, S. (2011). Trips and parking related to land use: Vol. (No. 453).
[19] Nidhi Mehta, Khatri Pallavi V, & Juremalani, J. (2015). Review of Parking Problems in CBD Area of Urban Cities in Developing Countries. IJIRST-International Journal for Innovative Research in Science & Technology|, 1. www.ijirst.org.
[20] Rodrigue, J. P., Comtois, C., & Slack, B. (2017). The Geography of Transport Systems. Routledge.
[21] Shoup, D. C. (2006). Cruising for parking. Transport Policy, 13(6), 479–486.https://doi.org/10.1016/j.tranpol.2006.05.005
[22] LR, D. K. (2011). Traffic Engineering and Transportation Planning.
[23] van Ommeren, J. N., Wentink, D., & Rietveld, P. (2012). Empirical evidence on cruising for parking. Transportation Research https://doi.org/10.1016/j.tra.2011.09.011.
[24] Dalla Chiara, G., & Goodchild, A. (2020). Do commercial vehicles cruise for parking? Empirical evidence from Seattle. Transport Policy, 97, 26–36. https://doi.org/10.1016/j.tranpol.2020.06.013
[25] Weinberger, R. R., Millard-Ball, A., & Hampshire, R. C. (2020). Parking search caused congestion: Where's all the fuss? Transportation Research Part C: Emerging Technologies, 120. https://doi.org/10.1016/j.trc.2020.102781
[26] King, D. (2010). Estimating Environnmental and Congestion Effects from Cruising for Parking. Paper Presented at Transportation Research Board Annual Meeting.
[27] Cao, J., & Menendez, M. (2018). Quantification of potential cruising time savings through intelligent parking services. Transportation Research Part A: Policy and Practice, 116, 151–165. https://doi.org/10.1016/j.tra.2018.06.010
[28] O'Flaherty, C. A. (2018). Transport Planning and Traffic Engineering. In Transport Planning and Traffic Engineering. https://doi.org/10.1201/b12865
[29] Pratama, A. R., Arliansyah, J., & Agustien, M. (2019). Analysis of Air Pollution due to Vehicle Exhaust Emissions on the Road Networks of Beringin Janggut Area. Journal of Physics: Conference Series, 1198(8). https://doi.org/10.1088/1742-6596/1198/8/082030
[30] Obanya, H. E., Amaeze, N. H., Togunde, O., & Otitoloju, A. A. (2018). Air pollution monitoring around residential and transportation sector locations in Lagos Mainland. Journal of Health and Pollution, 8(19). https://doi.org/10.5696/2156-9614-8.19.180903
[31] Kurek, A., & Macioszek, E. (2022). Impact of Parking Maneuvers on the Capacity of the Inlets of Intersections with Traffic Lights for Road Traffic Conditions in Poland. Sustainability (Switzerland), 14(1). https://doi.org/10.3390/su14010432
[32] Asmael, N. M., & Turky, G. F. (2021). Parking Requirement of Shopping Centers. Transport Technic and Technology , XVII(2).
[33] Chawdhury, S. (2014). Demand and Supply Analysis of parking in commercial Area: A Case Study Probortak More Area, Chittagong. International Journal of Innovation and Scientific Research, 12(1).
[34] Zhang, R., & Zhu, L. (2016). Curbside parking pricing in a city centre using a threshold. Transport Policy, 52. https://doi.org/10.1016/j.tranpol.2016.06.008.
[35] Mangiaracina, R., Perego, A., Tumino, A., Miragliotta, G., & Salvadori, G. (2017). Smart parking management in a smart city: Costs and benefits. Proceedings - 2017 IEEE International Conference on Service Operations and Logistics, and Informatics, SOLI 2017, 2017-January. https://doi.org/10.1109/SOLI.2017.8120964
[36] Yan, X., Levine, J., & Marans, R. (2019). The effectiveness of parking policies to reduce parking demand pressure and car use. Transport Policy, 73. https://doi.org/10.1016/j.tranpol.2018.10.009.
[37] Eka Gandara, Utamy Sukmayu Saputri, Ardin Rozadi, Muhammad Hidayat, Zalavsky Nikolay Ivanovich. (2021), Analysis of the Impact of Parking on Traffic Performance on the Roads Around the Cisaat Market, International Journal of Engineering and Applied Technology (IJEAT) Vol. 4., No. 1, Mei 2021, pp. 11-23
[38] Gedefaye Geremew (2024), Modeling and analyzing the impact of on-street parking on traffic flow: a study of the main highway in Debre Markos Town, Ethiopia, Transportation 2024, https://doi.org/10.1007/s11116-024-10513-5
[39] Al-Harbawee, T. Y. "Recommended traffic and parking program for university of Mosul main campus" M.Sc Thesis, University of Mosul, Iraq (1990).
[40] Kraidi, R. A. 'Parking study at AL-MUSTANSIRIYA university main campus' M.Sc. thesis, university of AL-MUSTANSIRIYA, (2011).
[41] K. Al-Obaidi, M., M. Ahmed, A., N. Aboud, S., M. Khalaf, A.-H., W. Ibrahim, I., & A. Abdullah, B. (2018). Analysis of Parking Performance of Public Off-Street Parks in Baghdad City. International Journal of Advances in Scientific Research and Engineering, 4(7). https://doi.org/10.31695/ijasre.2018.32806
[42] Alabassi, S., & Al-Jameel, H. (2018). DESIGN AND STUDY OF A SMART PARK SYSTEM:

UNIVERSITY OF KUFA AS A CASE STUDY. Kufa Journal of Engineering, 09(4), 128–145.

[43] Hassan Kadhim, M. (2018). Arduino Smart Parking Manage System based on Ultrasonic Internet of Things(IoT) Technologies. In International Journal of Engineering & Technology (Vol. 7, Issue 3). https://www.researchgate.net/publication/328615718

[44] Alabassi, S., & Al-Jameel, H. (2018). DESIGN AND STUDY OF A SMART PARK SYSTEM: UNIVERSITY OF KUFA AS A CASE STUDY. Kufa Journal of Engineering, 09(4), 128–145. https://doi.org/10.30572/2018/kje/090409

[45] Sonya Sulistyono, Harnen Sulistio, Ludfi Djakfar, Achmad Wicaksono, and Ririn Endah Badriani (2018). On street parking and its impact on road performance, MATEC Web of Conferences 181, 06008 (2018) https://doi.org/10.1051/matecconf/201818106008

[46] Rukaya M. Atif and Hasan H .Joni (2023), Effect of on-Street Parking on Traffic Flow in the CBD Area in Baghdad City Using VISSIM Simulation, AIP Conference Proceedings 2775, 060011 (2023) https://doi.org/10.1063/5.0140352

[47] Al-Rikabi, B. I. (2019). Smart Parking System Designed by using the Arduino for University park. Wasit Journal of Engineering Sciences, 7(1), 27–32.

[48] Jony, H., Jawad, M., & Al-Jameel, H. A. (2020). Off-street parking characteristics in Al-Hilla City Center. Conference Series: Materials Science and Engineering, 737(1). https://doi.org/10.1088/1757-899X/737/1/012132

[49] Al-Tamimi, A. M., & Asmael, N. M. (2020). Characteristics of Selected Off-Street Parking in AL Mansour Neighborhood / Baghdad. IOP Conference Series: Materials Science and Engineering, 881(1). https://doi.org/10.1088/1757-899X/881/1/012169

[50] Eedan Al-Jameel, H. A., & Muzhar, R. R. (2020). Characteristics of On-street Parking On-street Parking in Al-Najaf City Urban Streets. Transportation Research Procedia, 45, 612–620. https://doi.org/10.1016/j.trpro.2020.03.050

[51] Shnewer, F. M., Handhal, M. M., & Al. Saedi, A. S. J. (2021). Studying and evaluating the capacity of parking at commercial street in Amara city, Iraq. IOP Conference Series: Materials Science and Engineering, 1090(1). https://doi.org/10.1088/1757-899x/1090/1/012083

[52] Allbadi, Y., Shehab, J. N., & Jasim, M. M. (2021). The Smart Parking System Using Ultrasonic Control Sensors. IOP Conference Series: Materials Science and Engineering, 1076(1). https://doi.org/10.1088/1757-899x/1076/1/012064

[53] Al-Harbawee, T. Y. “Recommended traffic and parking program for university of Mosul main campus” M.Sc Thesis, University of Mosul, Iraq (1990)

[54] Kraidi, R. A. ‘Parking study at AL-MUSTANSIRIYA university main campus’ M.Sc. thesis, university of AL-MUSTANSIRIYA, (2011).

[55] TRB, National Research Council: Highway Capacity Manual. Washington, D. C., 2010.

[56] TROUTBECK, R. J. – BRILON, W.: Unsignalised Intersection Theory, Traffic Flow Theory. Transportation Research Board Special Report, 2000.

[57] Rasha Hassan Al-Rubaee and Irfan Talib Hameed (2024), Performance analysis, evaluation, and improvement of selected unsignalized intersection using SIDRA software– Case study, Open Engineering 2024; 14: 20220537 https://doi.org/10.1515/eng-2022-0537

[58] Ibrahim M. I. RAMADAN, Mohamed S. ABDEL-MONEM, Osama H. AHMED (2022), SELECTION OF INTERSECTION CONTROL TYPE IN URBAN AREAS, Civil and Environmental Engineering Vol. 18, Issue 1, 164-173, DOI: 10.2478/cee-2022-0015

[59] FHWA: Manual on Uniform Traffic Control Devices for Streets and Highways. U. S. Department of Transportation, Washington, D. C., 2009.

[60] Albrka SI, Ismail A, Yahia HA, Ladin MA. Application of transyt-7f on signalized road junction networks in Shah Alam and Petaling Jaya. J Teknol. 2014;69(2):126–33.

[61] Younes, M. K., Suleiman, G., Abushammala, M. F., & Al OMARI, K. (2021). Modelling of traffic noise along urban corridor: A case study of Amman. Civil and Environmental Engineering, 17(2), 456-464.

[62] Zion, M., List, G., & Manning, C. (1989). Testing delay models with field data for four-way, stop sign-controlled intersections. Transportation Research Record, (1225).

[63] Sisiopiku, V. P., & Oh, H. U. (2001). Evaluation of roundabout performance using SIDRA. Journal of transportation engineering, 127(2), 143-150.

[64] MCKINLEY, D. W.: In Traffic Control Devices Handbook. ITE, Washington, D. C., 2001, pp. 261 361.

[65] Polus, A., & Vlahos, E. (2005). Unsignalized Intersections in Delaware.

[66] RUSSELL, E. R. – MANDAVILLI, S. – RYS, M. J.: Operational Performance of Kansas Roundabouts: Phase II. Report # K-TRAN: KSU-02-4. Kansas U. S. Department of Transportation, Topeka, 2005.

[67] KYTE, M. – TIAN, Z. – MIR, Z. et al.: Capacity and Level of Service at Unsignalized Intersections: Final Report, Vol. 2, All-Way Stop-Controlled Intersections, 2007.

[68] KIRK, A. – JONES, C. – STAMATIADIS, N.: Improving Intersection Design Practices.

Transportation Research Record: Journal of the Transportation Research Board, No. 2223, 2011, pp. 1–8.

[69] Joni H. H. and Mohammed A.A.,(2016). Using aaSIDRA Software for Traffic Flow to Evaluation Analysis Pubic Transportation Iraq, IJIRCT, Vol. 2, Issue 2.

[70] Ali Mohammed , Hassan Jony, Alaa Shakir, and Kamarudin Bin Ambak (2018), Simulation of traffic flow in unsignalization intersection using computer software SIDRA in Baghdad city MATEC Web of Conferences 162, 01035 https://doi.org/10.1051/matecconf/201816201035

[71] Aboud G. M. , Abdulwahab M. A., Banyhussan Q. S. and Zubaidi H. A., (2019). A Case Study on Roundabout under Congestion: Proposal to Improve Current Traffic Operation. Civil Engineering Journal Vol. 5, No. 9. http://dx.doi.org/10.28991/cej 2019-03091391

[72] Zubaidi H. A., Anderson J. C. , and Hernandez S., (2020). Understanding roundabout safety through the application of advanced econometric techniques. International Journal of Transportation Science and Technology, Vol. 9, pp 309–321. https://doi.org/10.1016/j.ijtst.2020.03.001

[73] Jameel, A. K. (2011). Estimating delay time at Palestine street intersections in Baghdad City using HCM AND SIDRA models. Al-Qadisiyah Journal for Engineering Sciences, Vol. 4, Issue 1, 613-633.

[74] Omar D.H. and Hussein S. K., (2022). Optimization of Delay at Isolated Signalized Intersection Using HCS 2010 and SIDRA Intersection 8 Software: A Case Study. IRECE, Vol. 13, No.6.

[75] Adeleke, O. O., Oguntayo, D. O., Ayobami, I. T., & Ogunkunbi, G. A., (2023). Improving Traffic Flow in Emerging Cities: A SIDRA Intersection Based Traffic Signal Design. Periodica Polytechnica Transportation Engineering.Vol. 51, Issue 2, pp. 166-171. https://doi.org/10.3311/PPtr.18018

[76] Ahmida W., Mohamed A., Fadiel A. and Abu Lebdeh T., (2023). Performance Evaluation and Improvement of Main Road Intersections in Al-Bayda City Using Sidra Software. American Journal of Engineering and Applied Sciences, 16 (1), pp 23-28.