JISSE
ISSN: 2636-4425

Journal of International Society for Science and Engineering
Vol. 3, No. 4, 61-75 (2021)

JISSE
E-ISSN:2682-3438

Toward Solving the Car Parking Issue for Egyptian Cities

Abdelwahab Mohamed Amer[1,*]; Ayman Elalfy; Nermin Mokhtar Farrag

[1] *Civil Engineering Department, Engineering and Renewable Energy Research Institute, National Research Centre, Cairo, Egypt*

ARTICLEINFO

Article history:
Received: 2021-10-25
Accepted: 2021-12-01
Online: 2021-12-01

Keywords:
Car parking problems, Urban planning, Parking management, Creative parking, Egyptian cities.

ABSTRACT

Car parking nowadays is a big common issue for both developed and developing nations' metropolitan centers. Many cities are suffering nowadays from a lack of car parks which is generated as a result of an increasing rate of car ownership. Having an imbalance between parking availability and its demand can be considered as the root cause of urban car parking issues. Part of the reason for this mismatch is due to inadequate land use future planning and the miscalculation of future car parking needs. The current research focuses on the city's car parking problem, especially in Egyptian cities. In this regard the research begins by listing some current major car parking issues in Cairo as an example of Egyptian cities, showing its various causes and its current tried-and-true - yet ineffective - solutions. The research deals with some methods of solving Car parking problems for Egyptian cities within three major axes, namely planning, management and new car parking technologies. Based on a study of some current planning and management trends as well as innovative technical solutions, the research concludes some recommendations to assist easing Egyptian cities car parking problems. Suggests a way to accomplish bigger community goals such as improving urban mobility and making cities more livable and efficient.

1. Introduction

Although governments all around the world encourage city residents to use public transportation for environmental safety reasons, and to lower car densities and parking area demand inside its city, yet public transportation facilities in Egyptian cities still does not fulfill most of its citizen's needs. Also, the personal safety reasons drive ladies to use their private cars for transportation rather than getting a taxi car. Another reason for owning a car is the cultural image that a person getting wealthier owning his private car. For this reason, most of the Egyptian cities residents still prefer to own and use their private cars for their transportation. Car sales rate in Egypt is following a dramatic increase during past five years, according to Central Agency for Public Mobilization and Statistics of Egypt [1], reports currently that there are 10.88 million licensed cars in Egypt most of it are concentrated in Egyptian cities, the automotive information council mentioned that Cairo's cars that were licensed in 2021 reached 22 thousand cars. Egyptian code for cellular and urban road works [2] specifies car parking rates for every building type of activity indicate the number of car parking units as shown in Annex (1). Building license regulations require the provision of a specific car parking area for every building type mainly located in building basements. The building's basements most of Egyptian cities are currently not used for car parking purposes as it is officially designed, many building owners convert the building's basements into stores or shops seeking a better investment. Having a lack of building's basement parking areas led to streets becoming an open "parking area" which consequently affects the traffic congestion. Data from the Central Agency for Public Mobilization and Statistics as shown in Figure (1) indicate that the number of available Garages in Egypt is 435 thousand, of which 232 thousand are in the countryside and 203 thousand are in the urban areas. Most of these garages are currently closed or used for other commercial activities. Egypt spends LE 50 billion ($8 billion) on traffic congestion each year, accounting for 4% of the Country's Gross Domestic Product GDP [3]. This loss is due to the waste of productivity that daily occur when individuals spend the majority of their working time stuck in traffic or trying to find a place to park their cars. The loss of idle fuel consumption

* Abdelwahab Mohamed Amer, Civil Engineering Department, National Research Centre, Cairo, Egypt, +201114055344, abdwhab@gmail.com

and pollution caused by excessive car emissions are other types of traffic congestion problems.

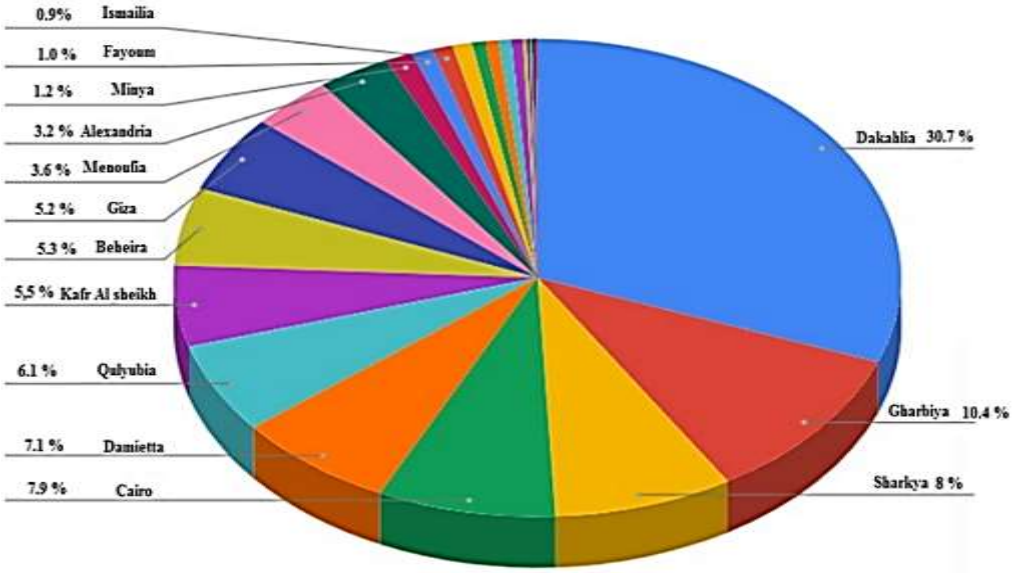


Figure 1: Percentage of available Garages in Egyptian cities and countries to the total number of available Garages in Egypt [4].

2. Research Problem

Many Egyptian cities, especially Cairo and Alexandria consist of a blend of historic areas, mostly located in city centers and modern annexed expanding urban areas on its edges. Residential, business and commercial activities are found in all of city districts. Despite the fact that an effective parking system may improve urban mobility and city environments while improving inhabitants' quality of life, parking is an often-overlooked part of the local urban planning and transportation studies. In Egyptian cities like Cairo, for modern planned districts, most of the car parking spaces are in building's basements and side street curb parking. Buildings license regulations in Egypt specify a specific basement car parking area according to the building's size and type. Nowadays, in Cairo, the majority of traffic routes are re-planned, as an example the streets in Heliopolis district is recently widened to facilitate the traffic flow reaching form the new Capital, which is located in Cairo-Suez Road 60 Km from central Cairo, side street curb parking in the Heliopolis district became very limited. Car parking space available nowadays became a major issue that has to be solved by the Egyptian government on both planning and urban design levels. Urban planners, designers and government decision makers should explore more efficient parking systems and new solutions that are feasible for application in the various conditions of Egyptian cities districts.

3. Research Objectives

In order to improve inhabitants' quality of life in Egyptian cities, the study investigates the issue of auto parking in Egyptian cities and its urban annexed regions, that is with regard to planning factors, management, technology, environment and aesthetics. The research aims to:

- Identify the origins of car parking problems in Egyptian cities, showing its negative consequences.
- Examine many traditional - but ineffective - ways to address car parking problems in Egypt, both in planning and management levels.
- Explore new solutions that make use of modern parking systems and technology which consider environmental and aesthetic concerns that are applicable to use in Egyptian Cities.

4. Research Methodology

To recommend new car parking solutions that get use of modern mechanical and technical advancements as well as environmental concerns that can be applied in Egyptian Cities, the research begins by illustration some auto parking problems in Egypt and its causes especially in its big cities having Cairo as an example and showing its negative consequents. Followed by a literature review that is based on a body of research on the topic of auto parking in cities in metropolitan regions. The acquired information is listed and categorized according to various kinds of parking solutions based on planning, management and parking design levels. Ultimately ending with the capabilities of application within the various conditions of Egyptian cities districts.

5. Parking issues in Egyptian cities and their causes

In Egyptian cities there is a discrepancy between car parking demand and its availability. This discrepancy exists for numerous reasons:

- Egyptian Cities like Cairo and Alexandria were built through a long period of time, these cities were planned to have narrow streets sufficient for horse carets at that time. Passing through time, these cities became a blend of wide streets, modern planned urban areas that include some narrow streets in historical districts causing central city traffic jams during daytime.
- Downtown Cairo accommodates a lot of activities and facilities such as commercial facilities, office buildings and

governmental institutions, sharing near locations causing a high density of automobiles in its surrounding streets.

- Despite the numerous office buildings and commercial centers, there is no land allotted for multi-story parking structures in order to absorb the rising number of automobiles. At least in regions with concentrated amenities even in the design of new cities and new urban regions (the city of New Cairo).
- In cities such as Cairo and some districts such as Zamalek and Mohandessin, a majority of homeowners are converting their residential buildings into commercial purposes seeking better business which leads to a high traffic density.
- Violations of construction regulations and zoning restrictions specify various building uses and a certain number of floors for each city location. Construction regulations specify a provision of car parking areas in basements, according to the expected car density [5]. Figure (2) is listing some types of car parking issues that might arise in any community.

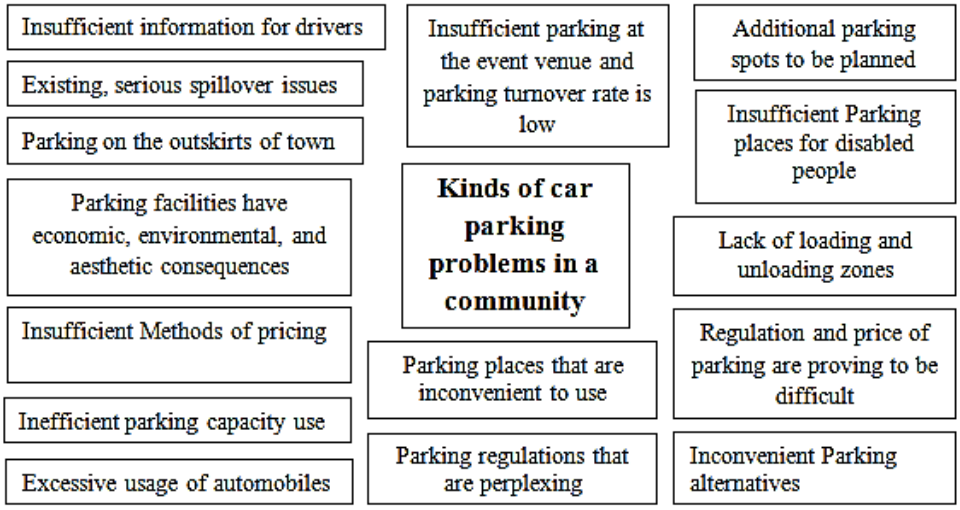


Figure 2: Parking Issues and their Causes in a community.

6. Negative consequences of auto parking issues

The parking crisis skews urban planning, parking areas generate numerous gaps in between building facades, making it difficult to maintain a visually acceptable street façade curb parking in front of buildings which happen in rows distort and affects pedestrian's ability to enter these buildings through their designated entrances [6]. Public squares, public fields and places of social meetings are being turned into parking lots. The parking lots are widely regarded as the least appealing and ecologically damaging land use [7]. To hide the presence of these lots it is preferable to isolate surface lots behind the buildings or screen them using fences, walls, or bushes. Some local governments often establish parking lanes at the expense of pavement width, causing them to be out of the standard and lacking certain of their functions in order to give extra lanes for curb parking without disturbing traffic flow. Figure (3) shows the use of safety barriers to prevent cars parking on the pavement stock, also pedestrians on small streets or downtown finds it difficult, inconvenient and walk during peak hours. In many Egyptian cities', drivers are unable to find a parking space, so they circle the adjacent blocks impatient looking for a parking spot [8]. This occurrence causes the roadways to become clogged, cars consume more fuel and produce more pollutants and causes additional delays for other individuals who are simply trying to go somewhere.

Figure 3: Showing the use of safety barriers to prevent cars parking on the pavement stock [1]

7. Egyptian Cities current parking solutions

To alleviate Cairo's chaotic, clogged traffic and the phenomena of a car keeper, Cairo's Governorate is currently working on building multi-story smart parking lots that can accommodate a large number of vehicles. In Cairo, parking guidance and information system PGI has been recently implemented in 2015 to help drivers to find the available parking spaces.

Cairo city currently has four main types for car parking

A. Side Street curbs parking – where car parking is permitted.
B. Formal surface public parking – rented through government.

C. Informal surface parking – rented by landowners.
D. Multi-floor car park - built and rented through government.

In order to maximize the number of automobiles that can be parked in, every type of parking facility includes numerous forms of automobile circulation and layout shape. Each of the four types of parking systems include three main components:

- Number.
- Quality.
- Administration.

In most cases parking planning emphasizes quantity above quality, which is based on the premise that the more is always better, and that there is no such thing as too much. This style of planning is based mostly on meeting minimal parking needs and ensuring an ample supply of parking.

While parking planning factors include: the comfort and security of going from a parking place to a destination, parking facilities' attractiveness, parking places security and environmental needs. Parking management strives to maximize the economic value of parking spots, particularly in parking lots and on the street. It focuses on developing unique operational and pricing rules for each situation.

Cairo's government built multi stories concrete skeleton garage by getting use of the land of the burned KHADAWY Opera in 1971, which is located in Cairo's downtown to serve downtown area followed by the building of a similar garage in ATTABA square to serve the shopping area close to it. Table (1) shows the capacities and prices of a sample of available public garages in Cairo the and the coordinates of their locations in World Geodetic System 1984 UTM Zone 36 R of the garages in Cairo on the other hand, the figure (4) is illustrating these positions [1]. The main issues concerning these garages is its capacity currently does not fulfill its parking density requirements especially during daily working hours, its limited entrances and exits and its low rate of discharge during rush hours added to the lack of its ability to future expansion.

Table 1: The capacities, Coordinates the locations of garages in Cairo related to WGS84 - UTM system and prices of a sample of available public garages in Cairo [1].

Garage	Area	No. of floors	No. of cars	price	WGS84 UTM (Z 36 R)	
					E	N
Roxy	10,000 m^2	four underground ,6 automatic systems, 6 car entrances and exits, and 12 electronic elevators	1700 cars	10 Egyptian pounds (EGP) per hour	338057 E	3330369N
El Tahrir	20,000 m^2	multi story garage- 4 floors	1700 cars, in addition to a private garage that can accommodate 24 tourist buses.	The first hour is 10 (EGP) and 8 (EGP) for every extra hour	329760 E	3325143 N
Al-Azhar (Al Darasa)	20,000 m^2	three undergrounds	410 cars	20 (EGP) per hour	333070 E	3324911 N
		rooftop garage	140 cars			
El Opera	20,000 m^2	multi story garage –6 (2 levels)	1130 cars	10 (EGP) for 1st hour and 8 (EGP)for every extra hour	331110 E	3325700 N
Omar Makram	5,000 m^2	underground -4floors	600 cars	5 (EGP) per hour for the first 6 hours	329758 E	3324936 N
Al Bustan	10,000 m^2	multi story garage –9 floors	900 cars	10 (EGP) per hour	330204 E	3325167 N
El Falaki	300 m^2	Parking lot	135 cars	5 (EGP) per hour	330271 E	3325049 N
Abdel Monaim Riad	5,000 m^2	Parking lot	500 cars	5 EGP per hour	329910 E	3325755 N

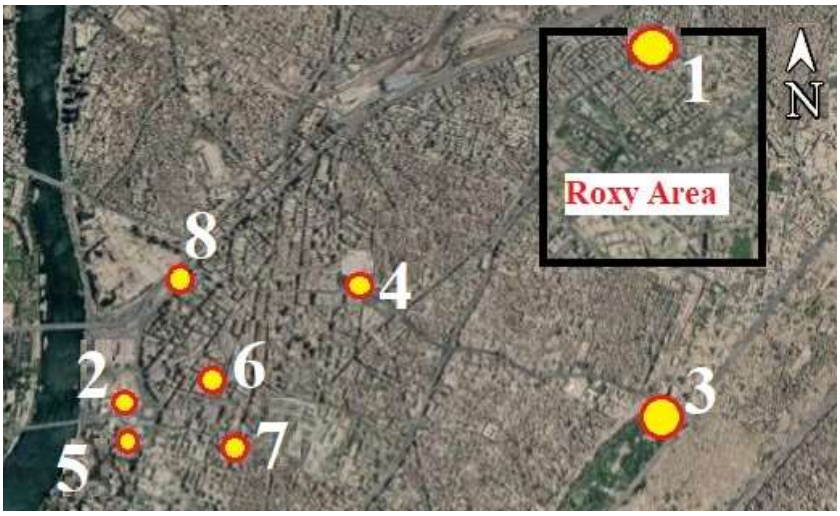


Figure 4: Showing the locations of the Garages [1]

It is observed that the geographical distribution of the parking spaces in the Central Business District in Cairo is uneven distribution which increases the walking distances between the parking places and the working areas. This is due to the

accumulation of urbanization and the lack of available land for the construction of public parking lots with adequate capacity. Although underground multi stories parking is more expensive to construct and operate than rising ones, yet it has the benefit that it does not affect the urban character especially in historic areas, two underground garages were built in Cairo, Roxy area is the center of Heliopolis district built by Baron Empain in the 1894 giving its buildings Islamic character drove the government decision to build the underground Roxy mechanical garage. The Roxy Garage is divided into four underground stories, each covering 10,000 square meters. The parking lot is the largest in the Middle East in terms of size, and it also has the world's greatest capacity, with a capacity of 1,700 cars. It consists of 6 automatic systems, 6 car entrances and exits, and 12 electronic elevators equipped with batteries to transport cars from inside to outside and back. The Roxy Garage is part of the government's strategy to alleviate traffic congestion, which is particularly important given that Korba is one of Egypt's most congested districts, Figure (5a,5b,5c,5d).

Figure 5 a : Section A-A of Roxy garage

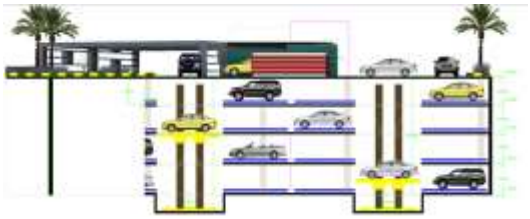


Figure 5 b : Section B-B of Roxy garage

Figure 5 c : Elevations of Roxy garage

Figure 5 d: Layout of Roxy garage

Figure (5a, 5b, 5c, 5d): Roxy mechanical garage at Roxy Square –Heliopolis, Cairo.

AL Tahrir garage, shown in Figure (6) was built in the underground to preserve the classic character of Museum of Egyptian Antiquities built in 1901, as it is built in front of its classic façade. The garage is built on an area of 20,000 square meters and includes 4 floors below the ground and can accommodate 1,700 cars, in addition to a private garage that can accommodate 24 tourist buses. Although the two underground garages fulfilled the urban character preservation function, there are problems concerning their capacity and the time needed to exit the garage during the rush hours.

Figure 6: Tahrir garage at Tahrir Square, downtown - Cairo. Egypt [Google Earth]

Another parking solution that the Egyptian government started recently to apply is the Rotatory mechanical parking system. It can fit in existing public gardens, converting some parts of the garden areas to car parking purposes. The Rotary mechanical parking system has the disadvantage of high noise especially when erected close to residential areas. The combination of parking planning and management systems guarantees that parking demand is accurately calculated based on the development's real demands and operating conditions, rather than predetermined generic norms. It also saves money, time, and convenience for users, as well as the green infrastructure required for environmental balance [9].

7. 1. Global parking planning solutions

Governmental regulations establish the minimum number of parking spots that must be given for each land use, accordingly calculating the parking areas required for various districts according to the main district activities and the expected traffic density for each in the major city plan. The number of spaces

required for a project is calculated using the following formula: Many spaces associated to parking area/unit associated to the facility **(**which may be users or area unit). the minimum car parking regulations in Egypt on the other hand have unforeseen the following facts [10]:

- Even when car parking is free and there is no public transportation annexed to it.
- In most city areas parking is free, but there are hidden expenses mostly of products pricing and services.
- If car parking looks to be free that will lead to an increase in the parking demand, increase in traffic, congestion increase resulting to an increase in pollution rate.
- To alleviate the resultant congestion, citizens must pay for the construction of extra parking lots and for a wider roadway.

In order to construct a good city's parking plan, in addition to identifying the minimum number of spaces necessary for each land use, the following elements should be determined [11]:

- Parking priority areas.
- Traffic and parking pressure zones.
- Traffic density on major thoroughfares which are congested due to overpopulation or the presence of subsidiary street bottlenecks.
- The entrances to the main service areas which have front auto parking causing obstruction for service performance.
- Secondary and tiny streets that are congested because of informal car side street parking, particularly during peak hours and during cruise time.
- Residential locations where commercial service trucks informally park, producing noise and congestion as well as nuisance to residents.
- Archaeological, touristic, and commercial zones are examples of particular natural regions that need to be developed to have gardens, pedestrian pathways and walks.

Because there are so many variables linked with the city center, the parking plan for the city center is one of the most significant plans to design and administer [10].

City center variables that should be evaluated on a regular basis are:

- Future Population census.
- Total number of auto owners.
- Daily working trip ratio in relation to overall trips, particularly during peak hours.
- Capability of the city-center-feeding road network.
- Quality and sufficiency of public transportation.
- Parking lot's efficiency.
- Changes that happen for the area's population attractiveness after development and rejuvenation.

Cairo City performs a continuous urban expansion mostly at its perimeter, such expansion happens in two forms, governmental planned and constructed districts mostly in the form of a gathered residential categorized similar sized residential units built in the form in multi stories building blocks or separate two floors' units. These future planned districts should follow parking design guidelines. The second type of urban expansion is the informal expansion by which citizens build their own houses randomly and illegally on governmental owned lands at the city edges, this type of unplanned residential areas leads the government to form car parking areas by allocating suitable parking places, then demolish informal buildings and use its land as a surface parking area.

Planning for car parking in Cairo city center, takes two main routes as the high land cost and the rare of its availability either planners and governmental decision makers decide to convert a demolished building to a multistory garage, or to use a part of a public garden to build multistory garage [12]. Table (2) shows recommendation for parking design guidelines of the city center.

Table 2: parking design guidelines for the city center.

Aims	Design Guidelines
To guarantee that parking lots do not become the prominent feature of the city center.	•Designated pedestrian routes in the city center are not permitted to be positioned between a building and the street. •Intersections are not permitted to have parking lots. •Parking should be located at the back of buildings or on the sides of buildings. • Pedestrian linkages between parking and the core area's key anchors and retail spine should be attractive and simple to utilize. • Parking spaces should not be positioned in front of commercial buildings along important pedestrian arteries. • Surface parking should not create big gaps in the development structure or isolate critical applications. • Parking should be positioned underground or behind active uses in interior-block constructions. • In an urban context, parallel parking is preferred over angled parking while on-street parking is required.
Create a screen to minimize the impression of surface parking on the streetscape.	•parking spots shared by two or more users who do not have concurrent peak parking needs. •minimizing storm water runoff and 'heat island' impacts in accordance with environmental sustainability standards. Tree planting and permeable pavement should be adopted, as shown in Figures (7a, 7b).
To reduce the visual impact of vast amounts of surface parking.	• By situating a modest structure at the parking lot entrance or crossroads corner, it is ideal to reduce the parking lot frontage along the key pedestrian route while maintaining the impression of spatial enclosure. • When parking lots have more than 200 slots, they must be separated into smaller linked lots to reduce parking effect. • *I*n commercial areas, curb cuts for parking lots should be limited by having shared entrances and exits 13].

To help increase the amount of greenery in the city core.	• A landscaping buffer of shade trees along the perimeter of the parking lot should soften and screen the visual effect of the parking [14]. • To screen parking lots from neighboring public streets and sidewalks, low ornamental walls and iron fences, as well as elevated plants, should be employed. • Ample parking and a well-kept lawn Lightning will lead to the creation of visibility and the preparation of security. Lighting fixtures must not exceed a height of 7.5 meters and must be protected from causing off-site glare.

1) Community gathering area
2) Sustainable lighting and energy practices

Figure 7a: Using innovative site design, stormwater management, and safer pedestrian connections.

1)Naturalized drainage is designed to absorb stormwater
2)Maximize shading and greening
3)Use safe pedestrian and vehicular strategies
4)Use pavements that infiltrate

Figure 7b: Incorporating green and sustainable practices to have a significant positive impact on the county's communities.

Figures (7a, 7b): Sustainable green parking lots [15].

7.2. Parking management solutions

Parking management encompasses a variety of policies and initiatives that result in more effective parking resource utilization; it also provides considerable economic, social, and environmental advantages. Individual parking management techniques generally have minor effects, but their combined consequences are significant. A cost-effective integrated parking management scheme may frequently reduce parking needs by 20-40% while also enhancing user convenience and assisting with other planning goals [16]. The cost of parking is argued to vary considerably depending on the type and location of the development and the type of its parking facilities it is influenced by three major elements from an economic standpoint:

- The required number of parking spots.
- The worth of land that could have been used for higher-value activities but was instead used for parking.
- The construction cost of the parking space.

The most effective approach to minimize driving is to charge individuals directly for driving and to adjust the price according to demand. In this context, parking spaces should be considered real estate either in parking lots or as curb parking. And like with all real estate, its value is determined by their location. A parking spot in a major city that serves a large number of people, jobs, and facilities is more valuable than a street space in a small town or a city space in the middle of the night that serves a small number of people, jobs, and amenities. As a result, if parking were priced like most other commodities [5]. The cost would fluctuate depending on the time and place. It would be more expensive in large cities than in small towns, in commercial areas than in neighborhoods, and at midday than at midnight.

The provision of more off-street parking spaces will not necessarily eliminate cruising for parking if the price of on-street parking is kept so low that it is always almost fully occupied. If the price of on-street parking is cheaper than off-street, there is always an incentive to cruise for street parking as long as the value of expected cruising time is less than the differential between the on-street and off-street parking prices. It is generally on-street parking that is underpriced, either because no price is charged, or because the meter price is set too low. Owners of off-street parking facilities will presumably not set prices so low that customers are frequently turned away.

Shared parking is a means of managing parking lots that involves the use of one parking facility by more than one land-use activity. The issue is to take advantage of both different parking demand patterns and different peak times for each use. Shared parking implies that parking spaces are not assigned to a particular use; instead, it is operated as a pooled parking resource. An office building and a recreational center can share a parking facility with a capacity less than the total parking spaces when they have two separate parking lots due to the varying peaks of occupancy rate. This strategy can be adopted at various scales, from the scale of a single building to the macro-scale of several developments. Shared parking policy has its impact on the land-use strategy set by planners in the master plan of the city, Table (3)

Table 3: Key-determinants of parking requirements in planning and management contexts [9].

Key Determinants	*Determinants*	*Details*
Demographic	Characteristics of users	People of different ages, social classes, and economic levels tend to have different car ownership rates.
	Car ownership	The higher car ownership rate, the more parking spaces demanded.
Types & characteristics of development	Types & nature of land-use, e.g., length of stay and number of visitors	For Example, a sit-down restaurant would require more parking spaces compared with a take-away restaurant with the same number of customers per hour.
	Dimensions of the company	Parking demand is generally higher at larger enterprises.
	Mixed land-use	When several uses utilize the same parking facility, parking requirements may be lowered, if uses have different peak demand times.
	Density of the district	Auto ownership drops by 32-40% every time residential density increases.
	Accessibility of the district (auto or non-auto accessibility)	Increased non-auto accessibility, e.g., walking or biking, will typically result in some reduction in parking demand.
Surroundings	Availability of surrounding parking	Users of cars can use parking lots available on surrounding sites within up to 45 m from the development.
	Availability of transportation choices	Providing adequate transportation options for people decreases parking demand.
Financial issues	Cost of land	The opportunity cost of the land, used for parking instead of being used to house higher value activities, is to affect parking standards.
	Parking pricing	Demand for parking typically decreases with increasing parking price
Time	Time factor	Parking demand at a location varies by time of day, week, and year, depending on the land use. As a result, there are daily, weekly, and seasonal parking profiles, as well as seasonal parking needs.

A smart parking management system is used. A parking lot management system (which is an innovative mix of hardware and software) for off-street parking provides a solution that allows operators to manage and regulate the entry and exit of the parking lot whether the parking lot is gateless or gated, the system also controls parking payment and enables income optimization for the parking operator owing to a rapid Reduced Operating Cost (ROC). Regarding Cairo city a car parking lot management system could be an ideal improvement that can be easily applied in existing multi-floors concrete skeleton parking lots located in downtown high density business areas. Most of car owners in Egypt currently use cell phone applications to get current traffic information and to get directions to the shortest route to reach their destinations, that makes it easy to add and apply parking managing application capable to inform car drivers through the internet about the surrounding parking lots space availability.

7.3. Innovative Design Solutions

Innovative design solutions for car parking problems are mainly associated with the automation of multi-story parking structures. Mechanical vehicle parking systems allow cars to be autonomously parked in parking spaces as small as a few centimeters in between by the use of computer-driven hydraulics. These systems provide significantly more car parking capacity in relation to the available parking area. Mechanical parking systems are considered to be essential elements that offer more useable public and private spaces especially for high density housing regions. Systems that stack two vehicles vertically on a single slot are becoming more common in use than those that move cars horizontally across hundreds of slots. The automated mechanical parking system type chosen for use is mainly governed by the parking environment and its demand.

7.3.1. Using vertical space instead of horizontal space

Because of the rise in population accompanied with an increase in automobiles number, parking plots became more expensive, making the traditional surface parking unfeasible. Automobile ramps take up a lot of parking area in a multistory garage building, automated car parking systems using car lifts are a viable option. The advantages of using a mechanical multi-level vehicle parking system MLCPS rather than a traditional surface parking system are numerous. The automated car parking systems can be either open air steel skeleton, standalone automated mechanical system such as the rotary system, or assembled inside above ground or underground buildings. Table (4) illustrates some MLCPS benefits.

Table 4: Benefits of using a mechanical multi-level car parking system

Get the most effective use of space	Pallets and elevators are used to park and retrieve automobiles to the parking slots. Driving roads and car ramps are no longer required.
Low construction costs.	Mechanical MLCPS has a low construction cost in comparison with building a similar car parking capacity concrete Skelton building. It's delivered and assembled on the spot. Additional parking costs such as structure construction, security, and so on are eliminated.
Low Working and maintenance costs.	Mechanical MLCPS systems need low energy to operate. In this scenario, the ventilation system utilized for subterranean parking is not required. The system cladding can be changed to complement the building's appearance.
Vehicle safety is paramount.	MLCPS's parked automobiles are secure and cannot be accessed by anyone. Additionally, damage to the vehicle is prevented, which is common while parking in tight driveways.
Environment Friendly	The most significant advantage of MLCPS is that it saves ground area that would otherwise be lost in traditional space parking. The vacant land that has been conserved can be used to grow trees or construct other structures.
Car driver has an advantage to save time and effort.	MLCPS makes parking easy since the motorist is not required to drive from the parking lot to obtain a free parking spot and is not required to park in the free parking lot [17]. The driver isn't even required to get the car out of the parking spot. All of this saves a significant amount of time and effort.
Advantage for the architect.	MLCPS may be utilized in both public and private environments. It is intended to accommodate various numbers of automobiles. It has an impact on the way parking places are planned and designed.
Advantage for the builder.	MLCPS makes better use of the parking space's surface area and volume. This results in more automobiles being parked in the same area. The builders will make better land investment.

Mechanical MLCPS's Restrictions:

• MLCPS vehicles generate noise and pollution in the adjacent residential blocks.

• The pollution of parking lots is caused by contaminants such as motor oil.

• The parking lot must be constructed in such a way that runoff water is efficiently channeled, collected, and drained.

7.3.2. Multilevel Automated Parking

The Automated Multilevel Parking system has been shown to be a viable solution to the city's time and space issues. Figure (8) illustrates some automated multilevel parking technologies: Modular or Puzzle Type, Tower or Elevated Type, Multi-Level Floor Parking, Multi-Level Circulation Automated Parking System, Rotary type and car stacker parking system [18]. Table (6) shows a comparison between various automated multilevel car parking systems.

7.3.3. Environmental and aesthetic properties of multilevel automated parking structures

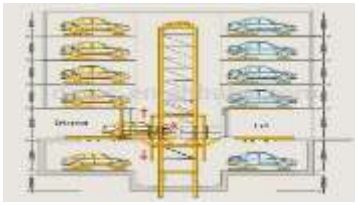
- With multilevel automated parking structures attractive designs, it made life easier and became an added value to cities while preserving the city's architectural texture [20].
- Multilevel automated parking structures help in having a better use of storm water. By equipping the building with water storage and recycling system that collect storm for using it in irrigating site green spaces or irrigating building green roof plants. Also, the system helps in reducing the heat gain of the roof.
- Multilevel automated parking structures have an energy saving integrated system which includes a model that calculates energy reduction rate from its various sources, such as the electricity needed for building operation, lighting, and ventilation in a way that is designed to reduce the use of energy over time. The parking structure is preferable if it relies on renewable energies such as photovoltaic cells, wind power, and photocell receptors. Also, the system can reduce energy consumption by utilizing timers and dimmers that are as energy efficient as feasible. The automated parking garage saves 9,000 gallons of fuel per year and decreases CO2 emissions by more than 100 tons per year.

  Smart Parking Technologies are now available all over the world**.** Smart technology plays a main role in automated parking systems. Smart car parking management systems assembled in parking lots are mainly to locate vacant car spaces and display its information to car drivers looking for parking places. Table (5) illustrates some capabilities of Smart Parking Technologies from all over the world.

Puzzle Type or Modular

Stacker Parking System

Parking on many levels tray system



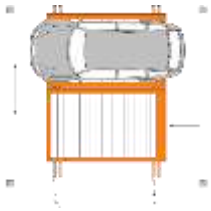
Automated Parking System with Multi-Level Circulation

Figure 8: Automated multilevel parking technologies [1].

8. Aesthetical aspects for parking structures

Most individual parking structures, either non-automated or automated, have been designed considering only function and cost aspects while neglecting any contextual and aesthetical aspects, Figures (9a, 9b). Architecturally and urban design wise they can be so innovative, high-tech, beautiful, and can act as a landmark in the urban city context, Figures (10a, 10b, 10c).

Table 5: A comparison between various automated multilevel car parking systems [19].

Criteria	Stack parking system	Puzzle parking system	Pallet parking system	Vertical parking system	Rotary parking system
					
Space Optimization	poor	poor	Max space optimization	Max space optimization	Max space optimization
Capital Investment	Low as compared to others	Low as compared to others	Very High	Reasonable	High
Operating and Maintenance Expenses	Low	Very high	Very high	Low	high
Ease of Installation	Simple	Simple	Complex	Simple	Simple
Construction Time	Low	Low	High	Low	Low
Retrieval Time	High	Very high	High	Low	Low
Technology	Simple	Outdated	Better than Puzzle	Superior	Simple
Noise	Low	Very high	Very high	Low	Very high
-N0. Of floors -parking spaces -area		7 levels & horizontally to as much space available on ground		30 60 50 m^2	5-9 floor 8- 12 12 m^2

Manual Override	Not there	Facility available	Not there	Facility is there	Not there
Reliability	Medium	poor	reasonable	good	good
Security	Less secure	Reasonable Secured	Highly Secured	Highly Secured	Reasonable Secured
Centering device	Not there	Not there	Not there	Available	Available
Life cycle	10-15 years	10-15 years	15-20 years	20-25 years	10-15 years
Maintenance cost	3-4% of capital cost	3-4% of capital cost	2-3% of capital cost	2-3% of capital cost	2-3% of capital cost

Table 6: Some capabilities of Smart Parking Technologies from all over the world

Smart Parking System using Wireless Sensor Networks	Wireless sensor networks (WSN) are one of the smart parking technologies that are used to find out how many parking spaces are currently available in the parking lot area. A WIFI connection seen on a monitor screen is used as a monitoring device for the parking slot area, allowing visitors to determine if the parking lot has still vacant parking slots or fully occupied. An ultrasonic sensor is installed in each parking slot area, that sensor detects the vacant parking slot that could filled by a car. The data gathered by the ultrasonic sensors is electronically managed in the monitor area. The vacant or occupied parking places are displayed by a monitor using a computer software 2013 [21].
Smart Parking Applications using Radio Frequency Identification (RFID) Technology	Radio Frequency Identification (RFID) technology is a smart parking application that eliminates the need for human involvement and allows vehicle detection. It may also be used to create an automated parking fee collection system. This technology reduces the time needed for vehicles to check in and check out of the parking lot, also the system ensure that the parking lot is safe. The RFID sensor fixed at the parking entry point helps to minimize double check-ins which reduces parking lot traffic congestion. The RFID technology allows for automated parking charge collection saving drivers time. The components of RFID system consist of: RFID labels, RFID readers, a software system, and a barrier to regulate the gate. The RFID software used is in charge of parking fees transaction, management and operational activities reporting. The vehicle tracking data is also managed and recorded using a database management system, which is considered as a part of the software requirements [22].
car Parking System using Global System for Mobile communication (GSM) and Radio Frequency Identification (RFID)	With the use of Radio Frequency Identification Technology (RFID) in parking system automation, transaction costs may be drastically reduced. The proposed system includes Global System for Mobile communication (GSM) kit, Radio Frequency Identification (RFID) readers, RFID tags, barrier gates, personal computers, software, and Light Emitting Diode (LED). This system is self-contained and adaptable to any type of organization also it can help the organization to prevent cars theft. The proposed system handles car check-ins and check-outs using a smart card and a RFID vehicle tag. In the event of any car theft activity the authorized members are notified through SMS, and a security alarm will be activated [23].
Smart Parking System Based on Reservation (SPSR) - Quick Response (QR)code based Vehicle Parking System	Smart Parking System Based on Reservation (SPSR) produces a unique QR code and delivers it to the user when the parking space is vacant and confirmed. As a result, the condition of parking resources is affected by users' parking decisions. The reservation authority recognizes each user by his unique QR code that was provided to him by the management system at the time of reservation. The administration changes the data as soon as the reservation is completed. According to the status of the parking lot, the system does the following: • Analyzes the amount of congestion and the vacancy situation. • Selects parking charges based on the pricing scheme. • Show the parking fees to all users on a regular basis. • It saves the QR codes, pricing, and parking information for future examination [24].
Multi-level Car Parking System using Image Processing	Multi-level Car Parking System using Image Processing uses Image processing exercises for automated car parking mechanism that transports cars to different parking levels. As a result, this car parking system uses less floor space than the traditional multi-level concrete skeleton parking lot with ramps, helping to lower the parking lot building construction costs. In the majority of situations, a circular parking system is used, with automobiles being raised from the ground level. The base revolves in a circular motion, while a rack-pinion system lifts the cars to different elevations in the parking chamber. Lifting and parking cars in an empty area is a time-consuming process, which is why parking systems use robotic arms or grasping mechanisms [25]

Figure (9a) Illustrating an example for using automated parking structure neglecting any contextual and aesthetical aspects [1].

Figure (9b): Old form of parking structures; dull and ugly buildings constitute a source of visual pollution in cities. Opera Garage in downtown Cairo [1].

Figure 10 a : City View Garage — Miami, Florida

Figure 10 b : Santa Monica Civic Center parking garage, USA

Figure 10 c: Ballet Valet parking garage in Miami, USA.

Figures (10a,10b,10c): Illustrates the new forms of parking structures; pleasant, colorful, and environment- friendly buildings [26].

9. General principles for city parking solutions:

Egyptian cities have a continuous expansion mainly at its outer boarders, some planned annexed districts are built by the Egyptian government to accommodate the Egyptian population increase, in order to prevent the future occurrence of parking problems in annexed districts, the authors as shown in Table (7) recommend some general principals to be taken in consideration during the planning phase concerning car parking facilities.

Table 7: Some general principles parking solutions recommend by authors

1-Recognize the right function of parking in the city	Create parking solutions that focus on making a small, walkable and interesting downtown environment. This can be accomplished through the following methods: - Infill development with well-kept safe walkways and curbs. - Regarding downtown area visitors, parking accessibility has the power to set the tone for the remainder of their stay.
2- Parking facilities should be strategically located	- locate parking spaces behind main street buildings. - Clearly label parking so that visitors can find it using good directional signage and/or a way finding system. - Parking facilities should not be located in high-traffic pedestrian areas.
3- Recognize the value of on-street parking	- Preserve as much on-street parking as feasible. - Parking on the street, both parallel and angled, must be thought to improve visibility for both pedestrian and car drivers, not blocking surrounding buildings accessibility, and to consider human safety. - Enforce on-street parking regulations to keep parking nesters each at a bay
4- Emphasizing High-Quality Design	- Parking lots should be lushly manicured and well-kept. - A visible barrier between the parking space and the neighboring walkway should be integrated into the street landscape. - Make the transition from automobile to pedestrian as pleasant as possible by utilizing visual amenities.

5- Making better use of parking spots	- Install a parking indication system capable to inform public about where frequently vacant parking spots may be found. - Encourage customers who experience high parking demand at various times to use shared parking facilities. - Directional signage, promoting parking places on websites, brochures, newspaper advertising, and specific downtown businesses disseminating information to employees and customers are all examples of ways to get the message out.
6- Managing the overall number of parking spots in the downtown area	- Instead of parking minimums, set parking maximums. Minimum requirements (too much parking discourage people from walking downtown). - For a traditional downtown, self-contained parking should be avoided since it prevents tourists from passing by other downtown shops.
7- Comprehensive parking planning	Parking solutions should be assessed in terms of its influence on: - Traffic patterns and car rate of flow. - Hands-on experience with pedestrians, density of the population, coverage prices for parking, pattern of activity, aesthetics as well as historical trends and feeling of being at the right location at the right time.

10. Results

The research study reached that most Egyptian cities share some common characteristics in its urban structure, Cairo as an example consist of several historic districts that were formed among a consequent historic period currently became centered in between modern city expansions that were formed at the old city boundaries. Cairo's districts currently have various combined residential and business activities and various car densities, which guide the choice of car parking method. Modern car parking technologies, telecommunication networks and cellphone applications gave a tremendous capability to improve the function of the existing city parking lots, also giving the architects and the decision makers a verity of modern solutions.

Suggested Car parking solutions for Cairo's mid-town area:

Cairo's mid-town area consists of old Cairo which is Islamic Fatimid historic area and Kidwai Ismail build European style buildings.

-Movable mechanical rotatory parking system is suitable for application on the border edges of old Cairo in the areas that are currently used as surface parking lot, as it does not need a permanent construction in a historic area site.

-Adding vertical floors and using car elevators instead of ramps in existing concrete skeleton multi-floors existing parking buildings, and creating cell phone applications to improve the existing parking management systems is the best suitable parking solution for Kidwai Ismail mid-town area as the low availability of parking areas.

-Modifying building regulations for demolished and re-constructed buildings in mid-town area to include enough car parking slots according to the proposed car density at its basements.

Suggested car parking solutions for Cairo's existing modern planned areas:

In Cairo's existing modern planned areas most of the citizens prefer side street curb parking in front of their houses as it is free of charge, another car parking area is either located in the building's basements or a surface parking lot annexed to central public gardens.

-Vertical double mechanical parking system is suitable for application in surface parking lot areas as is low cost compared to other mechanical systems, easy to install and it doubles the existing car parking lot capacity.

Suggested car parking recommendations for future city modern planned areas:

For future city modern planned areas planners and decision makers should distribute car parking lots and its car capacities according to the expected car densities.

-Plan for car parking lot's location to be close to public transportation to encourage people to leave their private cars and use public transportation facilities instead.

-Modify current Egyptian building regulations to increase the car no. for each residential unit into four cars instead of currently two cars for each family, letting the building owners afford four car parking slots in the building basement for new constructed buildings.

-Surface car parking lots are less expensive than any other mechanical parking system, so for modern planned city annexed districts it is preferable utilize some areas for future surface car parking purposes.

11. Conclusion:

According to the study of parking issues in major Egyptian cities, having Cairo as an example, the research reached that there are three major stages of cities car parking solutions: Future car parking planning, new parking management systems for existing parking facilities and implementing innovative mechanical car parking systems. Parking solutions in cities varies depending on the nature of each of its districts and its facilities. The study reached to the following:

1) Organizing and allocating Parking lots are critical issues to address.
2) Parking facilities efficiency can be improved by excellent management, which include parking sharing, pricing, parking laws and improved enforcement.

3) Parking structures may not be appealing buildings in the city context, but if they are well architecturally designed, they can be utilized as city landmarks.
4) Modern technical solutions such as automated parking systems, can aid in the solution of the city car parking problem, particularly in the congested areas and high-priced lands.
5) Egyptian building regulations must include the safety specifications of the modern technical automated parking systems and to consider it as an alternative to the traditional currently used multi-floors concrete skeleton car parking systems.
6) For a higher quality of life in cities, parking lots and parking structures should be planned and maintained in an environmentally friendly manner. They should also improve the safety criteria, aesthetics and the visual amenities.
7) When the demand for parking spaces outnumbers its availability, the solution is to assign the parking priority to different parking uses depending on the adjacent land use or activity. For a residential area as an example, Parking priority for residential zones is recommended in the following order: Parking for residents; parking for individuals with disabilities; parking for high-occupancy cars such as buses; parking for guests; loading zones; and commuter parking.

12. Recommendations

-City planners and urban designers should factor in the necessity for auto parking in their designs in order to minimize – or at the very least —the problem and its consequences in terms of traffic congestion and pollution.
- In city planning, the three types of parking provision should be considered: on-street parking (curb parking), off-street parking (parking lots), and parking structures. For each development or land use, planners should select the most acceptable form.
- Planners and urban designers should improve the parking facility's design, increase user convenience and safety, and make it more environmentally friendly.
- In their plans, planners should regard "parking structure" as a kind of land use, not only an area designated for parking lots. The development and deployment of effective mass transportation systems will have a favorable impact on the strain of the parking situation.

References

[1] Central Agency for Public Mobilization and Statistics of Egypt, (2021). Report.

[2] Egyptian code for cellular and urban road works, Code number 204/2008 part 2 – sector 4, page 50.

[3] Cairo Traffic Congestion Study, Phase 1, Final Report, (2010)

https://documents1.worldbank.org/curated/en/650141468248419267/pdf/718450ESW0Whit0ing0Annexes00PUBLIC0.pdf

[4] Central Agency for Public Mobilization and Statistics of Egypt, (2021)

https://knoema.com/atlas/sources/CAPMAS

[5] Parmar, J.; Dasp,P.; Sanjaykumar,M. & Davea. (2020). Study on demand and characteristics of parking system in urban areas: A review, Journal of Traffic and Transportation Engineering (English Edition), ScienceDirect, Volume 7, Issue 1, Pages 111-124
https://www.sciencedirect.com/science/article/pii/S2095756418305786

[6] Manville,M.(2014).Improving Cities Through Parking Policy, JOURNEYS.

https://docplayer.net/25363484-Improving-cities-through-parking-policy-michael-manville.html

[7] Hossam El-Din I. & S. Ahmed. (2017). Car Parking Problem In Urban Areas, Causes And Solutions, The 1st International Conference: Towards A Better Quality of Life 24 - 26 November, Technische Universität Berlin Campus El Gouna, Egypt.

[8] Bin Mahmood, M. & Hajjaj, S. (2018). Design and Implementation of a Rotary Parking System for a Truly Smart City in line with Smart Cities Technologies and Trends. 8th IEEE International Conference on Control System, Computing and Engineering (ICCSCE).

https://ieeexplore.ieee.org/document/8685011

[9] Youssef, Kh. & Megahed, S. (2010). The perplexity of parking requirements: Standardization versus Customization. 8th International Architectural Conference, Architecture & Built Environment – Contemporary Issues, Assiut University.

https://docplayer.net/145855755-The-perplexity-of-parking-requirements-standardization-versus-customization.html

[10] Abdel-Baqi, M. (2004). Environmental considerations in planning movement hubs in new cities in Egypt, Center for Planning and Architectural Studies, Cairo [in Arabic] www.cpas-egypt.com.

[11] O'Looney, B. & Payton, N. (2006). Seeking urban parking solutions, Places, 18 (1).https://escholarship.org/uc/item/0897x236

[12] Liu, Y. & et al. (2012). Metropolis parking problems and Management Planning Solutions for Traffic Operation. Effectiveness, Mathematical Problems in Engineering. Hindawi Publishing Corporation, Vol 2012, Article ID 678952.

https://www.researchgate.net/publication/258386283_Metropolis_Parking_Problems_and_Management_Planning_Solutions_for_Traffic_Operation_Effectiveness

[13] Shakibamanesh,A.&Behzadfar,M. (2011) Promoting city center parking qualities; using urban design guideline, International Journal of Architectural Engineering & Urban Planning, Vol. 21, No. 1.

http://www.iust.ac.ir/ijaup/article-1-77-en.html&sw=Design

[14] Toronto City Planning. (2013). Design Guidelines for "Greening" Surface Parking Lots.

https://www.toronto.ca/city-government/planning-development/official-plan-guidelines/design-guidelines/greening-surface-parking-lots/

[15] Montgomery County Planning Commission. (2016). Green-Sustainable-Parking-Guide.

https://www.montcopa.org/DocumentCenter/View/9735/Green-Sustainable-Parking-Guide-2_10_2016-Web

[16] Todd, L., (2006). Parking Management: Innovative Solutions to Vehicle Parking Problems, www.planetizen.com.

[17] Sanngoen,W; Akihisa, O. & Takashi, T. (2012). Parking Place Inspection System Utilizing a Mobile Robot with a Laser Range Finder.

https://ieeexplore.ieee.org/document/6426967

[18] Rogers, SA. (2013). Car Parks or Works of Art: 14 Exemplary Parking Facilities, https://weburbanist.com/2013/08/28/car-parks-or-works-of-art-14-exemplary-parking-facilities/

[19] https://www.nbmcw.com/product-technology/others/multilevel-car-parking-systems.html

[20] Husian,M.&Hassan,S. (2019) Sustainability consideration in multistory car parking design University multistory car parking as an example. Proceeding of ICCEET

https://www.researchgate.net/publication/336145071_Sustainability_consideration_in_multistory_car_parking_design_University_multistory_car_parking_as_an_example

[21] SahfutrinN.;Husni,N.;M. Nawawi. ;Lutfi,I ; Evelina ; Silvia,A&Prihatini,E. (2018). Smart Parking Using Wireless Sensor Network System, International Conference on Electrical Engineering and Computer Science (ICECOS).https://ieeexplore.ieee.org/document/8605241

[22] Siegman, P. (2014), Solving Parking Shortages, New Solutions for an Old Problem, Nelson\Nygaard Consulting Associates

[23] Urdiain, L. O.; Romero, C. P.; Doggen, J.; Dams, T.; &Houtven, P. V. (2012). Wireless Sensor Network Protocol for Smart Parking Application Experimental Study on the Arduino Platform, 4

http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.677.1286&rep=rep1&type=pdf

[24] Okazaki,S;Li,H; &Hirose,M.(2012). Benchmarking the Use of QR Code in Mobile Promotion, Journal of Advertizing Research, vol. 52, pages 102-117

http://www.journalofadvertisingresearch.com/content/52/1/102

[25] Reza,M,O; Ismail,M; Rokoni,A; &Sarkar,M. (2012). Smart Parking System with Image Processing Facility, MECS, vol. 47]I.J. Intelligent Systems and Applications, 2012, 3, 41-47

https://www.researchgate.net/publication/224910014_Smart_Parking_System_with_Image_Processing_Facility

[26] Rogers, SA. (2013), Car Parks or Works of Art: 14 Exemplary Parking Facilities, www.weburbanist.com.

Abbreviation and symbols

GDP	Gross Domestic Product
GSM	Global System for Mobile
LED	light emitting diode
MLCPS	Multi-level car parking system
PGI	parking guidance and information
QR	Quick Response
RFID	Radio Frequency Identification
SPSR	Smart Parking System Based On Reservation

Annex (1)

Egyptian code for cellular and urban road works, Code number 204/2008 part 2. Page 50 **[Car Parking Rates]**

Building Type	Number of parking units
Residential	- 1 parking unit for residential unit of area limit 200 Mt². - 1.25 parking unit for residential unit of area 200 Mt² - 250 Mt². - 1.50 parking unit for residential unit of area 250 Mt² - 300 Mt². - 2 parking units for residential unit of area more than 300 Mt².
Administrative	- 1 parking unit for each 1 Mt². of floor area (low density). - 2 parking units for each 1 Mt². of floor area (low density).
Hotels including utilities of an area limit 1000 Mt².	- 0.6 parking unit for each hotel room.
Cinema / Theater / Conference Hall	- 0.2 parking unit for each seat.
Centers/ Shops	- 3 parking units for each 1 Mt². of floor area (inside cities). - 4 parking units for each 1 Mt².of floor area (outside cities).
Restaurants	- 3 parking units for each 1 Mt². of the total floor area.
Private Hospitals	- 1.5 parking unit for each bed. 0.012 parking unit for each 1 Mt². of total hospital floor area.
Universities	- 0.2 parking unit / student (including teaching staff & administration employee)
Car Service Centers	- 1 parking unit for each 1 Mt². of the building.
Private Schools	- 0.05 parking unit / student or Teacher. - 0.3 Bus seat for each student -number of buses and its capacity is first determined then bus parking area is determined
Social & Sport Clubs	- 0.45 parking unit for each 1 Mt². of the club area.
Enclosed Sport Halls.	- 0.2 parking unit for each fan seat.