Automated vehicles parking technology in Dubai

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Abstract. The research aims to determine the optimal design aspects of the automated vehicle parking and its areas in relation with the residential and commercial use in Dubai by studying the five cases or projects of automated parking downtown the city of Dubai, also analyzing the urban indicators including capacity, main floor area, number of floors and the total estimated area, the number of entrance and the exit cabins and the time of vehicle retrieval. The research reached the conclusion that the total capacity of automated parking is proportional with the number of entrance and exit cabins, the main floor area, the total area designed for parking (all floors), and the number of elevators. The new general indicator proposed to assess the automated parking efficiency by the number of vehicles for each floor (vehicle/ lift/ floor) showed a total rate of (15 vehicle/ lift/ floor) in all cases of the research. The research showed the fact that the automated parking in Dubai can hold up to 60% more than conventional parking buildings and the occupation area for the single vehicle is (25 sq. m) in comparison with (42 sq. m) for the parking total constructional area conventional parking areas. It also reached the ratio of automated parking area to the residential and commercial usage building according to urban and constructional aspects and indicators.

Introduction
The increasing need of parking areas in Dubai is the main factor to its vast development that this city is facing, and due to the limited areas available in the city and the competition of land usages, new automated parking technologies and systems must be implemented to solve the congestion problems and providing the easy flow of transportation within the city in the way that large number of vehicles is accommodated with the less possible environmental effect. The main aim of using the vehicle automated parking areas is to accommodate the largest number of vehicles through the less space available specially when the lands are limited, rare and expensive and there is a major competition on land usage like urban downtowns.

The automated parking systems (APS) can be defined as a mechanical system to receive, lift, mobilize, park and retrieve the vehicles in different levels or floors in a way accomplishes reducing the size and area needed without the intervention of the driver or operator of the vehicle [1]. Any automated parking system consists of basically a platform or cabin to receive the vehicles, the driver parks his car in the platform or cabin and leave, then the vehicle is mobilized horizontally by horizontal conveyors to a lift that takes it to other levels or floors then again mobilizes the vehicle by horizontal conveyors in each and every level or floor and parks it in a designated space there. When the owner wants to retrieve his vehicle, it is done vice versa. This is controlled automatically by
computers, by the computerized mechanical and electrical control rooms and other supportive systems [2].

**Goal, Tasks, Methods of Study**

The purpose of this work is to determine optimal design aspects of the automated vehicle parking and its areas in relation with residential and commercial uses in Dubai. The results of this work are important to specialized architects, designers and planners to determine the basic design and planning for such building and its relation to the urban planning and construction regulations of Dubai. To achieve these goals, the following tasks were adopted such as collection of data and information to build a technical database for statistical analysis and modeling, comparing and identifying criteria for the derivation of indicators and design parameters. The main method of the research is an on-site/ field survey study of (5) automated parking projects in Dubai and technical expert's, contractors and manufacturers interview and comments on the selected projects, the practical value of the research consists in the application of its results for the purpose of new automated parking projects

**Experimental Part**

Dubai witnessed a vast urban development by the beginning of 90’s of last century and it is modernizing very quickly in comparison with many pioneering regional and international cities with combination of increasing of the individual income and the ratio of vehicles owning resulted the need of transportation especially in vehicles parking areas. With the limited urban space in the city and the competition in land usages, the administrations responsible of urban organization such as Municipality of Dubai and Road and transportation Authority (RTA) had gone towards encouraging the establishment of vehicle automated parking areas. The first one was established in Dubai in year 2009 which was related to Ibn Batoota Gate project that accommodates (765) vehicles [3], and the next one was Emirates Financial Tower in year 2011 that accommodates (1200) vehicles [4] then Conrad’s Hotel parking in year 2014 that accommodates (1053) vehicles [5] and now there is the new Hikmah Tower automated park which will accommodate (1252) vehicles alongside Dubai Courts Compound which will accommodate (1248) vehicles that will come to service in year 2020 [2]. Table (1)

| Project          | Vehicle Capacity | Ground Area or footprint [sq.m] | Levels count | Total Level Area [sq.m] | Space/Car | Transfer Cabins | Vertical Lift | Operation | System Manufacturer |
|------------------|------------------|---------------------------------|--------------|-------------------------|-----------|-----------------|--------------|-----------|----------------------|
| Ibn Battuta Gate | 765              | 2.513                           | 7            | 20.104                  | 26.3      | 8               | 8            | 2009      | Robotic Parking      |
| Emirates Financial | 1.200           | 3.567                           | 9            | 35.670                  | 29.7      | 9               | 8            | 2011      | Robotic Parking      |
| Conrad Hotel     | 1.053            | 2.600                           | 12           | 33.800                  | 32.1      | 8               | 8            | 2014      | Westfalia            |
| Dubai Courts     | 1.248            | 3.300                           | 8            | 29.700                  | 23.8      | 10              | 10           | 2020      | NGP solutions        |
| Hikmah Tower     | 1.252            | 1,260                           | 17           | 22.680                  | 18.1      | 7               | 6            | 2020      | Spacegate            |

Vehicle automated parking are planned in Dubai in accordance to its capacity and the effect of vehicle flow through the nearby streets following transportation studies prepared by special consultants and according to Dubai Municipality and Roads and Transportation Authority (RTA)
regulations in the way that accomplish the minimum waiting time and speed up when available the delivery and retrieve time of vehicles [2]. The time estimated to receive and park the vehicle automatically about (90 seconds) while retrieving it on demand is about (120 seconds) at Al-Hikmah Tower Vehicle Automated Parking that is considered the largest in Dubai [2].

Most vehicles spend (90%) of its life cycle standing still or parked somewhere whether it was a parking lot or multi-floor parking area, the driver needs at least (9) minutes to enter and search for a spot at a multi-floor parking area, (4-5) minutes the engine is still running consuming fuel and polluting the environment. The cost to maintain the single parking area of one car is ($650) a year just to cover the management, cleaning, lifts operation, security, and emergency services. Despite that, more than half of this type of parking areas doesn’t feel safe while being or moving at multi-floor parking areas [6]. The reasons of increased desire of establishing vehicle automated parking in Dubai can be summarized as following:

1- Utilization and area saving by (175%) and volume by (350%) in comparison with conventional parking lots which need (39 sq. m) per vehicle (sedan car) while the automated parking needs only (22 sq. m) per vehicle. As for volume and height of the floors, only one car can be parked at the conventional parking while it can be two cars one above the other at the automated parking.

2- Less car and pedestrians’ accidents, arguments, and racing to occupy the space in the conventional parking system.

3- Less vehicle waiting lanes to enter the conventional parking lots thus, fewer streets jams.

4- Less manpower to manage and operate the conventional parking lots.

5- Less pollution caused by engines.

6- Less time to search for available spot and park the vehicle.

7- Stop crime rates that happen in the conventional parking lots like looting and theft for cars and individuals.

8- The increased public desire and demand for vehicle automated parking specially at the places that have huge population of visitors daily like shopping malls, offices districts, housing towers, hospitals, universities, and governmental buildings.

9- The flexibility in design and architectural Formation, the less establishment cost and time in comparison with conventional parking lots [2].

The main factor of success in vehicle automated parking is the flexibility and vehicle flow around the establishment in accordance to its location with streets, whether it was on single street or two streets location at least that will increase the entrances and exits, because it is a standard protocol to designate one street for entrance and the second for exit [2]. Basic factors in designing vehicle automated parking are:

1- The independence of the building affects the design efficiency, the more independent and separation of the vehicle automated parking from the main building it serves, the more efficient architectural, operational design and more capacity.

2- The two main factors in increasing the capacity and the speed of mobilizing the vehicle vertically through the levels or floors of automated parking that is measured by (vehicle\hour) are the number of entrance and exit cabins and the number of lifts operating in the building [2].

According to a field study done by the researcher through May 2019 included (5) automated parking sites that are Ibn Batoota (765 Vehicles), Emirates Financial Tower (1200 Vehicles), Conrad Hotel (1053 Vehicles), Al-Hikmah Tower (1252 Vehicles), Dubai Courthouse Complex (1248 Vehicles) in Dubai city. Data gathered through design indicators for these structures that include the capacity, the total area of the main entrance, number of floors, the total construction area, number of entrance and exit cabins, and the vehicle retrieving time and with statistical analysis found the following:

1- The parking capacity is proportional with

- The number of entrance and exit cabins. It is logical that the increase of cabins would increase the capacity of the parking space and it should be no less than (2) cabins at any given time to accommodate up to (100) vehicles.
- Main parking entrance area: the increase of entrance level area is important and crucial in the efficiency and capacity of the Automated Parking lot through providing more area for entrance and exit cabins. It was found that the minimum entrance area should be no less than (650 sq. m) and whenever the area of main entrance level increased that will lead to increase in cabins and lifts.
- Total area designated (all levels): it is certain that increasing the areas of the vehicle automated parkin through increasing the levels or floors the consequence is the increase of the capacity to accommodate more vehicles therefore the number of floors or levels should be not less than (4) the more levels or floors added should lead to the addition of more entrance and exit also the lifts.
- The number of lifts: The number of lifts is related to the number of the cabins and equal to them in all cases of study.
- 2- The retrieval time is related to the capacity of the parking area, it is generally between (128-180) seconds in all cases of the study and it is considered an optimal time frame.
- 3- There is a parameter to describe the efficiency of the automated parking lot which is vehicles to the lifts to level (vehicle/lift/level) at the average of (15) vehicle per lift per level in all cases of the study.
- 4- The study showed that the vehicle automated parking in Dubai city accommodate (60%) more than conventional parking areas and the occupation area is (25 sq. m) per vehicle in comparison for (42 sq. m) in conventional parking buildings.

Table (2) shows the design indicators that describe the characteristics of vehicle automated parking lots in relation with their capacity that are resulted from the case study.

| Vehicle Capacity | Estimated No. of transfer cabins | Estimated minimum Ground area [sq. m] | Estimated Minimum Levels | Estimated Total Levels Area [sq. m] | Car/Cabin ratio | Estimated level Min. No. Lifts | Car/Lift ratio | Car/Lift/Level ratio | Estimated Retrieval Time [sec] |
|------------------|---------------------------------|----------------------------------------|--------------------------|------------------------------------|----------------|-----------------------------|---------------|----------------------|-----------------------------|
| 100              | 2                               | 650                                    | 4                        | 2.600                              | 50             | 2                          | 50            | 12                   | 128                         |
| 200              | 3                               | 850                                    | 6                        | 5.100                              | 66             | 2                          | 100           | 16                   | 130                         |
| 400              | 4                               | 1.250                                  | 9                        | 11.250                             | 100            | 3                          | 133           | 14                   | 134                         |
| 600              | 5                               | 1.600                                  | 10                       | 16.000                             | 120            | 4                          | 150           | 15                   | 138                         |
| 800              | 6                               | 2.000                                  | 11                       | 22.000                             | 133            | 5                          | 160           | 14                   | 142                         |
| 1,000            | 7                               | 2.400                                  | 11                       | 26.400                             | 142            | 6                          | 166           | 15                   | 147                         |
| 1,200            | 8                               | 2.800                                  | 11                       | 30.800                             | 150            | 7                          | 171           | 15                   | 151                         |
| 1,400            | 8                               | 3.200                                  | 12                       | 38.400                             | 175            | 7                          | 200           | 16                   | 155                         |
| 1,600            | 9                               | 3.600                                  | 12                       | 43.200                             | 177            | 8                          | 200           | 16                   | 159                         |
| 1,800            | 10                              | 4.000                                  | 12                       | 48.000                             | 180            | 9                          | 200           | 16                   | 163                         |
| 2,000            | 11                              | 4.400                                  | 12                       | 52.800                             | 181            | 10                         | 200           | 16                   | 167                         |
| 2,200            | 12                              | 4.800                                  | 12                       | 57.600                             | 183            | 11                         | 200           | 16                   | 171                         |
| 2,400            | 13                              | 5.200                                  | 13                       | 67.600                             | 184            | 12                         | 200           | 15                   | 176                         |
| 2,600            | 14                              | 5.600                                  | 13                       | 72.800                             | 185            | 13                         | 200           | 15                   | 180                         |

Figures (1-4) show the basic relation that combine design indicators of the automated parking lots that resulted from the case study.

The demand on parking areas differs in general according to the usage of urban land. It is surely that land usages is more in cities for residential and commercial, as for Dubai city that has residential, offices, hotel towers and also commercial usages, the need for parking areas are more demanded and it
is a necessity regulated by Dubai Municipality in vast details combined all urban constructions and buildings.

Table (3) shows the need for automated parking areas in comparison to the building areas for residential and commercial usage. This was reached according to Dubai Municipality’s indicators related to providing parking lots in accordance to every use and according to the field study done by the researcher.

![Figure 1](image1.png)  **Figure 1.** Capacity vs Ground area

![Figure 2](image2.png)  **Figure 2.** Capacity vs Transfer Cabins

![Figure 3](image3.png)  **Figure 3.** Capacity vs Level count

![Figure 4](image4.png)  **Figure 4.** Capacity vs Retrieval time

| Land use             | Building Type                                      | Automated car parking (total building area) as a ratio to total main building area |
|---------------------|----------------------------------------------------|----------------------------------------------------------------------------------|
| Residential, Towers | 1 bedroom apartment or studio up to (150) [sq. m]  | 13[%]                                                                           |
|                     | 2 bedroom apartment or studio (150-200) [sq. m]    | 16[%]                                                                           |
|                     | 3 bedroom apartment or studio (200-250) [sq. m]    | 17[%]                                                                           |
|                     | 4 bedroom apartment or studio (250-300) [sq. m]    | 17[%]                                                                           |
|                      | 5 bedroom apartment or studio over (300) [sq. m] | 19[%] |
|----------------------|-----------------------------------------------|-------|
| Commercial           | Office, Shopping centers, restaurants & café  | 43[%] |
|                      | Banks                                         | 27[%] |
|                      | Showrooms                                     | 27[%] |
|                      | Retail (Shops)                                | 77[%] |
| Hotels               | Typical room hotel                            | 19[%] |
|                      | Suite room hotel                              | 32[%] |
|                      | Apartment hotel                               | 15[%] |
|                      | Luxury apartment hotel                        | 26[%] |

**Conclusions**

1- The capacity of the parking building is proportional with the number of the entrance and exit cabins, the total area of the main floor, the total area specified for the parking building (all levels) and also with the number of lifts.

2- The retrieval time needed is between (128-180) seconds per vehicle in all cases of the study.

3- The general indicator for vehicle per lift per level that is (15) (vehicle/lift/level) to measure the efficiency of the vehicle automated parking building.

4- The automated parking buildings in Dubai accommodate (60%) more than the conventional parking buildings and it is (25 sq. m) per vehicle as an average in all cases of the study.

**Summary**

In frames of the field and analytic study for (5) automated parking buildings in Dubai, a conclusion was reached that the design and urban indicators could be calculated as the capacity and efficiency of urban lands to accommodate parking projects in connection with the area of the land and also the number of level or floors as basic structural indicators, besides the number of entrance and exit cabins along with the number of the lifts to indicate the relation to the total capacity of the parking project, it also showed the ratio of the area of automated parking lot to the nature of its urban usage specially residential, commercial and hotel buildings. These indicators can participate in helping the researchers and specialized architects, designers and planners to determine the basic design and planning for such building and its relation to the urban planning and construction regulations of Dubai.

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