# Application of Technology to Car Parking Facilities in Asian Smart Cities

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## ABSTRACT

**Purpose:** This study is aimed at investigating the status of applying technology in car parking facilities. It also examines the factors affecting the deployment of these technologies as they improve the efficiency and convenience of car parking facilities amidst changing transport needs in Asian smart cities.

**Design/methodology/approach:** A comprehensive literature review informs the relationships between car park provisions and the traffic congestion problem. A typology covering different technological solutions is then formulated. The factors affecting the use of two such common technologies (i.e., mechanical car parks and intelligent information systems) are examined in two emerging smart cities in Asia, with the aid of a desk-top study for Singapore and a survey covering over 600 samples (including users and non-users, since both groups are important to derive influencing factors) in Hong Kong.

**Findings:** The extent to which mechanical car parks may help relieve the space shortage problem depends on their relative costs and the facility management performance. For real time vacancy information systems, their wide spread use depends on drivers' age and past parking experience.

**Research limitations/implications:** Due to geographical constraints, only two Asian cities (Singapore and Hong Kong), where the use of smart technologies is flourishing, are included in the study. The survey on car parking apps is preliminary due to their relative short deployment in Asia. It is expected that the phenomena will quickly spread in the region as more smart cities are developed.

**Originality/Value:** By expounding on the development of modern parking technologies in smart cities, the important influence of car parks as a strategic facility towards solving traffic congestion and environmental problems is brought to the attention of policy makers, in particular the influencing factors affecting strategies to promote the use of parking apps.

**Keywords:** Transport, car parking facilities, technology, facilities management (premises), smart cities, Asia

## 1. Background

The shortage of car parking space is a perennial problem in densely built urban cities due to ever-rising commuting needs with an exponential growth in vehicle numbers, particularly when strong economy prevails. In earlier centuries, city planners focused on increasing the provisions of car parks in pace with new developments in the built environment. A wave of New Urbanism, has however, emerged since the last century due to a drive towards sustainability. Moving away from the mere provision of roads and car parks, new policies are favoring the adoption of a "car-lite" concept (less dependent on cars but rely more on public transport). However, the reduction of parking provisions in new development planning is counter-acted by the rapid growth in car ownership, which is estimated to double up to 2 billion vehicles by 2040 (World Economic Forum, 2016). The fastest growth is forecast in Asia, with a 3.7 per cent annual car sales increase as in 2017 (Nikkei Asia, 2017). Faced with this dichotomy, parking policies need reviewing and technology is being exploited to alleviate the space shortage and reduce congestion arising from car cruising around looking for car parks (Shoup, 2006), particularly in smart cities where efficiency and comfort are fostered with the use of Information and Communication Technologies (ICT). Firstly, additional car parking space is created through mechanization; and secondly, real time information is provided to drivers for making better use of vacant car park lots. Vertically extended mechanical car park systems have been common in Japan and Korea for many years, but recently, other Asian countries facing car park shortages are making increased use of the technology with the advent in computer control and electronic payment system (EPS), enabling a higher level of automation. For real time information systems, a typology exists:- (a) Highway display, (b) Local guide, (c) Vicinity guide, (d) Within car park guide, (e) Mobile apps using smart phones, and (f) Electronic payment system.

This paper aims at examining the state of technology deployment in urban car parks, firstly based on maximizing existing space and secondly, on providing drivers with real time information, drawing upon experience from examples of Asian smart cities including Singapore and Hong Kong. Whilst exploring the implications of these car-parking facilities on the built environment in smart cities, relevant statistical data on the use of mechanized car parks and a method for distilling the factors affecting the popularity of the real time parking information system are depicted in Singapore and Hong Kong respectively.

## 2. Literature Review

As car sales and ownership increase in metropolitan cities due to vibrant economic development, parking woes bring about air pollution, congestion and safety hazards since up to 50 per cent of traffic arises from cars cruising while looking for car parks (Chaniotakis and Pel, 2015). In the recent decade, Asian cities have climbed to the top of this league (Sultana et al, 2015). It is also obvious that the provision of ample carparks directly affects the success of business activities, especially in shopping malls (Sepe and Pitt, 2017). The availability of adequate parking facilities should also feature as an important performance attribute of residential buildings (Seshadhri and Kumar, 2017). Earlier on, many planning initiatives have been undertaken to provide additional car park spaces, such as the integration of multi-storey car parks in public housing estates in Singapore, even at the expenses of possible air quality impairment, privacy intrusion and noise to nearby residents (Wong and Ling, 2003). To curb car growth, Electronic Road Pricing and Certificates of Entitlement (a type of car ownership tax) were mandated, alongside softer campaigns such as car-pooling and taxi-sharing, which help slightly (Wang et al, 2018). Development provisions for car-parking are minimized (Barter, 2012). Starting from February of 2018, Singapore started to implement a “zero” car growth policy (Goh, 2017) due to its scarce land resources for roads and car parks. Apart from infrastructure construction such as transits and public transport enhancement (e.g., buses and the legalization of the Uber service), the use of technology is a partial solution to this bottleneck problem in the economy and the built environment. This is particularly applicable to smart cities, which embrace the use of technology for enhancing efficiency, safety, comfort and convenience of their citizens (Albino et al, 2015). However, many of the emerging smart cities have a dense urban environment, where transport issues are thorny. Hong Kong, for example, suffers from a severe land shortage and car number growth (3.8 per cent per annum), and parking spaces attract transaction prices (having risen 270 per cent from 2005-2017) higher than homes on a unit area basis (Kwok, 2017). Economic and social developments also cause some reduction of car parking lots when government rebuilds for offices and other uses at sites of demolished public multi-storey carparks (Li, 2017). Added to these, Asian businesses are not yet used to home offices as advocated in western countries (Dabson, 2000). Hence office parking is also a bottleneck area.

Technology has come to the fore in carparking with the advent of robotics in electro-mechanics, Internet of Things (IoT), as well as Information and Communication (ICT). Advanced computer simulation can optimize operations in mechanized car parks (Bekker and Viviers, 2008). Smart parking solutions employing wireless automatic counting (Lee et al, 2008). Indoor 3D navigation and positioning of vehicles in multi-storey carparks are facilitated by on-board motion sensors (Bojja, et al, 2013), although the technology has yet to diffuse widely in the society. Faheem et al (2013) carried out a review of intelligent car parking systems including ultrasonic sensors, magnetometers and image processing, and found the most effective solutions with the use of ultrasound. Such sensors and the "cloud" enable vacancy detection and transfer of real time information to drivers via their smart phones (Ji et al, 2014). In the US, parking technologies facilitating access, vacancy identification and revenue control have permeated into airports, making them competitive with discount satellite lots (Bill, 2018). The global market for such smart parking systems was valued at USD81.3 million in 2015, with about 73 per cent of these installations in off-street car parks (Grand View Research, 2016) and is estimated to proliferate at a compound annual growth rate of 10.6 per cent, reaching USD 5 billion in 2021, with Asia taking the lead (MarketsandMarkets, 2016). As Barter (2012) predicted, many Asian cities are shifting away from the parking supply expansion policy towards more market-oriented approaches, and technology use is very much a tool to enhance parking efficiency apart from pricing. Developments in car-sharing and ride-sharing are worth noting since technology (e.g., smartphones and internet) is also being deployed to enable dynamic matching of users (Agatz et al, 2012; Shaheen, et al, 2009). Further advancement in autonomous vehicle research already saw an average reduction of 62 per cent (maximum 87 per cent) in parking space (Nourinejad et al, 2018). If all these are successful, they may have a negative effect on the growth of carparking needs.

## 3. Typology of Car Parking Technologies

To facilitate a discussion of the status quo of different car parking technologies and their implications on the built environment facilities, a typology is depicted as follows (Fig. 1):-

### 3.1 Space-saving Solutions

#### 3.1.1 Mechanical Carparks

Double-stack garage systems with movement enabled by electrically-controlled hydraulic arms and racks can fit in existing space if the load-bearing capacity, headroom and fire sprinklers allow. Users may be expected to help themselves with parking and car retrieval with the simple controls. Multi-storey automated parking facilities (APF) may be purpose-built either above and/or below ground. Vertical elevators and horizontal conveyors or pallets maneuver cars around tight storage space, aided by computers. Some designs come without pallets. When compared with a conventional multi-storey carpark, APFs can save up to 50 per cent space to house the same number of cars by avoiding space reserved for driving lanes, ramps, walkways and passengers boarding and alighting. Lower ceiling heights may be possible, subject to fire-fighting requirements. There is a big range of construction cost, but in sizeable above-ground facilities, APFs can save about 10 per cent from conventional car parking unit cost, but annual maintenance can cost 80 per cent more (Monahan, 2011).

Car parking and retrieval from APF takes about 3 minutes, but if a larger number of drivers arrive at the same time, it could take longer. Hence, APFs are considered unsuitable for premises with peak demand periods, such as sports venues or auditoria. APFs best suit real estate with a split or evenly spread people movement. Ground level entrances and exits require adequate buffer space to avoid queues forming into public roads during peak periods. The large number of mechanical components entails high maintenance, but ventilation and lighting can be minimal due to the automatic operation. Noise and vibration, however, need to be taken care of if the APFs are integrated with residences. Normally, car and personal security is better than conventional multi-story carparks, although accidents (such as car falls) did happen in the US, resulting in legal proceedings (Robles, 2015).

Leading the world in terms of numbers, there are over 144,000 APFs in China, totaling 336,000 parking spaces spread over 491 cities (CHMIA, 2015). In some provinces such as Guangdong, some APFs were found to be under-utilized due to the adjourning development not being materialized and the unfamiliarity of drivers (Ifeng, 2017). Other Asian cities such as Singapore have put a high hope on APFs as a solution to the space shortage problem. Three pilot schemes have been carried out in public housing estates, and they will be further elaborated in a later section.

APFs have found their way into private high rise luxurious apartments as private “car lifts”. They help owners to deliver their “art pieces” right into their living rooms after road use (WSJ, 2012). Multi-storey “automotive-vending machines” also emerged in car-traders’ premises to save storage places and pose as a marketing gimmick (Calfas, 2017). These state-of-the-art carparking innovations are being tried out in compact city environment such as Singapore, where space is at a premium. Fast elevator systems feature heavily in such semi-automated carparks, which make them costly.

### 3.1.2. Automatic valet

Cars can be parked in tighter space when assisted by automated pallets in conventional off-street carparks. Running on guide rails or floor marks and steered by sensors and wireless controls, the pallets may traverse ordinary carpark floors without risk of collision. Drivers may retrieve their cars using a mobile app in 2 minutes, or between 10 to 15 minutes in peak period (Abdullah, 2017). China and Singapore are putting them into commercial use lately.

## 3.2 Intelligent Parking Systems

Parking guidance and information (PGI) systems have been used in many developed countries since the 70s, with gantry-mounted electronic boards showing variable message signs (VMS), providing drivers with directions and parking vacancy information as they approach their destinations. Time lags may affect the effectiveness of such messages. The use of smart phones improves the real time search capability. Even for on-street parking, enforcement of paid durations (against overstays) has been made easier. Despite the free provision of the information, innovative business models have emerged (e.g., shopping mall developers use such systems to attract visitors to their premises by providing exclusive information of their car parks). Rye et al (2008) praised the availability of real time vacancy information as a useful demand management tool.

### 3.2.1 Highway displays

The locations and directions of district carparks are shown at overhead gantries or curb-side boards along major approach roads. Large LED displays (powered and fed by wired connections) and district maps enhance visibility of drivers at long distances. They need to be designed for structure stability against the weather (DfT, 2002).

### 3.2.2 Local guides

Illuminated signboards are located at major intersections displaying vacancy information in the district along the main roads leading to the carparks (DfT, 2002). Directional arrows with associated distance labels provide additional assistance.

### 3.2.3 Vicinity guides

Being located at entrances or turning points adjacent to the car parks, they provide specific vacancy information on them, usually with “full” alerts and parking charges. Often, to encourage “park and ride” (driving to public transport stations, where the cars are parked before boarding), these displays are integrated with mass transit information for long-distance travelers (CIVITAS, 2013).

### 3.2.4 Within-carpark guides

At each floor level, electronic signs show the vacancies and sometimes the available parking lot numbers with a legend or floor plans. The parking lots also may have magnetic or ultrasonic sensors to trigger ceiling-mounted lights with different colors indicating vacancy, occupation, disabled parking space, or electric chargers being available (Venkatchalapathy et al, 2015).

### 3.2.5 Mobile Apps

Car park owners may participate in a district network by sending their car park vacancy and charge information to a cloud-based data integrator, which operates the hardware and software for updating and dispatching the data on a real time basis via Wi-fi networks to drivers. The latter may download a mobile app and search for vacant parking lots via their smart phones (Ji et al, 2014). These systems can be connected to GPS for gaining navigational aids to the car parks. Parking space reservations may be made at a charge. Sensors or image processing cameras detect the accurate number and location of vacant lots. In Japan, the updating of GIS information is carried out by a team of “walking surveyors” for feeding data into vehicle-mounted GPS navigational systems showing car park vacancies as well. Alternatively, a fleet of vehicles equipped with multiple sensors may be deployed to capture street scene for transforming into GIS data.

With the proliferation of such car parking apps serving discrete districts (e.g, in Hong Kong at the time of writing), drivers may need to download different apps to cover a wider area of their travel. Sometimes, information displayed on different apps with geographical overlap may conflict. Different technologies may cause such discrepancies (e.g., movement of people within car parks may affect different detection systems to a different extent, and there may be differences in the frequencies of updating information).

Amongst different users, Thompson and Bonsall (1997) demonstrated that tourists' awareness of PGI system is high, but regular drivers may ignore the passive information and rely on their own knowledge of the areas. Other influencing factors include city sizes, types of facilities, prices, etc. More recently, Chaniotakis and Pel (2015) found that car park choices are affected by walking distances to destination, access time, expected car park searching and waiting time, and to a less extent, driver's age and parking duration. This is the subject of investigation of the survey carried out in Hong Kong, where parking apps have been available for 6 months.

### 3.3 Revenue and Access Control

Cashless electronic payment systems (EPS) have been used in many modern car parks (Benelli and Pozzebon, 2010). There are 3 main types: (a) Antenna sensing emitter units mounted within vehicles at entry/exit points for keeping time records and activating automatic deduction of parking charges; (b) Same as above, but drivers need to insert or tab their cash cards to effect payment (system cost cheaper by half), and (c) Similar, but mainly for access control of season parking without payment ability. The varying efficiencies of these different EPS affect the convenience and smooth operation of parking facilities, depending on the time taken for each entry/exit.

Insert Fig.1.(Typology of Car Parking Technologies) here

## 4. Investigation on the Use of Carparking Technologies in Asia

### 4.1 Singapore

The Housing Development Board (HDB) is the public car park developers, as part of its mission to provide accommodation for over 80 per cent of the 4 million population. Forty per cent of the public households are car owners. Island-wide, HDB constructed and manages 1,800 car parks (over half a million lots) and approximately 220 of them face shortages due to strong localized demand (Tan, 2016). Due to the shortage of land and the ever-increasing transport needs (despite various measures taken as mentioned earlier by the Land Transport Authority), HDB pilot tested by building 3 multi-storey mechanized car parks in locations where older estates were built without expecting today's demand for car parking. Details of the mechanized car parks are shown in Table 1.

**Table 1:** Three pilot projects of mechanized car parks by HDB, Singapore

| Location/Configuration | Capacity -parking lots/ | Estimated | Construction cost |
|---|---|---|---|

| (all above ground) | (Utilization rate) | Construction Cost | per lot |
|---|---|---|---|
| Changi Village/5-storey Cart system (short-term parking) | 137 (90%) | S$10 million | S$72,922 |
| Bangkit Road/15-storey Tower parking system (season parking) | 60 (50%) | S$5 million | S$83,333 |
| Yishun Avenue/13-storey Tower parking system (season parking) | 22 (90%) | S$3 million | S$136,363 |

Exchange rate: US$1 = S$1.33 in Feb 2018

(Date source: Todayonline, 2014)

The projects were completed in 2015, with 54,000 parking transactions in the first 6 months and an official breakdown rate of 0.02%. Maintenance cost was reported as ranging from S$60 – 100 (USD 45 – 75) per lot per month. Car parking or retrieval time varies from 10-15 minutes, depending on the queue, which still compares favorably with the traditional parking time of more than 30 minutes at the peak periods (Singapore Parliament, 2016). The facilities are equipped with emergency generators and a 24-hotline is maintained, with cars covered by damage insurance. As shown in Table 1, the more economical systems have higher parking capacities, but utilization rates depend on location (higher near offices and eateries). On average, they cost 5-6 times more compared with ordinary multi-storey carparks, as calculated from official figures (MND, 2011), with rather high maintenance cost. To-date, HDB charges the same parking rates as all other carparks. Users' comments have been that the facilities are slow, but safe (Seow, 2016).

### 4.2 Hong Kong

The parking space information system is part of the Smart City initiatives for Hong Kong. To-date, at least 3 smart parking systems have been developed by different parties including the government and some private shopping mall owners providing Mobile Applications (Apps) via smart phones to transmit real-time parking space information to drivers. Users can easily download one of these Mobile Applications (Apps) for free regular use to find available parking spots near to their destinations, with a suggested route to the destination (as an option). For them, the Apps afford an opportunity to relieve the congestion caused by cruising traffic movement resulting in convenience, time and petrol cost savings and reduced vehicle mileage/depreciation. Owing to the second Central Business District in Kowloon being earmarked for trials as a pilot smart city, a survey was launched in 2017, aimed at investigating the usage of Apps as part of a smart parking space information system in Hong Kong, including an identification of the factors affecting the use of such new technology.

## 5. Survey Methodology

A questionnaire was designed with bilingual online versions of Chinese and English, being hosted in a university website (URL:  see appendix for hardcopy version at blind review stage). A brief description was given on the questionnaire so that respondents may answer the questions about the car parking APPs whether or not they have used them, provided that they are drivers. The questionnaire was designed to solicit demographic characteristics of the respondents and the significant factors affecting the respondents' usage of the Apps, if any. The survey was carried out from June to November, 2017 in Hong Kong (when the carparking app were available for about half a year) by snow-ball distribution of the URL to acquaintances (knowing that they are drivers, whereas it is not possible to access other driver database due to privacy issues) via social media and through invitation mail shots inserted into residential estates (having carparks) with a random geographical distribution. Responses are shown in Table 2, showing a total sample size of 833, comprising 219 returns with missing answers and 616 with full answers (including users and non-users; both groups being important to derive the influencing factors), which should be representative of the Hong Kong population (Mitchell & Carson, 1989). The demographics are shown in Table 3.

**Table 2.** Case Processing Summary

| | N | Percent |
|---|---|---|
| Valid samples (included in analysis) | 616 | 73.9 |
| Missing Answer Cases | 217 | 26.1 |
| Total | 833 | 100.0 |

**Table 3.** Respondents' demographic profile

| Variables | Classification | Frequency | Percent | Description | Mean | Std. Deviation |
|---|---|---|---|---|---|---|
| Gender | Female | 127 | 20.6 | 1 = *Female*;<br>2 = *Male*. | - | - |
| | Male | 489 | 79.4 | | | |
| Age | 18~30 | 49 | 8.0 | 1 = *18~30*;<br>2 = *31~45*;<br>3 = *46~60*;<br>4 = *Above 60*. | 2.55 | 0.735 |
| | 31~45 | 218 | 35.4 | | | |
| | 46~60 | 308 | 50.0 | | | |
| | Above 60 | 41 | 6.7 | | | |
| Highest education level | Primary | 4 | 0.6 | 1 = Primary;<br>2 = Secondary;<br>3 = Post-secondary; | 3.49 | 0.792 |
| | Secondary | 104 | 16.9 | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| | Post-secondary | 92 | 14.9 | 4 = University and above;<br>5 = Others. | | |
| | University and above | 416 | 67.5 | | | |
| | Others | 0 | 0 | | | |
| Driving experience | Not at all | 2 | 0.3 | 1 = *Not at all*;<br>2 = *Less than 1-year*;<br>3 = *1~3 years*;<br>4 = *4~10 years*;<br>5 = *More than 10 years*. | 4.51 | 0.883 |
| | Less than 1 year | 33 | 5.4 | | | |
| | 1~3 years | 52 | 8.4 | | | |
| | 4~10 years | 91 | 14.8 | | | |
| | More than 10 years | 438 | 71.1 | | | |

## 6. Analysis of The Model

In accordance with overseas studies (Chaniotakis & Pel, 2015; Bonsall & Thompson, 1997; Ottomanelli et al, 2011; Ibeas et al., 2014) on "parking choice behavior and considerations", the "weekly driving time, the usage of GPS navigation system", the "time required for seeking a parking space on average", the "frequency to seek parking space", the "alternative venues for parking", and the "frequency of using e-payment services" are listed in the questionnaire as the explanatory valuables for App usage. The likelihood of a driver using a carparking app is to be estimated and hence put as the dependent variable in the model.

The dependent in this study is a dichotomous choice (referendum) variable. Respondents were asked whether they had used any Apps as part of a carpark information system through their smart phones for checking the availability of vehicle parking space before driving into a car park. A binary logistic regression model was used to investigate the relationship between the dichotomous variable and the explanatory variables as presented in Equation 1, since the functional form enables the discrete dependent variable to be analyzed in response to unitary changes in the independent variables (Pampel, 2000).

In this research, the estimation of the probability ($P_i$) of Apps usage is based on the relationship between this binary dependent variable ($Y = 1$) and a set of explanatory variables ($\boldsymbol{X}$), including gender, age, education, driving experience, etc. (Kay & Little, 1987).

$$P_i = Prob.\,(\,Y = 1 \mid \boldsymbol{X}) \qquad \text{(Eq. 1)}$$

$Y$ is set as a binary response variable, $Y = 1$ if the response is *Yes*; $Y = 0$ if the response is *No*; $\boldsymbol{X}$ denote the vector of explanatory variables $x_1, x_2, \dots \dots \dots .. x_i$.

With the theoretic interpretation of binary logistic regression, a probability model can be depicted in Equation 2 (Dobson & Barnett, 2008; McCullagh & Nelder, 1989):

$$logit\ (P_i) = \mu_0 + \boldsymbol{\mu_1 X} \qquad \text{(Eq. 2)}$$

where $\mu_0$ is the estimated constant, and $\boldsymbol{\mu_1}$ is the vector of the coefficients to the explanatory variables $x_1, x_2, \dots \dots \dots .. x_i$ in the analysis.

Rearranging into exponential format in Equation 3:

$$P_i = exp\ (\mu_0 + \boldsymbol{\mu_1 X}) / \left[1 + \exp(\mu_0 + \boldsymbol{\mu_1 X})\right] \qquad \text{(Eq.3)}$$

Hence the model of binary logistic regression was used to examine the relationship between the probability ($P_i$) of Apps usage and the explanatory variables presented as follows:

$$logit\ (P_i) = \alpha_0 + \alpha_1 x_1 + \alpha_2 x_2 + \cdots \alpha_i x_i \qquad \text{(Eq. 4)}$$

where $\alpha_0$ is the estimated constant, $\alpha_1$, $\alpha_2$ … $\alpha_i$ are coefficients to the explanatory variables $x_1, x_2, \dots \dots \dots .. x_i$.

Table 4 shows the answers obtained for the Dependent Variable (whether respondents used the car parking Apps) and Table 5 shows the descriptive statistical results of all Independent Variables.

**Table 4.** Description of the dependent variable: usage of smart car parking Apps (Question: Whether the respondent used any App about carpark availability system in smart phone for checking vehicle parking space before driving into a car park entrance?)

| Answer | Frequency | Percentage |
|---|---|---|
| Yes | 62 | 10.1 |
| No | 554 | 89.9 |
| Total | 616 | 100 |

**Table 5.** Descriptive co-variates

| Variables | Description | Mean | Std. Deviation |
|---|---|---|---|
| Whether ever paid for downloading any Apps on mobile phone | 0 = *No*; 1 = *Yes*. | - | - |
| Weekly driving time | 1 = *Less than 1 hour*;<br>2 = *1~5 hours*;<br>3 = *6~10 hours*;<br>4 = *11 ~ 15 hours*;<br>5 = *More than 15 hours*. | 2.85 | 1.311 |
| Whether ever used GPS navigation system | 0 = *No*; 1 = *Yes*. | | |
| How long usually need to seek a parking space on average | 1 = *Less than 5 minutes*;<br>2 = *6~10 minutes*;<br>3 = *11-15 minutes*;<br>4 = *16 - 20 minutes*;<br>5 = *Others*. | 2.22 | 0.975 |
| How many times on average per week to seek parking space | *No. of times* | 3.46 | 3.821 |
| Whether you have other alternative car parks in mind | 0 = *No*; 1 = *Yes*. | | |
| How often use e-services or mobile services | 1 = *Never*<br>to<br>5 = *Always*. | 3.46 | 1.141 |

## 7. Findings and Discussion

As shown in Table 3, the majority of the respondents are drivers and hence potential users of the smart parking Apps. 79.4% of the respondents are males. Respondents are in the age range of 18 ~ 60 (85.4%), and the majority has more than 10 years' driving experience (71.1%), which can represent the main body of motorists in Hong Kong.

The variables listed in Table 3 and Table 5 were input into the model, including 1 dependent variable of *usage* (whether respondent used the apps), 11 independent variables, namely, "gender", "age", "education level", "driving experience", "whether the respondent ever paid for downloading any App on mobile phone", "weekly driving time", the "usage of GPS navigation system", the "time required for seeking a parking space on average" (*Parking-time*), the "frequency to seek parking space" (*Parking-frequency*), "alternative parking venues", and the "frequency of using e-payment services". As shown in Table 6, after iterative steps with the stepwise backward conditional method[1] in SPSS, 3 independent variables have statistically significant levels at 0.004 (*Age*), 0.029 (*Parking-time* ), 0.032 (*Parking- frequency*), which are smaller than the criterion significance level of 0.05 (Pampel, 2000). The other 8 variables are statistically insignificant with *p*-values larger than 0.05. Thus, an explanatory model on the usage of the Apps can be generalized with the 3 statistically significant independent variables as follows (Equation 5):

[1]A manipulative approach of binary logistic regression in the SPSS. Initially, including all the variables in the modelling; then removing insignificant variables progressively, one at a time; finally, only choose and including statistically significant variables in the analysis (Cook et al., 2001). The model shown in Table 6 was the result after processing with 10 iterations eliminating insignificant independent variables.

$$logit\ (P_i) = -1.990 - 0.557 * A\ + 0.301 *\ T +\ 0.061 * F \qquad \text{(Eq.5)}$$

where $P_i$ denotes the probability of *usage* (whether respondent used any Apps about carpark availability system in smart phone for checking vehicle parking space before driving into a car park), A for *Age*, T for *Parking-time* (how long the respondent usually need to seek a parking space), F is *Parking-frequency* (how many times on average per week to seek parking space).

**Table 6.** Logit model with statistically significant variables

| Variables | B | S.E. | Wald | Sig. | Exp(B) |
|---|---|---|---|---|---|
| Age | -0.557** | 0.191 | 8.519 | 0.004 | 0.573 |
| How long usually need to seek a parking (*Parking-time*) | 0.301** | 0.138 | 4.762 | 0.029 | 1.351 |
| How many times on average per week to seek parking space (*Parking-frequency*) | 0.061** | 0.028 | 4.588 | 0.032 | 1.063 |
| Constant | -1.990*** | 0.588 | 011.455 | 0.001 | 0.137 |

** Significance level at 0.05.
*** Significance level at 0.01.

Insert Fig. 2. (Variables in the model of usage of smart car parking APPs) here

Logistic analysis identifies the statistically significant explanatory variables and their influence on whether a respondent uses any car parking app in Hong Kong (Fig.2). *Age* has a negative (also the highest absolute value) coefficient (-0.557), meaning that the younger generation of drivers is more inclined to use parking apps. The positive coefficient (0.301) of *Parking-time* indicates that those who have longer waiting experience for car parks have a higher tendency to use the parking Apps. The third significant coefficient of *Parking- frequency* (parking times per week) is also positive (0.061), indicating that drivers who have to park frequently like to use parking Apps.

Due to the limited time span (about half a year) between launching the apps and the survey in Hong Kong, these results gleaned from 62 App users (representing 10 percent of the drivers sampled) are only preliminary, but they do throw some useful light in the development of possible strategies for promoting the use of real time car parking information systems in an emerging smart city environment. Since previous studies only investigated parking behaviors based on the drivers' judgement on the choice of carparks, this study fills the knowledge gap by identifying factors influencing drivers' use of a new technology assisting them in the search for parking.

## 8. Conclusions

Although we have high hope to reduce the number of cars as far as possible by various planning and taxation measures, car parks are still indispensable facilities in any city. To cope with increasing car ownership, especially in fast growing Asia, we have got to make parking more efficient and convenient, as well as to minimize the environmental detriments caused by carparking and its associated traffic. Technology has come to the fore to help, as examined in this study, through mechanized parking means and intelligent parking information systems deployed in many smart cities with the prevalent use of ICT. To make the best use of such technologies, we need to integrate them in a seamless manner to the built environment. On one hand, the space-saving mechanical car parks need to be user friendly (in terms of reliability, safety and cost). Their designs should take into consideration the adjacent environment and the real demand. Parking habits in these mechanical car vaults need to be cultivated, perhaps via pilot schemes in the initial phases, as exemplified in the case of Singapore. Useful assistance is being rendered by real time parking apps and electronic payment systems. This preliminary study has shown the influential factors affecting the use of the parking apps, including age, waiting time experienced by drivers and their frequencies of parking. To foster wide spread use, on one hand, further promotion needs to focus on these factors, as demonstrated in the case of Hong Kong. Advertisements about the availability of the carparking apps may be targeted at younger drivers, especially those who drive regularly, preferably at popular shopping malls and busy districts, where waiting times for carparks are long. On the other hand, technologies, being transient invention, would be subject to changes. They can be disruptive as well. Concomitant business models need to be developed to enable sustainability. The increased use of electrical vehicles, for example, may change the behavior of parking and the built facilities supporting it. For example, car parks need to be equipped with suitable and adequate charging points, which should be properly managed to avoid jamming by traditional cars. The recent development of autonomous vehicles, which can park themselves, may perhaps reduce parking space in the future. Unexplored possibilities exist, such as parking cars in vertical positions. The built facilities in a smart city need to match up with all these, in order to make driving a pleasure apart from deriving its functional benefits of efficiency and convenience

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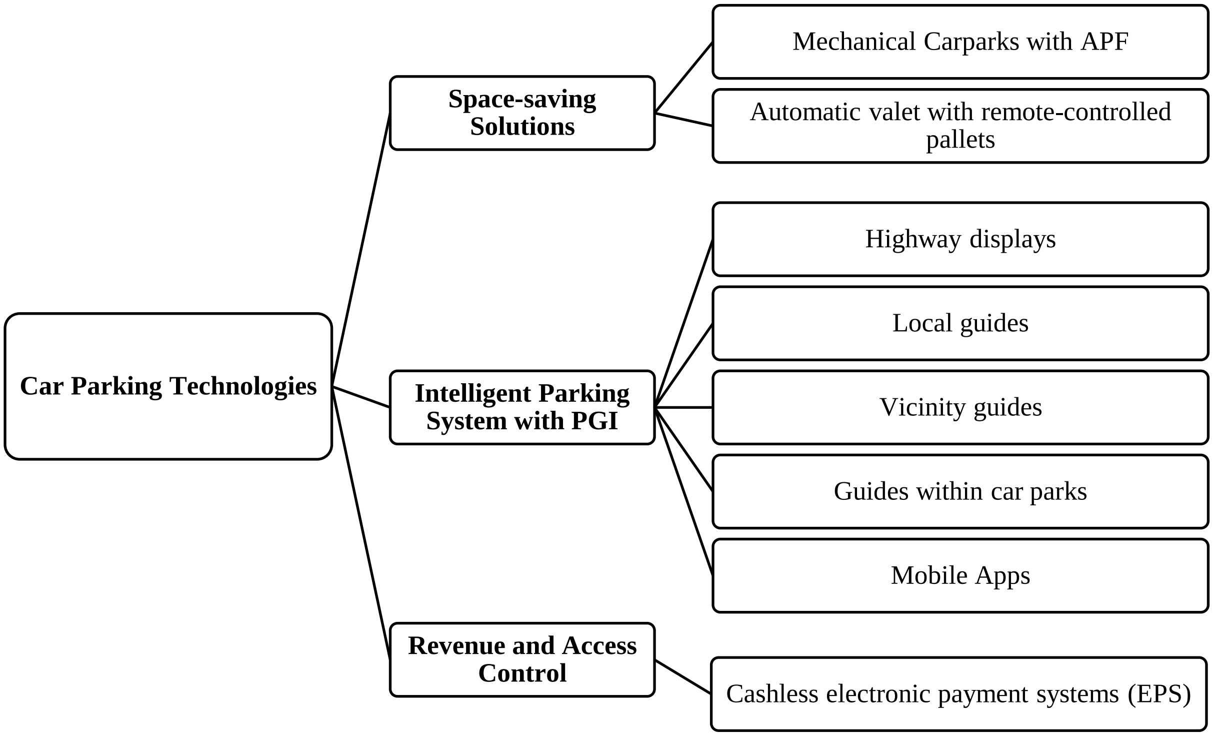


**Fig.1: Typology of Car Parking Technologies**

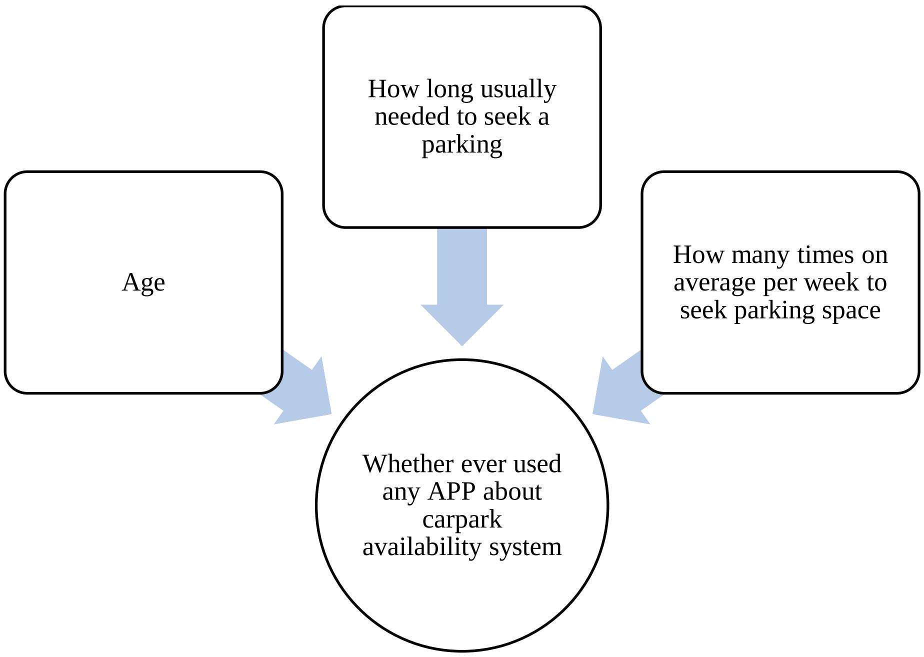


**Fig.2: Significant variables in the model affecting usage of smart car parking APPs**