GLOBAL REVIEW OF PARKING MANAGEMENT SYSTEMS & STRATEGIES

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ABSTRACT
Parking challenges have been a part of our society for a long time and traditional parking management strategies have come a long way. The problems associated with parking are common to most of us. This paper attempts to review globally implemented parking management strategies that leverage innovative technologies. Further, by examining a variety of parking management solutions from around the world, this paper aims to examine the shift in focus of modern parking management strategies. These solutions address conventional parking challenges local to their region, in an unconventional way. Finally, the paper performs a comparative analysis between traditional and modern (innovative & technology-driven) parking management strategies/systems. The motivation for this research paper is to identify the positive commonalities of the innovative approaches, which would aid in designing future parking management models.

Keywords: Global Parking Management, Review of Parking Strategies
INTRODUCTION

The Parking Problem

Everyone who owns a vehicle needs a place to park. As the number of vehicles grows, so does the need for parking. According to the U.S Department of Transportation’s Federal Highway Association (USDOT FHWA), the number of publicly owned motor vehicles has risen, more than 20% from 3,493,570 in 1994 to 4,224,542 in 2009, as shown in Figure 1. Vehicle ownership rates in densely populated countries are even higher. The conventional parking management strategy has been to increase the existing capacity. Other innovative strategies address the rising vehicle ownership trends more effectively. Due to this growth, parking space has become an integrated component of the building and road infrastructure. A lack of adequate, easy-to-find, and inexpensive parking facility aggravates operators who must routinely travel to carry out a gamut of their daily activities. Ignoring the issue or under-investing in parking management is likely to contribute to increase in traffic congestions, traffic violations, vehicular accidents and injuries, and waste of time and money.

Figure 1

![Graph showing the increase in number of vehicles from 1994 to 2009](image)

Lack of effective parking management creates problems for everyone. Either improvements in the existing solutions require significant financial commitments or they are difficult to implement due to their complex nature. Individual entities such as cities, firms, stadiums, and subways have their own particular parking arrangements. However, there is no standard parking management skeleton. Each setting is different and what works for one organization may not work for another. Two motives are common among all who wish to provide a parking solution;
first, they all strive to address their unique parking needs and second, earn the most from investment in their parking facility. Due to the substantial investment and complexity involved in parking management, on the other hand, many institutions choose to outsource. These institutions are either unable or unwilling to deal with the challenges of operating and maintaining a parking facility.

The planning and resources needed for setting up a parking facility vary significantly across organizations. It could be as simple as posting a person outside a gated lot, or it could be as complex as managing the vehicles of all commuters at an airport. The amount of resources, including parking space is, of course, limited. Instead of searching for individual parking solutions, energies should be expensed on having a comprehensive view of the problem and identifying a standard solution that would be applicable to most parking systems.

Goals/Scope of this paper

This paper identifies the common strategies emerging from parking problems in various countries. While, peculiar parking challenges are dealt with by using unconventional methods, most conventional strategies used today attempt to solve the problem by relying on traditional approaches. Such methods may include expanding parking capacity, investing in parking infrastructure, providing incentives to use public transportation, and penalizing those who violate the parking rules. This paper attempts to review, discuss, and perform a comparative analysis of parking management strategies used globally. Further, it evaluates and compares the innovative solutions used to address the parking problems and traditional approaches. Next, the paper highlights some common strategies and features that emerge from the solutions. Lastly, the paper analyzes the strengths and weaknesses of the solutions utilized in these strategies and suggest few recommendations.

PARKING MANAGEMENT

Parking systems routinely experience parking related challenges, especially in the urban and metropolitan areas. The most significant of them is the availability of space. Either the operators cannot find parking slots or the capacity is under-utilized. Many institutions use management tools to solve their particular parking issues. According to some transportation authorities, such as Victoria Transportation Policy Institute (VTPI) and Texas Transportation Institute (TTI), parking management refers to policies and programs that result in efficient use of parking resources (VTPI) or strategies aimed at making better use of available parking supply (TTI). These definitions are very broad. However, for a parking management strategy to be effective in solving parking problems, the following must be true:

i. A comprehensive needs analysis of the facility must be conducted
ii. A small scale prototype be deployed and the findings carefully analyzed
There are several types of parking management systems in existence. Discussed below are some
the traditional parking management strategies.

**Overview of Traditional Parking Management Approaches**

Effective parking strategy relies on either a specific type that meets the needs of a system or a
combination thereof. Reviewed below are some of the currently practiced parking management
approaches:

1. *Brick and Mortar Facility:* Majority of institutions use these traditional parking facilities
   either investing in large spaces of land or constructing large buildings to accommodate
   vehicles. This approach has been the tried and true approach. It addresses several parking
   management challenges effectively.

2. *Preferential Parking:* Use of this approach is to make the most of a given parking space. A
   good example would The Los Angeles Department of Transportation. They implement and
   enforce Preferential Parking Districts in residential areas where employees and customers of
   nearby businesses and attractions regularly park for long periods of times making it difficult
   for residents to find parking. Preferential Parking Districts restrict parking for all motorists,
   but area residents and their guests are exempt from the special parking restrictions if they
   purchase and display Preferential Parking Permits [1]. Another example would include
   spaces reserved for people with two or more individuals in a vehicle, similar to a HOV car
   pool lane.

3. *Price Discounts:* This approach usually applies to carpools and or short-term parkers. This is
   desirable for change-mode parking facilities [2] such as airports and subways, where
   commuters often park their vehicles before using public transportation services. In addition,
   carpool lanes on busy highways offer timesaving.

4. *Change-mode Parking Facility:* This approach is perfect for institution such as airports,
   subways, park-and-ride shuttle services. All of these institutions require the incumbents to
   locate a parking space promptly and continue commuting in a public transportation vehicle
   [2].

5. *Disincentives:* On those who contribute to traffic-congestions (illegal parking, parking near
   an expired meter), the state and local governments may impose citations. For example, a
   person is fined for travelling alone in a car pool lane that requires two or more passengers

6. *Satellite Parking:* This approach is also known as remote parking or off-site parking. This
   approach is used when the place to park is far away. Usually in this arrangement, a parking
   facility is shared with other entities or there are other incentives involved. Logan airport in
   Boston, for example, provides shuttle services to neighboring cities and towns. Another
   popular example is a free shuttle service to any casino is Las Vegas.

7. *Shared Parking:* This is a popular approach to address a need for large space requirements
   with significantly reduced investment. Typical examples include universities, business parks,
   and privately owned doctor’s practices.
When parking management strategies are appropriately applied, they can effectively manage the number of parking spaces required in a particular situation and they provide a variety of undeniable economic, social, and environmental benefits. Each of these strategies, however, has its own strengths and weaknesses to be discussed later.

**Challenges of Traditional Parking Management Approaches**

It is well known that all of the above-mentioned traditional approaches are used to address different types of parking needs. Furthermore, all of these approaches come with their set of challenges as shown in Table 1 below:

<table>
<thead>
<tr>
<th>INNOVATIVE PARKING MANAGEMENT APPROACHES (METHODS)</th>
</tr>
</thead>
</table>
| Traditional parking management approaches address the fundamental parking space problem by expanding the parking capacity. This solution works however, is not efficient. Example, a university typically has most of the classes during the daytime. Most of the students park their cars and occupy all or most of the available spaces. However, in the afternoons or evenings those same spaces are vacant. In other words, the parking capacity is underutilized. Innovative parking management approaches have a different focus. One of the goals of these modern day parking management strategies has been to increase the utilization factor (usage/occupancy rate) of the existing capacity, Figure 2. They accomplish this by many ways:

1. Delivering current parking information to its users efficiently
2. Identifying peak/busy times and determine methods to maintain constant occupancy (renting, sharing, & leasing available parking spaces)
3. Implementing demand responsive pricing methodologies (example, SFPark)
4. Analyzing past parking trends and using that data to predict future parking availability (analytics)
Sixteen parking management strategies from different nations are reviewed. These strategies are divided in three groups:

**Policy Based Solutions**

These are parking management solutions governed by institution-determined policies. FutureLink, the maker of **Parking Guidance Systems** is a Dubai based company that supplies to the major cities in the UAE. It manufactures a sensor supported parking system, as shown in Figure 3. This system provides current parking availability update on screens placed throughout the parking facility. This real-time visual presentation of free spaces allows for easy parking and increases the utilization factor for a parking facility. In addition to the time savings, the system offers direct guidance, as depicted in Figure 4, to the destination via electronically controlled variable message signs. Another parking management solution from FutureLink, **Mobile Car Parks** caters to short term parking problems, especially when there is limited construction time and parking capacity. This system constructs parking lot buildings with the mindset that they are temporary. While these buildings, shown in Figure 5, are weather resistant and sturdy, they do not need the typical construction cost of a permanent parking structure. Reuse of buildings is possible and is easy to add capacity. Omnitec is another Dubai based company, which provides **Automated Number Plate Recognition System & Access Control Management.** This is extremely useful to institutions to enforce policy based parking management. This solution relies on a camera mounted at the parking gate, as shown in Figure 6. The camera scans the vehicles number plates, checks the internal database for a matching number, and controls access to the facility.
Another solution from Omnitec is the Signal Ramp SP-143 Detector [3] shown in Figure 7. This device is mounted throughout the parking facility. It constantly monitors the parking spaces for availability and then relays that information to the parking management system. This system then provides parking information in real-time.

In Ireland, there is heavy reliance on industrial size parking management solutions. These solutions often require large startup costs and on-going maintenance. Easy Park Parking Solutions provides some unusual parking management solutions discussed below, to use the limited parking spaces and strict institution policies. Parking Boy Model [4] is a parking space protector designed for disabled, VIP, and designated spaces. The goal here is to make it impossible for an unauthorized vehicle to park in a reserved space. The uniqueness lies in the radio-controlled hoop-shaped bar for individual parking spaces. When a car approaches a parking space, a hand-held radio transmitter lowers the device, as shown in Figure 8. When the car leaves the spot, the device acts like a barricade and prevents unauthorized entry. These are some examples of innovative parking management solutions, which provide policy based parking management addressing a variety of parking needs.

Technology Driven Solutions

These solutions provide parking management using advanced technological innovations. Known for their efficiency, innovativeness, and several economic benefits, in Australia, there are many technology-driven parking management solutions. One of the reasons is the size and uniformity of the highway infrastructure. In addition, a nation of 23 million, Australia has a literacy rate of 99.1%. This, coupled with the significant investments in research and development, makes Australian innovation more productive. Park Mobile International is a technology company that has made clever use of the Australian parking meter infrastructure. The street parking meters in Australia have a unique code. ParkMobile [5] was created as a Smartphone application that allowed the user to pay for parking via their phones. User was required to input the parking meter serial number and the amount of time. The application would then transmit that
information to the city police who would receive instructions not to impose citations to the parked vehicle. S & K Car Park Management Pty Ltd is the maker of SecurePark [6]. Similar to ParkMobile, the key difference is that SecurePark uses a mobile application to locate available parking across the city. It displays available parking on a map based on user’s location, as shown in Figure 9. Its application capability to pinpoint the cheapest available parking in the vicinity is also an option. Similar to SecurePark is a parking management solution called SFPark [7], developed in order to improve the city’s parking facilities in San Francisco. This system also relays real-time parking information to the user’s smartphones, as shown in Figure 10. However, what makes the system unique is the focus on increasing the utilization factor using technology.

They call is demand-responsive pricing. The system responds to bring the supply and demand levels in balance by periodically adjusting meter and garage prices. Demand-responsive pricing encourages drivers to park in underused areas and garages, shifting demand from overused areas.

The abovementioned examples illustrate the use of technology to boost the utilization factor of existing parking capacity. In addition, they also provide efficiency, economic benefits (tangible/intangible), timesaving, and safety to consumers. Technology driven parking management solutions like the ones seen above are new and are gaining popularity with generations after the baby boomers.

**Economic Driven Solutions**

These solutions are motivated by the parking needs and other external economic and environmental factors (such as laws limiting area used by parking spaces). Here the focus is not the use of technology but adherence of the external factors. As an example, the City of Lowell implements AURA [8], a smart parking meter developed by Metric Parking. The primary purpose of this modern parking meter is to prevent theft. The city had a problem of thieves stealing parking meters and therefore implemented this system, which is more secure than traditional coin operated meters. In addition, this meter manages multiple car spaces and accepts multiple modes of payment. Table 2 shows the key differences between traditional and AURA parking meters:
In Turkey, Katopark is a manufacturer of mechanical auto parking lift systems. This manufacturing company sells customized parking management solutions to malls, compact apartment complexes, office buildings, and other institutions where space is limited or restricted. However, these systems are expensive due to the need for customization, regular maintenance, and staff to help parking users. **Puzzle Parking** is a system manufactured by Katopark. This is a parking solution based on stacking the cars on floors on top of each other, as shown in Figure 11. Another solution from the same company is called **Square Parking**. This system is similar to Puzzle Parking however is customized to use the narrow basement spaces to its maximum capacity. The following figure (Figure 12) shows the system that incorporates car elevators.

<table>
<thead>
<tr>
<th>Traditional Parking Meter</th>
<th>AURA Parking Meter</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Price ranges from $362-$700 per meter</td>
<td>1. Cost of one meter is ~$10,000</td>
</tr>
<tr>
<td>2. Accepts one mode of payment (quarters)</td>
<td>2. Accepts multiple modes of payment</td>
</tr>
<tr>
<td>3. Not secure and may be stolen</td>
<td>3. Securely bolts on the ground with Anti-Theft device</td>
</tr>
<tr>
<td>4. One meter for one space</td>
<td>4. One meter for multiple spaces</td>
</tr>
<tr>
<td>5. Inconvenient collection of proceeds, individual meters need to be emptied</td>
<td>5. Armored car from bank collects proceeds from multiple space all at once</td>
</tr>
<tr>
<td>6. Cost of 20 spaces would range $7240 - $14000</td>
<td>6. Cost of 20 spaces would be ~$10,000, the cost of one unit</td>
</tr>
</tbody>
</table>

A cost effective alternative to the above-mentioned
Puzzle Parking and Square parking systems is Easy Park Parking’s **Easy Park VSS** that relies on stacking vehicles. As shown in Figure 13, this system is useful for doubling or even tripling the parking capacity.

**Australian Parking and Revenue Control (APARC):** This Company is a distributor for Parkeon, a company that manufactures high tech parking meters. One of its flagship parking meters is **Strada® NEOPS**. It is different from the AURA parking meter because APARC connects TicketManager™, a handheld enforcement solution to the vehicle sensors, which instantaneously provides the on-duty Parking Enforcement Officer (PEO) with the real-time occupancy status of each parking space. When a vehicle drives into a parking stall, vehicle sensors transmit this information to the back office. This is communicated in real-time to the handheld as a color-coded space list, which the PEO uses to identify the status of each space in a given area. The PEO is then able to quickly target and pinpoint the vehicles in violation [9].

University of Arizona, a state university uses **Radio Frequency Identification (RFID) tags** across its campus parking lots. RFID antennas installed at entrance and exit, as shown in Figure 14, communicate by radio frequency with the tags attached to vehicles. The system sends the tag number to a computer database for verification. Upon successful verification, the system allows entry. University of Massachusetts Lowell uses the RFID based **U-Card**, which eliminates the need to install RFID receivers throughout the parking lots and inside vehicles. The RFID chip is present in the ID card issued to faculty, staff, and students. The ID card is scanned at the entrance and authorized vehicles are permitted inside the parking facility. The campus parking lots use automated entry and exit systems, shown in Figure 15. In addition, at every entrance and exit, there are underground devices (load loops) which detect the presence of a vehicle.

Parking management solutions are most economic-driven solutions. One of the primary factors is the nation’s populations. Based on the data provided by the World Bank, the current population of China is 1.331 billion [10]. In China, there is a serious need for parking
management. The culture in China associates car ownership with high status in society. Therefore, more cars a family owns the higher the status it enjoys within the society. This has led to an explosion of number of vehicles in recent decades. According to a local newspaper, the number of cars in China has reached 100 million [11].

Today China is the most populated country in the world and, with the exponential growth, effective parking management is a keenly serious challenge. A good example of an economic driven parking management solution comes from a Balizhuang (suburb of Beijing) based company. They have introduced a parking space guidance system called Nestca. It was developed to curb the growing problem of a lack of local parking spaces. The web application allows users to view the large number of parking spaces left vacant by the local owners who drive out for work. The website [12] constantly displays available parking spaces as shown in Figure 16. People driving into the town use these vacant spaces. Nestca connects these commuters to the parking owners and provides them a digital map that highlights the rental parking slot’s location in a user-friendly interface and allows searching a spot by locality or rent.

The review of the above-mentioned sixteen solutions demonstrated the additional focus on increasing the utilization rate of parking management solutions. These innovative parking solutions have addressed a wide spectrum of parking related challenges in their own unique ways. The differences in these solutions were present due to several factors such as country of origin, economic and environmental factors, policy factors, and technological factors.

**Advantages/Disadvantages of Innovative Parking Management Approaches**

As seen, parking needs vary across the spectrum. Every condominium complex, business organization, church, school, city, hospital, airport, and subway within a country, for example, has different parking needs. Therefore, to provide an effective parking management solution, there must be a needs analysis of that particular entity. However, all entities that seek effective management solutions could benefit from innovative parking management solutions, which focus on increasing the utilization factor. Table 3 provides a summary of the sixteen innovative parking management solutions discussed above:
Table 3

<table>
<thead>
<tr>
<th>Detection Technology</th>
<th>Known Parking Installations</th>
<th>Advantages/Disadvantages</th>
<th>Types of Facilities</th>
<th>Facility Scale</th>
<th>Maintenance Needs</th>
<th>Installation Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parking Guidance Systems</td>
<td>Emirates Headquarters, Dubai International Airport, UAE</td>
<td>100% utilization rate, efficient, Good for policy-based solutions. Costly installation. Not Scalable</td>
<td>Structure or Surface</td>
<td>Best for large buildings</td>
<td>High</td>
<td>High-varies</td>
</tr>
<tr>
<td>Mobile Car Parks</td>
<td>None</td>
<td>Large parking capacity. Cheaper than permanent parking facilities, Reusable, not scalable</td>
<td>Structure</td>
<td>Large Buildings</td>
<td>Moderate</td>
<td>High-varies</td>
</tr>
<tr>
<td>Automated Number Plate Recognition</td>
<td>The Pearl, Qatar, UAE</td>
<td>Highly secure, Good policy driven parking management</td>
<td>Structure</td>
<td>Small, medium, &amp; large structures</td>
<td>Low - Moderate</td>
<td>Moderate</td>
</tr>
<tr>
<td>Signal Ramp Detector</td>
<td>Shangri-La Hotel, Dubai</td>
<td>Accurate Real-time Space availability, High resource consumption, 1 unit for 1 – 5 spaces</td>
<td>Structure</td>
<td>Large Structure</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Parking Boy Model</td>
<td>Irish Parking Association</td>
<td>Ideal for reserving spaces, None to minimal staffing, Efficient. Costly, 1 unit for 1 space</td>
<td>Surface only</td>
<td>Small to Medium areas</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>ParkMobile</td>
<td>Most cities, Australia</td>
<td>Easy, inexpensive, efficient</td>
<td>Surface</td>
<td>Large Areas - Cities</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>SecurePark</td>
<td>Most cities, Australia</td>
<td>Inexpensive, efficient</td>
<td>Surface</td>
<td>Large Areas</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>SFpark</td>
<td>Prototype in San Francisco</td>
<td>Demand responsive parking, real-time info. Does not cater to non-Smartphone users</td>
<td>Surface</td>
<td>Large Areas - Cities</td>
<td>Moderate</td>
<td>Moderate</td>
</tr>
<tr>
<td>AURA Parking Meter</td>
<td>City of Lowell - downtown area</td>
<td>Covers Multiple spaces, Secure, Accepts all Payment types, Expensive to install, Hard to access during bad weather</td>
<td>Surface</td>
<td>Large Areas - Cities</td>
<td>Moderate</td>
<td>High</td>
</tr>
<tr>
<td>Puzzle Parking</td>
<td>None</td>
<td>Ideal for small areas</td>
<td>Structure</td>
<td>Small Areas/Tall Structures</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Square Parking</td>
<td>None</td>
<td>Ideal for small areas</td>
<td>Structure</td>
<td>Small Areas/Tall Structures</td>
<td>High</td>
<td>High</td>
</tr>
</tbody>
</table>

[Table 3, continued]
Thus, as this review shows, there are several innovative parking management systems, which make good use of information technology (IT) and available resources.

Each of these solutions has certain strengths, which, of course, could be improved, and weaknesses that could be eliminated.

However, the most successful ones are those systems that focus on increasing the utilization factor of the existing parking capacity, such as Nestca, ParkMobile, SFPark, and SecurePark.

These solutions have made a clever use of today’s IT and addressed their unique parking challenges.

In addition to the technologies summarized above (Table 3), Table 4 [13] below provides information on some other innovative technologies and their distinct features:
<table>
<thead>
<tr>
<th>Detection Technology</th>
<th>Known Parking Installations</th>
<th>Advantages &amp; Disadvantages</th>
<th>Types of Facilities</th>
<th>Facility Scale</th>
<th>Maintenance Needs</th>
<th>Installed Costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Induction Loop</td>
<td>Metra (Chicago), MSP airport, Santa Monica, others</td>
<td>Reliable, widely deployed; must be installed below pavement</td>
<td>Surface or structure</td>
<td>Best for portal detection</td>
<td>Low maintenance, can be damaged during excavation</td>
<td>$750 - $1,500</td>
</tr>
<tr>
<td>Magneto-meter</td>
<td>San Francisco, Portland airport</td>
<td>Inexpensive, can be installed in or on pavement, can operate on battery power with wireless connection. One detector needed per space; eventual need for battery or sensor replacement. Flexible, can be installed over right-of-way</td>
<td>Surface or structure</td>
<td>Scalable; typically one detector per space</td>
<td>Battery life approximately five years</td>
<td>$300</td>
</tr>
<tr>
<td>Ultrasonic</td>
<td>Baltimore airport, Munich airport, others</td>
<td>Expensive; power requirements. Effective for measuring speed</td>
<td>Structure</td>
<td></td>
<td></td>
<td>$600 - $1,900</td>
</tr>
<tr>
<td>Passive Infrared</td>
<td>None</td>
<td>Dependent on visibility conditions. Can detect multiple zones;</td>
<td>Surface or structure</td>
<td></td>
<td></td>
<td>$700 - $1,200</td>
</tr>
<tr>
<td>Active Infrared</td>
<td>None</td>
<td>Dependent on visibility conditions. Expensive</td>
<td>Surface or structure</td>
<td></td>
<td></td>
<td>$6,500</td>
</tr>
<tr>
<td>Video</td>
<td>Seattle-Tacoma Airport</td>
<td>Can use existing equipment. Expensive</td>
<td>Surface or structure</td>
<td>Best for small zones or portal detection</td>
<td></td>
<td>$5,000 per unit – up to 30 detectors per camera</td>
</tr>
<tr>
<td>Microwave radar</td>
<td>None</td>
<td>Can detect multiple zones, not weather sensitive. Expensive</td>
<td>Surface or structure</td>
<td></td>
<td></td>
<td>$800 - $3,300</td>
</tr>
</tbody>
</table>
GLOBAL REVIEW OF PARKING SOLUTIONS (EXAMPLES)

Comparative Analysis by Country

<table>
<thead>
<tr>
<th>Solution(s)</th>
<th>Australia</th>
<th>China</th>
<th>Ireland</th>
<th>Turkey</th>
<th>UAE</th>
<th>USA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Secure</td>
<td>Nestca</td>
<td>Parking</td>
<td>Puzzle</td>
<td>Parking Guidance Systems,</td>
<td>AURA, SFPark, RFID Device tags,</td>
</tr>
<tr>
<td></td>
<td>Park, Park</td>
<td></td>
<td>Boy Model,</td>
<td>Parking Systems,</td>
<td>ANPR, Signal Ramp SP-143</td>
<td>RFID ID cards</td>
</tr>
<tr>
<td></td>
<td>Mobile,</td>
<td></td>
<td>Easy Park VSS</td>
<td>Square Parking</td>
<td>detector</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Strada</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td></td>
<td>NEOPS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Approach</td>
<td>Technology</td>
<td>Economic</td>
<td>Policy-Based,</td>
<td>Economic</td>
<td>Policy-Based</td>
<td>Technology, Economic Driven</td>
</tr>
<tr>
<td></td>
<td>Driven</td>
<td>Driven</td>
<td>Economic Driven</td>
<td>Driven</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Population [14]</td>
<td>21.8 million</td>
<td>1.33 billion</td>
<td>4.45 million</td>
<td>74.81 million</td>
<td>4.6 million</td>
<td>307 million</td>
</tr>
<tr>
<td>(World Bank, 2010)</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>(World Bank, 2010)</td>
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</tr>
</tbody>
</table>

Table 5

(A) Vehicle Ownership over Time in 18 Countries

Figure 17 [16] (Wang, Huo, Johnson, & He, 2006)
Comparative Analysis of Traditional vs. Innovative Parking Management Solutions

Innovation and technology are becoming more important as natural resources such as land are dispensed. Increasing the utilization rate is more practical and efficient than increasing physical capacity. Most parking management solutions have not considered the utilization factor. Because of that, they are not using the available resources efficiently. In addition, this type of a setup has several drawbacks:

- Heavy reliance on capacity may lead to high initial and on-going investment costs
- Large capacity requires trained personnel for its maintenance
- Scarce availability during peak hours & underutilized capacity during non-peak hours
- Impact on the environment:
  - Building large parking facilities use precious land and other resources
  - Frustrated users waste fuel trying to locate a parking space

Difficulties Linked to Increasing Utilization Rate

So why do institutions neglect the utilization rate? In the past, parking management providers have ignored the utilization factor. This is because the solutions were designed keeping in mind the capacity. For example, the mall would design the parking lot taking into consideration the traffic during the busiest time of the year. This trend was due to the following reasons:

- **Traditional mindset**: Historically, institutions have addressed the space issue by adding more space. This has been the tried and true method of dealing with the issue. Institutions have devoted large number of resources to address the parking problem
- **Investment for redesign**: Some institutions are trying to increase the utilization factor. However, the resources needed of redesign of a parking solution are seldom too high. Examples are investments in modern technology, knowledgeable staff, etc.
- **Lack of technological knowhow**: Some institutions find it hard to increase their parking utilization rate. This is because they have a traditional mindset and or lack the technological knowhow
### Emerging Common Features/Strategies from Review

**Table 6**

<table>
<thead>
<tr>
<th>Parking Solution</th>
<th>Utilization Rate Focused</th>
<th>Customer-Centric</th>
<th>Easy to Deploy</th>
<th>Life Expectancy</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Parking Guidance Systems</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>~5 years</td>
</tr>
<tr>
<td>2. Mobile Car Parks</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>5-8 years</td>
</tr>
<tr>
<td>3. Automated Number Plate Recognition</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>5-6 years</td>
</tr>
<tr>
<td>4. Signal Ramp Detector</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>3 years</td>
</tr>
<tr>
<td>5. Parking Boy Model</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>5-6 years</td>
</tr>
<tr>
<td>6. ParkMobile</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>&gt;20 years</td>
</tr>
<tr>
<td>7. SecurePark</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>~5 years</td>
</tr>
<tr>
<td>8. SFPark</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Data Unavailable</td>
</tr>
<tr>
<td>9. AURA meters</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>~12 years</td>
</tr>
<tr>
<td>10. Puzzle Parking</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>&gt;20 years</td>
</tr>
<tr>
<td>11. Square Parking</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>&gt;20 years</td>
</tr>
<tr>
<td>12. Easy Park VSS</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>&gt;20 years</td>
</tr>
<tr>
<td>13. Strada NEOPS</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>~12 years</td>
</tr>
<tr>
<td>14. RFID Tags</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>&gt;20 years</td>
</tr>
<tr>
<td>15. RFID Cards</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>&gt;20 years</td>
</tr>
<tr>
<td>16. Nestca</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>&gt;20 years</td>
</tr>
</tbody>
</table>
Table 6 above provides a representative list of sixteen parking management solutions. Innovative parking management strategies around the world either are one of the solutions mentioned above or are some variation of the same. Furthermore, the table shows how the solution providers have shifted their focus in terms of addressing the longstanding parking challenges. Out of all parking solutions reviewed in this paper:

- 68.7% of the solutions have focused on increasing the utilization rate
- 81.2% of these solutions are customer-centric
- 56.2% have a life expectancy of more than ten years

The data in Table 6 indicates that even though the parking management solutions are very different in their operation and implementation, they share some common strategic goals. These goals include but are not limited to:

- Boosting the utilization rate
- Being increasingly customer-centric
- Leveraging innovative technology to:
  - Reduce costs
  - Facilitate ease of use
  - Increase life expectancy

CONCLUSION/FUTURE DIRECTION

The versatility of the innovative parking solutions allows tremendous flexibility when implementing the various parking management solutions. There are a few ways the approach may be improved:

- Developing hardware, which is cost-effective, would be a major improvement. Due to the current high investment, costs associated with real-time parking related hardware such as sensors, RFID chips, etc. are high
- Reducing the costs associated with on-going maintenance would also help bring the cost down and therefore lead to wide acceptance
- Researching ways to increase the system uptime and study parking trends more efficiently will help make this model better

The innovative parking solutions approach has a wide range of applications. This approach may be applied in many types of scenarios such as university parking lots, street parking, airport parking, commercial car parks, etc. Of course, minor alterations to the required hardware are needed but the core functionality remains the same. Many would benefit from the use of this approach, local governments, universities, medical Institutions and finally the public.
REFERENCES


