WPT2

Innovative Tools to increase acceptability and effectiveness of low-carbon mobility policies for city centres.

Activity A.T2.1

Design and development of tools supporting Parking Regulation Schemes selection and implementation.

Transnational review for smart parking solutions

Version 1
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List of Acronyms, Abbreviations and Symbols

ANPR	Automatic Number Plate Recognition
ACPO	Association of Chief Police Officers
CCTV	Closed Circuit Television
CW	Continuous Wave
FMCW	Frequency Modulated Continuous Wave
FUA	Functional Urban Area
ILD	Inductive Loop Detector
ITS	Information Transport Systems
LEZ	Low Emission Zone
NAAS	National ACPO ANPR Standards
PT	Public Transport
RTI	Real Time Information
RPP	Residential Parking Permits
SUMP	Sustainable Urban Mobility Plan
VMS	Variable Message Signs
VRM	Vehicle Registration Mark
WIM	Weight In Motion

Terminology:

SMART ON STREET PARKING SYSTEM

system that provides anonymous detection of parking space occupancy and payment enforcement; it consists of smart on street parking detection system and payment supervision system

PAYMENT SUPERVISION SYSTEM

system that integrates all the enforcement and services related to payment, e.g. ANPR camera based enforcement, staff enforcement, parking app etc.

1 Foreword

This review identifies core smart parking principles and illustrates how smarter parking management can decrease car traffic in cities, benefit consumer in travel time, while also lead to more livable, attractive communities. Smart Parking brings together all aspects of parking management technology into one integrated system, from sensor-based vehicle detection, communication gateway, informative boards, kiosks for payments, mobile application for drivers and information system, simplifying the life of the system manager. Thus it is a parking management solution in real time, which collects key performance data and translates them into knowledge to make better policy and optimised management.

<u>Get inspired by succesful low carbon mobility strategies</u>

There are several very good examples of solving an overall strategy for parking in the city – Copenhagen urban planning decreasing up to 2 % of parking spaces in the centre of the city every year, San Francisco SF Park with smart parking technology deployment supported with third parties´ mobile apps profiting from open data city portal, Amsterdam with big savings in operation delivering the possibility to pay for parking only as two options – pay by a mobile app or pay a residential permit. The enforcement is then made with ANPR cameras mounted on enforcement cars which compares the readings with a common database. Also the mechanisms of transparency in using the parking payments are also well experienced e.g. in Oslo toll ring where a fix rate of 20 % of the money collected is directly invested in public transport enhancement. Another good example is SF park where a fix rate of the parking payments is reinvested in the place where it was collected so it is visible for citizens. (*For more information please see Annex I_Case studies)*

2 How to use the document

The aim of this review is to help SOLEZ partners involved in the development of Smart Parking Tool. Particularly in these areas:

- increase capacity of information about smart parking technology,
- build the capacity for followers who want to implement a similar system with the knowledge required to help to alleviate parking problems, and build political arguments to support them,
- identifies level of detection to prioritize within the context of each FUA,
- identifies most suistable detection technology for each FUA,
- identifies most appropriate communication option for each FUA.

Therefore this review is structured in the following way:

- Chapter 3 describes specific Parking Management strategies prioritized within the context of the goal of each Function Urban Areas (FUAs) and briefly identifies how they can be implemented. The next guide will describe and evaluate more details.
- Chapter 4 provides review of parking detection technology and increasing capacity information about suistanable detection technology for each FUA. The next guide will identify main producers. It also provides a review of communication options.
- Chapter 5 describes pricing/ tariffs options for smart parking solutions.
- Chapter 6 specifies minimum system requirements.
- Annex I provides case studies on smart parking systems.
- Annex II provides use cases of different smart parking tools.
- Annex III provides more technical in-depth information about ANPR cameras.

At the start of the SOLEZ project each of the FUA picked up one or two tools for implementation to address transport and emission related problems. In case of smart parking tool, where CDV is responsible to guide and help FUAs in the process of implementation, 5 FUAs specify the target goals which they want to achieve. They are listed in the table below.

FUA	Goal to be achieved
ŽILINA	Increase efficiency in parking usage and reduce path lenght for parking place searching
DUBROVNIK	Effective usage of on street parking detection solutions in LEZ framework
VICENZA	Effective usage of on street parking detection solutions in LEZ framework
GDANSK	Improve parking and access control to increase the LEZ effectiveness
BRNO	Parking related solutions to promote PT usage

Table 1: List of Functional Urban Areas goals

2.1 General info

Smart parking can be defined broadly as the use of advanced technologies to help motorists locate, reserve, and pay for parking. Smart parking management systems may provide a cost-effective tool to address short term parking constraints at transit stations. These smart parking systems typically provide real-time information via variable message signs (VMS) to motorists about the number of available parking spaces in park-and-ride lots, departure time of the next train, and downstream roadway traffic conditions (e.g. accidents and delays).

To efficiently control parking the overal information should be available: how much the parking space is occupied, at what time of the day, how long, how many cars use a particular spot a day, etc. To gain such information theres should be a technology enabling on-line monitoring of occupancy of a parking area or a particular spot. Such a technology is a smart onstreet parking system.

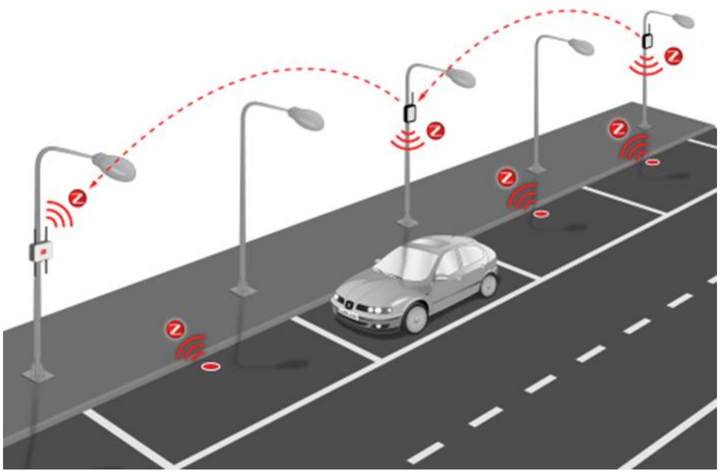

Figure 1: Smart parking solution example, source: Libelium

Smart parking is a modular system (it is extendable anytime)

To learn the interest about a particular parking place which should define the price for parking (performance charging) a smart parking system is used. It works on deployment of sensors detecting the occupancy of every parking place. The occupancy information is collected continuously in the long term which enables parking policy to flexibly react on the demand and specify parking areas with lower or higher prices. The rule to specify the right price consists in setting such a price that assures that not every parking spot is occupied. If fully occupied the drivers are forced to look for an empty space and this provides about 30 % residual traffic burden increase which cause extra noise and emmission pollution. The system enables to identify empty parking spaces and navigate drivers there through an in-vehicle system, via a mobile app or by a network of variable message signs.

The system also provides valuable information to the police enforcement. No to pay for parking becomes very hard and such drivers are dicovered. This points out the key target of the systém deployment – that to travel by car is always more expensive than to travel by public transport. This motivates people to use public transport, cycling, car sharing or car pooling and fulfils the goals of low carbon mobility policy.

The city gains by the tool deployment an immense potential for own traffic regulation and control improvement but also for urban planning. It also gains knowledge what territories will be prioritized, e.g. where the transfer of cars from on street to parking houses take place, at what time of the day the tarrif will be the highest, how to set up efficient enforcement regarding the level of the fines as well as its processing (information about possible fine in paper block at the windscreen, physical inhibitor, physical replacement of the vehicle)

2.2 Decision making process

Each of the project FUA that will adress transport and emissions related problems through smart parking tool, need to go through several steps which will help them to identify the best possible sollution which will fit best to their specific needs and overall conditions. First of all it is necessary to pick one or several objectives / goals which will fit the best the goal which is set (in application form) and need to be achieved within the SOLEZ project. Than the FUA should choose the propper approach/strategy (those are explained in chapter 3). Lastly according to the scale and target purpose of the smartparking solution, each FUA should choose the level of detection and used detection technology with proper communication (Analysis in chapter 4).

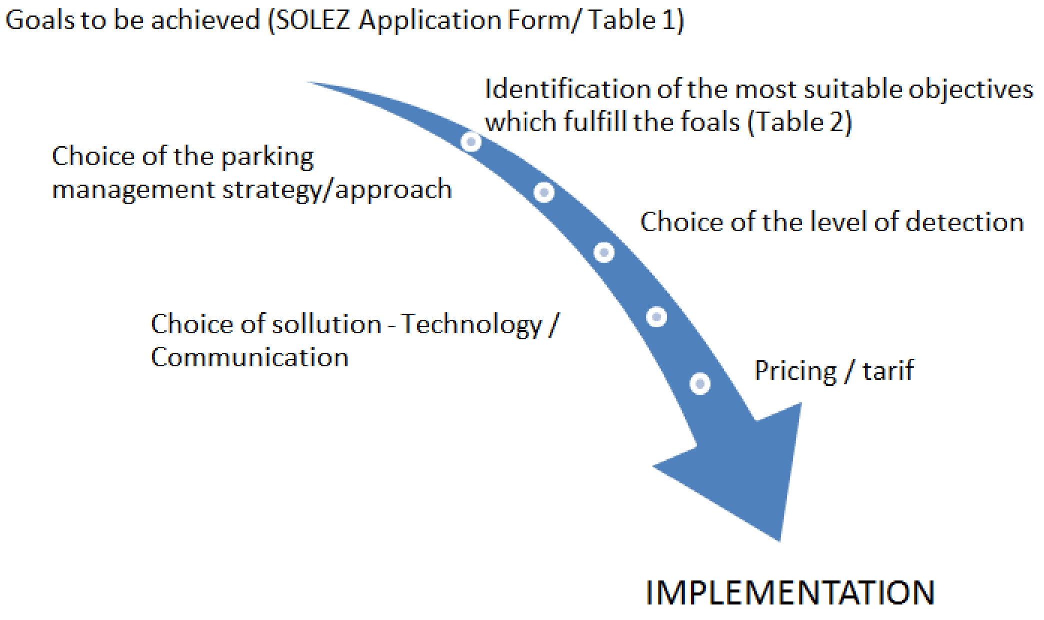

Figure 2: Decision making proces, source: CDV

Goals	Objectives	Functional requirements
Efficiency of parking facilities	Operate facilities as a system	Share real time information on parking availability from various stations with a central server
		Provide information on a nearby parking facilities when the closest facility is full
	Increase efficiency of facility staff	Provide real time availability to staff at each parking facility
		Provide staff with ability to adjust or correct real time information if they observe differencies
	Navigate cars to free parking facilities	Provide signage approaching each facility with the number of available spaces
		Provide signage approaching each facility with directions to nearest lot with spaces available
		Measure number of spaces available at a given time

	Real time information availability	Maintain database information with parking availability and pricing structure information
		Calculate the number of available spaces at a given time (estimation)
Improve customer satisfaction	Navigate cars to free parking places	Provide signage to open spots in each aisle and level when not readily apparent
	Prevent cars entering full parking facilities	Provide information to drivers regarding availability of spaces
		Keep entrance gate close when parking is full
		Provide greater ability to reserve parking spaces
Efficiency of payment system	Have complete updated pricing information	Maintain database information with parking availability and pricing structure information
Sharing RTI	Coordination with other traffic management and traveler information systems	Make real time parking information available to regional/national traffic/transport infromation systems
		Maintain database information with parking availability
		Maintain data archive with historic parking information

Table 2: Summary of goals, objectives and functional requirements, source: (1)

Decisions	**Options**	
Aproach	• Brick and mortar • Preferential parking • Price discounts • Change mode	• Disincentives • Satellite parking • Shared parking
Strategy	• Policy based solutions • Technology driven solutions • Economic driven solutions	
Level of detection	• Full • Entry / Exit • Occupancy / Presence • Movement detection	
Detection technology	In-roadway	Off-roadway
	• Inductive loops • Magnetic	• Ultrasonic • Microwave

	• Pneumatic road tubes • Piezoelectric • WIM detectors	• Infrared – passive, active • Videodetection • Acoustic
Data communication	• Wireless • Cable • Fibre	
Pricing	• Pass • Time-coded tickets • Single-space meters • Smart meters • Pay Box • Pay & Display meters • Per-space meters	• In-vehicle meter • Attendant • Valet • Controlled access • Automatic vehicle identification • Global location technology

Table 3: Decision making options, source: CDV

3 Parking management

3.1 Introduction

Parking management refers to policies that result in efficient use of parking resources aimed at making better use of available parking supply. These definitions are very broad. However, for a parking management strategy to be effective in solving parking problems, the following must be true:

- A comprehensive needs analysis of the facility must be conducted
- A small scale prototype be deployed and the findings carefully analyzed

When appropriately applied parking management can significantly reduce the number of parking spaces required in a particular situation, providing environmental benefits and get the city for people. Parking management includes several specific strategies: nearly 7 main are listed in table bellow and describes more deeply Parking Management strategies prioritized within the context of the goal each Function Urban Areas (FUAs)

3.2 Existing strategies/ solutions

Effective parking strategy relies on a specific type that meets the needs of a system or a combination thereof.

APPROACH	SPECIFICATION
Parking regulations	strategy that increase parking facility efficiency; regulations that favor higher-value uses such as service vehicles, deliveries, customers, quick errands, and people with special needs
Park sharing	strategy that increase parking facility efficiency, sharing available parking spaces
Pricing Methods	strategy that reduces parking demand; charge motorists directly for using parking facilities, with efficient prices that include lower rates during off-peak periods and higher rates during peak times and locations; use better charging techniques to make pricing more convenient and cost effective
Improve enforcement and control	strategy ensuring that parking regulation enforcement is efficient, considerate and fair
Improve user information	support strategy; provide convenient and accurate information on parking availability and price, using maps, signs, brochures and electronic communication
Change mode	Support strategies for park-and-ride services. For prompt location of a parking space and usage of PT for the rest of the journey.

Table 4: Overview of parking management approaches, source: 2

3.2.1 Parking regulations

Parking regulations control who, when and how long vehicles may park at a particular location, in order to prioritize parking facility use and situation. There are three general steps for development:

1) Rank parking facility use priorities.
    - deliveries and service vehicles,
    - rideshare and electric vehicles,
    - customers, tourist and visitors,
    - employees and residents.
2) Choose appropriate regulations to favor the higher-priority activities.

TYPE OF REGULATION	DESCRIPTION
Density of emmission	restriction of emission value
Duration	limit parking duration
Time period restriction	restrictions at certain times, such as before 10 a.m. to discourage commuters; or 10 p.m. to 5 a.m. to discourage residents
Residental parking permits	Residential Parking Permits (RPPs) to give area residents priority use of parking near their homes.
Restrict overnight permit	Prohibit overnight parking to discourage use by residents and campers.
Special use parking	User preferences and limitations
Arterial lanes	Prohibit on-street parking on arterials during peak periods, to increase traffic lanes.

Table 5: Description of types of regulation

3) Determine how regulations will be indicated and enforced

Specific smart strategy for implementation:

Regulation scheme	Technology	Case studies
• smart on street parking • urban logistics regulation • residential parking • user preferences and limitations • city traffic regulation • statistics (historical data)	• detectors for parking spaces occupancy • Mobile Enforcement App	• SFpark, San Francisco, USA (Case 1) • Fastprk, Moscow, Russia (Case 2) • Nice, France (Case 10)

Figure 3: Proposed regulation scheme, technology and case studies examples – Parking regulation

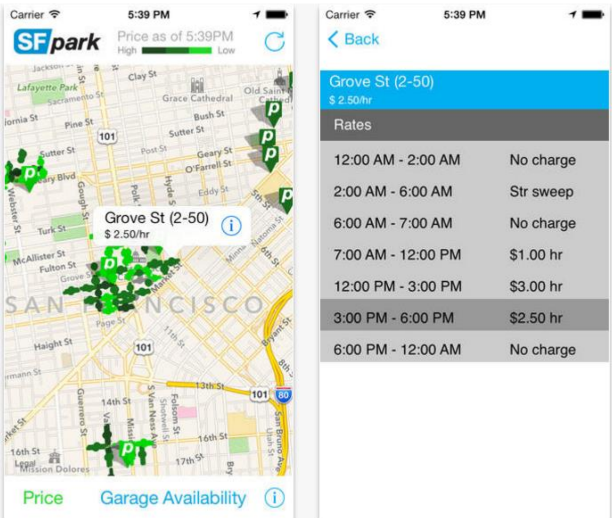

Figure 4: Example of smart parking mobile application, source: SF Park

Case: City traffic regulations

Zone traffic limitation/ LEZ

A city XY has deployed its ZTL/LEZ strategy with the aim to reduce carbon emission in the city centre. Using a special personalised mobile app every driver authorizes his/her parking and the end price for parking is derived from the vehicle he/she has come by. Not only the type of fuel and engine displacement but also the vehicle dimensions could be regarded in the price model as a city can promote clean and small vehicles in the central part of the city. Also the meteorological information could be influencing. The price model is so calculated within the app and presented to the driver within the navigation interface.

3.2.2 Park sharing

The new concept of park sharing may bring some additional positive effects and benefits. Shared Parking means that a parking facility serves multiple users or destinations. Spaces can be shared with private car parks managed by operators through online platforms, increasing the overall parking supply in cities.

There are some specifications:

- *share spaces within a parking lot* - motorists share parking spaces rather than being assigned reserved spaces,
- *share parking among destinations* - parking can be shared among multiple destinations; for example, an office building can share parking with a restaurant or theater, since peak demand for offices occurs during weekdays, and on weekend evenings for restaurants and theaters,
- *public parking facilities* - public parking, including on-street, municipal off-street, and commercial (for profit) facilities generally serve multiple destinations; converting from free, single-use to paid, public parking allows more efficient, shared use,
- *special parking assessment* - businesses in an area can be assessed a special assessment or tax to fund parking facilities in their area, as an alternative to each business supplying its own facilities. This is often implemented through a downtown business improvement district.

Specific smart strategy for implementation:

Smart regulation scheme	Technology	Case studies
• online platforms for invoicing • real time detection of free parking space • smart payment system	• vehicle detection sensors • Mobile Enforcement App	• Florence, Italy (Case 8)

Figure 5: Proposed regulation scheme, technology and case studies examples – Park sharing

3.2.3 Parking Pricing

Parking pricing can be implemented as a parking management strategy (to reduce parking problems), as a mobility management strategy (to reduce transport problems), to recover parking facility costs (so people are not forced to subsidize parking facilities they do not use), or to raise revenue for any purpose (such as funding local transport programs or downtown improvements). It is often intended to achieve a combination of objectives.

Rates should be set to optimize parking facility use, called performance-based pricing, which means that about 15% of parking spaces are unoccupied at any time, so drivers can usually see a parking space near their destination. Discounts can be set according to the emission class of the vehicle, or according to the type of vehicle (electric, hybrid).

Parking pricing implementation can be technically and politically difficult, so it is often best to establish long-term policies and plans that incrementally expand when and where parking is priced (for example, a city council may set a goal of pricing four additional blocks of on-street parking each year, slowly expanding from the city centre core outward into nearby streets), raise rates to efficient levels.

The objective is reward drivers of cleaner vehicles, whilst discouraging high polluters from entering city centre. It is also important to start with support policies, such as development of a Sustainable Urban Mobility Plan (SUMP).

Various methods can be used to price parking which differ in their costs, convenience and adjustability as summarized in Table 6. Newer electronic systems tend to be more convenient (they accept a wider variety of payment options, including coins, bills, debit and credit cards, and telephone payment, and only charge for the amount of time a vehicle is actually parked) and allow more price adjustability (prices can vary by location, time of day or week, and vehicle type), and so can be more efficient and equitable.

Type	Description	Capital costs	Opera-ting costs	User conve-nience	Price Adjust-ability	Enforce-ability
Pass	User purchase and display a pass.	Low	Low	Medium	Poor to medium	Good
Time-coded tickets	Parkers purchase a punch-card for a certain amount of time.	Low	Medium	Medium	Medium	Good
Single-space meters	Parkers prepay a mechanical or electronic meter located at each space.	High	High	Mechanical : low; Electronic: medium	Mechanical : poor; Electronic: good	Mechanical : poor; Electronic: good
Smart meters	Parkers prepay electronic meters, which automatically reset when vehicles leave.	High	High	Medium	Good	Good
Pay Box	Parkers prepay into a box with a slot for each space.	Low	Medium	Low	Poor to Medium	Poor
Pay & Display meters	Parkers prepay a meter, which prints a ticket that is displayed in their vehicle.	Medium	Medium	Medium	Mechanical : poor; Electronic: good	Good
Per-Space meters	Parkers pay for a specific space using electronic meters.	Medium	Medium	Medium	Very good	Good
In-Vehicle Meter	Parkers display an electronic meter inside their vehicle when parked.	Medium	Low	High	Moderate	Good
Attendant	Parkers pay an attendant when entering or leaving parking lot.	High	High	High	Good	Good
Valet	Parkers pay an attendant who parks their car	Low	High	High	Good	Good

Controlled Access	Parkers pay a machine when entering or leaving parking lot	High	Moderate	Medium	Good	Poor
Automatic vehicle identificatio n	System automatically records vehicles entering and leaving a parking area	High	Medium	High	Good	Good
Global location technology	Satellite-based systems automatically tracks parking use and calculates parking fees.	High but declining	High but declining	High	Very high	Good

Table 6: Parking pricing methods, Source : (2)

Specific smart strategy for implementation:

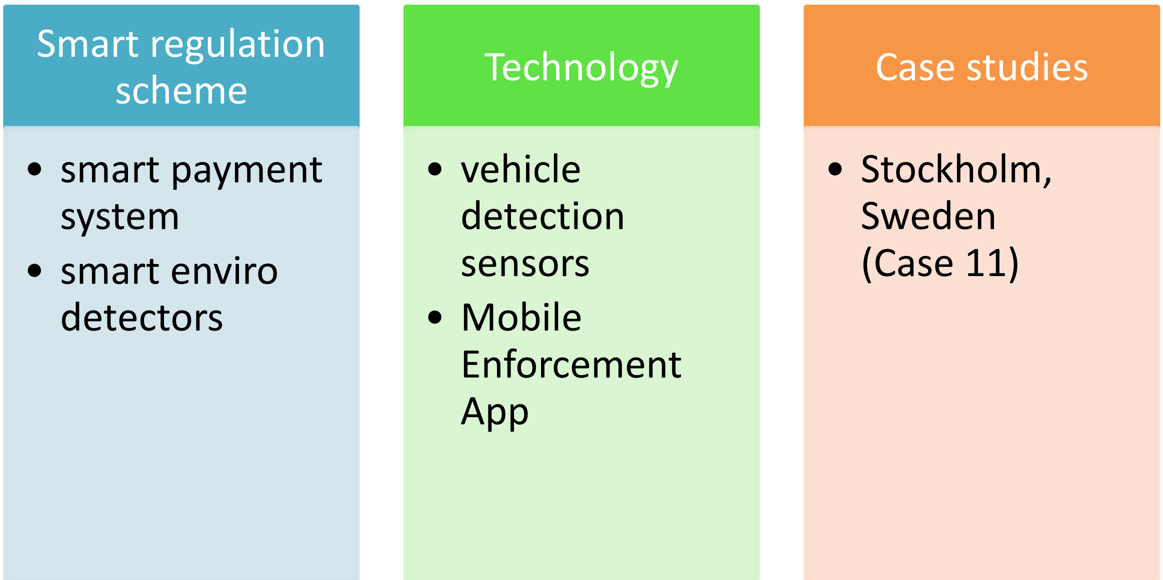

Figure 6: Proposed regulation scheme, technology and case studies examples – Parking Pricing

3.2.4 Improve Enforcement and Control

To be effective and politically acceptable, the enforcement process – from identification of the offence to follow up, appeals against penalties and debt collection – must be perceived as efficient, considerate and fair. Better user information and newer pricing methods can help address these problems, reducing violations. It may be appropriate to have exemptions to parking regulations and fines.

New, hand-held data systems allow enforcement officers to track individual vehicles, identifying those that overstay (for example, commuters who feed meters), and habitual violators (motorists who ignore numerous parking regulations). It is important to have a system to collect outstanding parking fines.

Specific smart strategy for implementation:

Smart regulation scheme	Technology	Case studies
• smart on street parking • residential parking	• vehicle detection sensors • Mobile Enforcement App	• Las Vegas, USA (case 6)

Figure 7: Proposed regulation scheme, technology and case studies examples – Improve Enforcement and Control

3.2.5 Improve User Information

User information refers to information for travelers about parking availability, access regulations and price, and about travel options, such as walking, ridesharing and transit. Many parking problems result in part from inadequate user information. User information can be provided by signs, maps, brochures, websites, and electronic guidance systems.

Advanced parking management systems that provide real-time information on parking availability and price can increase usage of on street parking.

Specific smart strategy for implementation:

Smart regulation scheme	Technology	Case studies
• smart on street parking • urban logistics regulation • residential parking • user preferences and limitations • city traffic regulation • statistics (historical data)	• vehicle detection sensors • parking management software	• Westminster City Council - London (Case 3) • Gliwice and Lodz, Poland (Case 4) • Rome, Italy (Case 5) • L'Escala, Spain (Case 6)

Figure 8: Proposed regulation scheme, technology and case studies examples – Improve User Information

3.2.6 Change mode

Park-and-ride (P&R) involves car parks with connections to public transport that allow commuters and other people travelling to city centres to leave their vehicles and transfer to a bus, rail system or carpool arrangement for the remaining part of the journey. Objectives of this approach are:

- to optimise the use of suitable space by static traffic using ITS;
- to change the ratio between individual and public transport in favour of public transport;
- to reduce vehicle km travelled and therefore air and noise pollution;
- to shiftparking away from centres areas reducing congestion and demand for parking freeing up land for other uses;
- to minimize disruption to local residents and businesses from informal on-street parking

Specific smart strategy for implementation:

Smart regulation scheme	Technology	Case studies
• real time information about empty spaces • real time information about trafic situation • connected to PT paying platform • connected to PT information system	• smart detectors • cameras	• Barcelona, Spain (Case 12)

Figure 9: Proposed regulation scheme, technology and case studies examples – Change mode

3.3 Generic outline for a Parking Management Plan

Define the Scope

Define the implementation zone. Parking planning can be performed at the site, street, district/neighborhood and regional scale.

Define Problems

Consider types of parking problems, such as high costs of providing parking facilities, inadequate user information, inconvenient pricing methods, inconsiderate enforcement, difficulties for walking between parking facilities and destinations, inadequate security, and unattractive parking facilities.

Technological implementation

Parking ticket vending machines have to be adapted to be able to deliver differentiated prices and recognise environmental tokens. The suitable areas for smart parking should be defined, piloted and scaled.

Organisational implementation

The city should empower an organization that is to manage the parking management system consisting of detection, communication, information and payment infrastructure including communication tools like a web for resident parking vehicle registration.

Marketing

Drivers needed to be aware of the new system. A robust information campaign should be considered.

How can be beneficiary parking management plan for access restriction policies?

The policy implementation should at least some of these arguments:

- increasing the acceptability of proposed interventions for private stakeholders and citizens
- supporting the effectiveness of policies to limit traffic in and to/from the city centers
- finding empty parking spaces and decrease the need for cruising
- enabling local authorities to influence urban mobility towards a cleaner, cost-efficient and
- providing energy savings in transport.

4 Detection technologies

Smart parking systems generally require some way of determining the location of parked vehicles within a parking area. Simpler systems may only detect entry to and exit from a facility, while systems that are more complex can identify position and movement within the parking area, either to general zones and floor locations or to a single space. This information can then be used to calculate remaining capacity and/or guide vehicles within the parking area.

4.1 Type of detectors

4.1.1 In-roadway

In-roadway detectors (intrusive) need to be built into the road surface. They are located on or below the surface of the road. In-roadway detectors was the most common type of detectors used in the past due to their advantages such as resistance to weather conditions (fog, rain, snow), reliability, accuracy. On the other hand there are also several disadvantages such as complicated instalation (cutting the road), possibility of damage (snow removal, road reconstruction), complicated maintanance or service that requires lane shutdown.

4.1.1.1 Inductive loop detectors

Inductive loop detectors (ILD) are still the most widespread type of detectors. They determine the presence of a vehicle by noting a disturbance in the magnetic field generated by the loop (electromagnetic induction). They generally detect presence only, though loops in sequence can be used to determine direction of travel or speed. Its architecture is very simple and also the function is fully reliable (assuming the correct instalation). It consist of an induction loop, proprietary derector and an analytical unit. The most common places for usage of loop detectors are those with long-term need of traffic information (speed, type and lenght of the vehicle, intensity):

- Highways (lane ocupancy)
- Parkings (Entrance and Exit count)
- Traffic lights (demand control system)

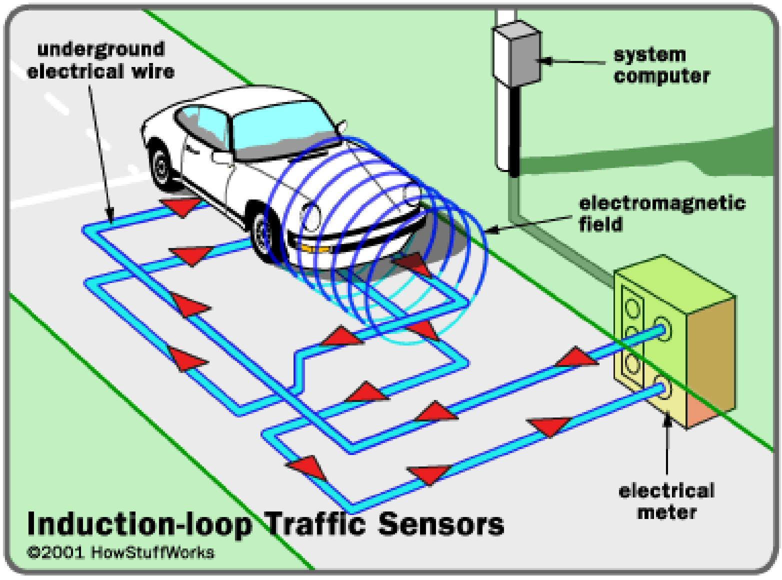

Figure 10: Principle of inductive loop, source: (5)

4.1.1.2 Magnetic detectors / Magnetometers

Magnetometers detect a local disturbance in the earth's magnetic field caused by a vehicle. Magnetometer capability is similar to loop detection but can be used in locations where loop detection cannot be used, such as on steel bridge grates. The magnetic detectors can be buried under the ground level of the pavement which makes them invisible for vandals or glue up on the road. The proper calibration of every detector is crucial for detection reliability level.

Magnetometers are typically used with other forms of detection such as infrared to reduce the possibility of false detection. It cannot be used in a certain latitudes (around magnetic equator), where angle of magnetic field is to low.

Figure 11: Magnetic in-roadway detector, source: (6)

4.1.1.3 Pneumatic road tubes

Pneumatic road tube detects vehicle via the air pressure created which closes a switch, producing signals when a vehicle pass or stop over the tube. (4) While it offers a low cost solution as well as quick instalation and easy maintenance, it has its disadvantages. Inaccuracies in axle count are also bound to happen when bus and truck numbers are high. In addition, the tubes are prone to vandalism.

Figure 12: Pneumatic road tubes, source: (8)

4.1.1.4 Piezoelectric

Piezoelectric sensors are made from specially processed material that is able to convert kinetic energy to electrical energy when subjected to vibration or mechanical impact. Vehicle differentiation can also be conducted with extreme precision as additional information is gathered rather than the passing of vehicle alone. It also provides a more accurate reading on vehicle speed and classification of vehicles based on weight and axle spacing. Among the disadvantages would be the need to use multiple detectors to instrument a location and it is also extremely sensitive to high temperature and traffic stress.

Figure 13: Piezoelectric detector, source: (9) (10)

4.1.1.5 WIM senzors

Wieght-in-motion (WIM) senzors are able to detect the weight of the vehicle whereby the data acquired are extremly useful to highway planner, designers and law enforcement agencies. The four technologies used in WIM system are: bending plate, piezoelectric, load cell and capacitance mat.

4.1.1.6 Infrared detectors – passive

Passive infrared sensors identify the occupancy status of a parking space by detecting changes in the energy emitted by the vehicle and the roads. While the sensors are able to be implemented in a multizone environment to measure vehicle speed, the sensitivity of the sensor is reduced in heavy rain, snow, leaves or dense fog. A single detector can be configured to process multiple zones, reducing the cost per lane or space.

Figure 14: Example of an infrared detector installation, source: (12)

4.1.2 Off-roadway

Off- roadway detectors (non-intrusive) don´t require any comlicated instalation into the roadway surface (cutting, digging) so their usage greatly reduce the risk of detector damage during construction works or road maintanance (recontruction, snow removal). Undisputed advantages are easy installation/removal, the ability to easily move detectors, detection of multiple lanes with one detector, or longer service life. The disadvantage of these detectors is their lower reliability in bad weather conditions (rain, fog, snow) or the need to place the detector on a higher place above the ground.

The principle of non-intrusive detectors is to record the presence of a vehicle by means of electromagnetic or mechanical waves or by video recording (subsequent image processing).

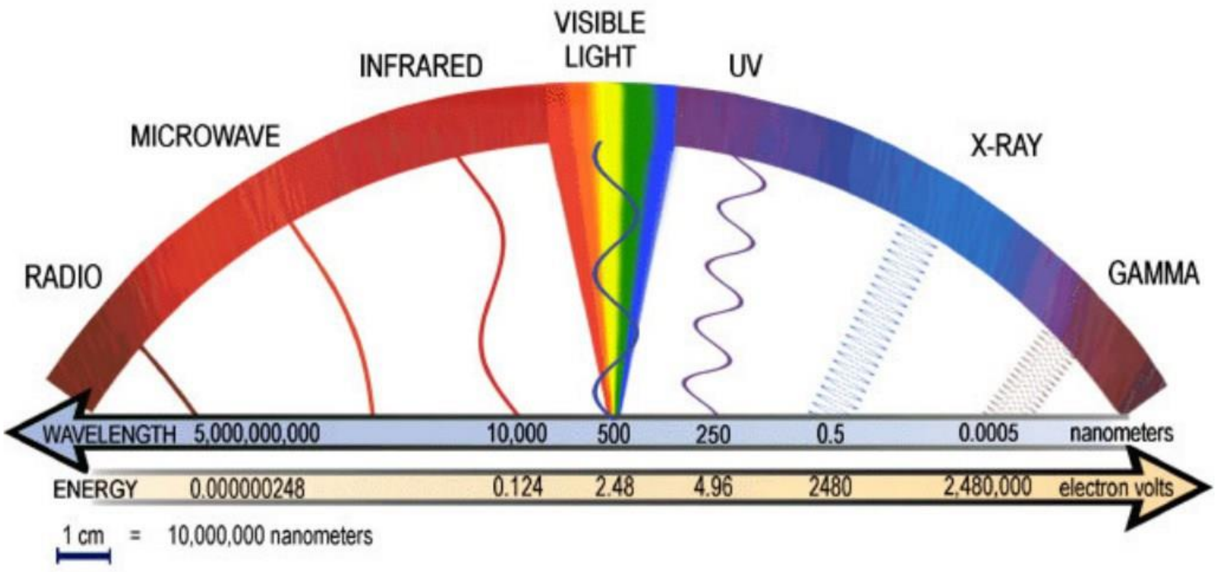

Figure 15: Electromagnetic spectrum, source: (11)

4.1.2.1 Ultrasonic detectors

Ultrasound detectors use a sonar-like sound pulse (25 – 50 kHz) to determine the presence of a vehicle. The detectors are calibrated with the known distance from detector to pavement and can then note a difference in echo time to determine the presence of a vehicle. Detector performance can be impacted by extreme wind and temperature, although newer detectors can adjust for temperature fluctuation. After induction loops, ultrasonic detection is likely the next most commonly used technology for advanced parking applications and are mainly devoted for interior use usually in parking houses.

Figure 16: Ultrasonic detector, source: (12)

4.1.2.2 Microwaves detectors

Microwave radar senzor transmits energy (1-30 GHz) through an antenna and detects vehicle by the energy reflected back towards the antenna. There are two types of microwaves antennas:

- Frequency-modulated Continuous Wave (FMCW)
- Continuous wave (CW)

Microwave radar systems are widely used in highway applications but are capable of detecting vehicle presence, as well as traffic speed and volume. FM/CW radar systems are somewhat costly but are generally unaffected by weather. A single unit can be configured to detect across up to eight adjacent zones. Among its disadvantages is that the Doppler sensors would have to be equipped with auxiliary sensors in attempt to detect stopped vehicle. (4)

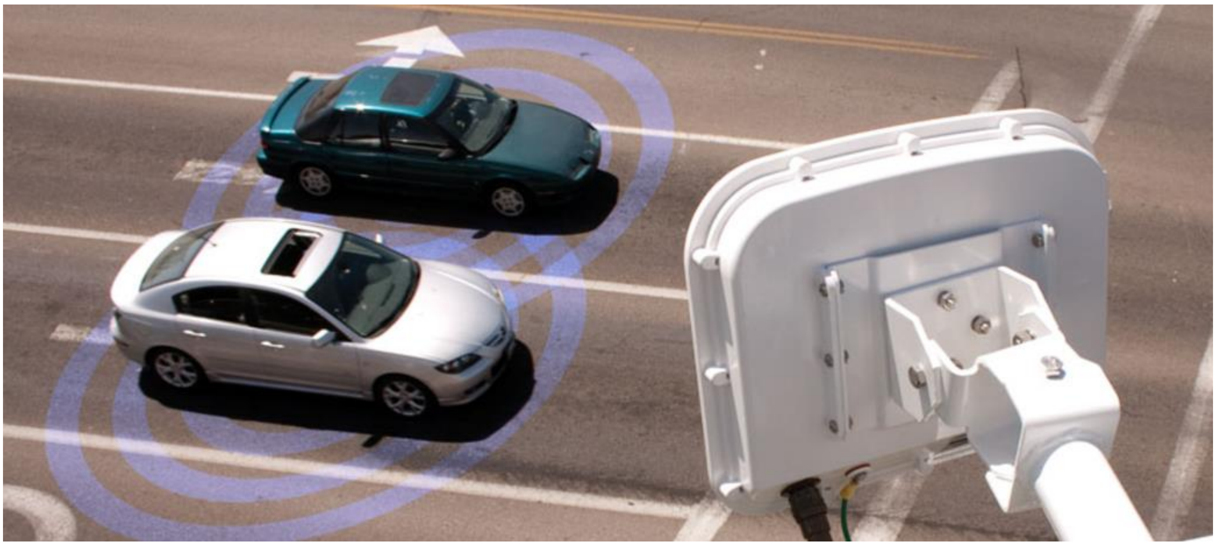

Figure 17: Microwave smart sensor, source: (13)

4.1.2.3 Infrared detectors – active

Active infrared systems work on similar principals to passive infrared systems, but illuminate the detection areas with beams of infrared light. By comparing the reflected beam against the known reflectivity of the pavement surface, vehicles can be identified and classified. By utilizing the active infrared detectors, multiple lane operations can be conducted. For an accurate measurement of vehicle position, speed and class, multiple beams are transmitted from the detector. Disadvantage of the detector would be its sensitivity to weather conditions such as fog or blowing snow which affects the operation and reliability.

4.1.2.4 Videodetection

Video detection uses video cameras in conjunction with video image processors to generate a stream of digital information from the camera. Careful analysis of continuous frames captured by the video image processor can be used in detection of vehicles as it reveals the differences between subsequent frames.

A system may be configured around a number of zones identified in a single camera's field of view, enabling one camera to provide information for as many as four adjoining zones. For best performance, the video cameras should be placed up to 50 feet above the surveyed zones. Lighting variations over the course of the day can impact system performance.

Figure 18: Overall ANPR system, source: CDV

Video detection equipment is relatively expensive and is generally considered cost effective only when multiple zones must be monitored. An additional degree of cost effectiveness could result if an existing video monitor system is already being used and maintained for security surveillance or other purposes. Video detection systems are used widely for traffic and security monitoring.

For more technical information about this topic see *Annex III: ANPR Standards & Requirements*.

4.1.2.6 Acoustic sensors

The acoustic sensors detects vehicle via the acoustic energy or audible sounds produced by the vehicle through microphones installed for vehicle detection. The advantages are support for multiple lane operation as well as passive detection. This type of detector is not recommended for detection of slow moving vehicles or in a stop and go traffic.

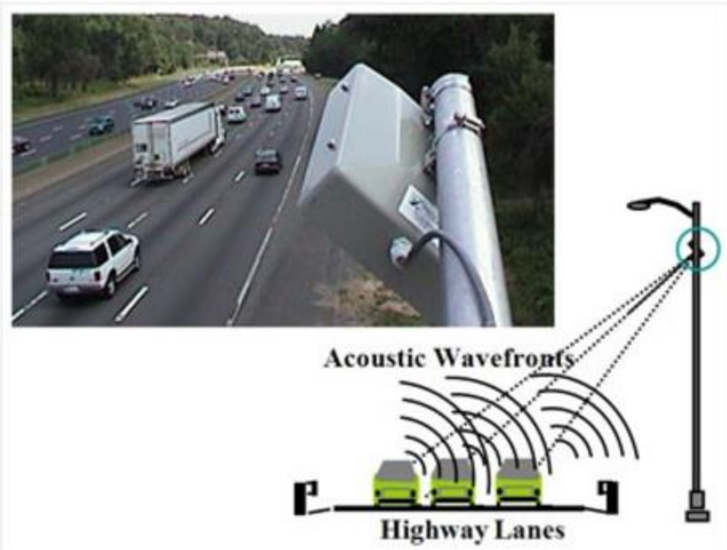

Figure 19: Acousitc senzor, source: (14)

4.2 Level of detection

The level of detection needed depends on the specific requirements of the system. General information needs, such as the number of currently available spaces in a given area or section, can be addressed using counts available from entry and exit detection. Systems designed to guide users directly to empty spaces require additional information, provided by localized detection, to determine the occupancy of each space.

4.2.1 Entry / Exit Detection

Entry/exit detection counts vehicles as they enter and exit a parking area or its section. Based on entry and exit counts, the number of available spaces can be determined. For smaller facilities, this type of portal detection may be sufficient to provide useable information, particularly if the parking area is anticipated to empty out on a daily basis. This also requires an area whose operations are simplified – i.e., only one or two entrances and exits with no reversible lanes, no special parking spaces, and very well defined and maintained number of spaces. This type of system may require occasional calibration with manual counts. Portal detection generally uses induction loops, although other sensor types like magnetometers can also be used for this purpose.

4.2.2 Occupancy / Presence Detection

Occupancy or presence detection determines whether a vehicle is present in a travel lane within an area or in an individual space. Presence detection can be used to calculate facility occupancy and can also be used in conjunction with guidance systems to guide drivers to an individual vacant space. Because these systems require detectors for each space, the cost of presence detection can be high, making them most appropriate for high-revenue, high-turnover installations such as short-term parking (railway stations, airports, hubs). In these situations, guidance may provide added value that can result in additional revenue that will offset the installation cost. Additionally, by reducing the need for circulating traffic patterns, guidance systems can enable more spaces to be placed in a given area, further resulting in additional revenue. A cost-benefit analysis is recommended to determine if occupancy/presence detection is an economically viable alternative.

4.2.3 Movement Detection

Larger areas may have a need for information regarding movement within the facility. One approach is to divide an area into multiple zones, with entry and exit detected between the zones. However, this only detects movement at the zone boundaries. This makes the process of determining available spaces more complex. When vehicles are counted as they enter the area, it is possible to inform drivers with a high degree of reliability if the facility is full. When measured at the Boundaries, it is necessary to inform drivers before they enter a section that this particular section is full. This requires an accurate occupancy count for each section. Approaches that are more elaborated may use detectors positioned above or below the roadways to determine in real time the location and direction of movement of a vehicle. This information can then be used in conjunction with guidance systems to direct vehicles to available spaces.

4.3 Communication

The communication is broadly classified into two major networks, namely, wired networks and wireless networks. Most of the parking technologies used fall under the category of wireless communication. (17)

Decision about what communication option would fit best to FUA purpose must be made upon answering these questions:

- What is the expected amount of data and the transmission frequency?
- What type is the existing communication network?
- What are the local site conditions?

The type of communication is mostly defined by the choice of detector technology and by the site conditions. Both of the above mentioned possibilities (wired, wireless) are possible. Wireless solutions are mostly installed on places with existing parking structures where conditions are already set and nobody wants to change/modify structural integrity of the facility. Wireless sollutions for parking space occupancy detection have several benefits such as lower instalations cost (no need to install new conduit/connection) and it is less error prone due to some structural changes of the parking surface. In the high bureaucracy and process burden which is present at the most public sector organizations the wireless, energy independent solutions are the simpliest and their deployment is very quick.

4.4 Summary

There are a lot of detection technologies and systems, but not all of them are suitable for each location and for each purpose we want to accomplish. When deciding which technology to implement at a given location, it is always crucial to define the specific requirements the system should perform. There are many factors which can affect the occupancy detection such as detector type chosen, car park type and layout of the area.

Entry/exit detectors can be used if these requirements are low (number of free parking spaces). On the contrary, different technology is suitable when there is a need of greater amount of information for navigating the driver to a particular parking space (videodetection, microwaves).

Unless a particular technology is specified in the procurement, the vendor of an existing system will choose the technology. Wide area detection is possible with some technologies – i.e. one sensor can monitor several spaces. Newer low-cost magnetometers are likely the most cost effective approach to space-level detection. If a high level of detail in the detection system is not required, cost differences between technologies would likely be minimal, as most of the reviewed technologies have their advantages and disadvantages.

Relative average purchase cost of different types of sensors can be compared in the next chart, where the cost of technology gets higher as one moves further from the center, so magnetic sensors are less costly relative to the competitive technologies.

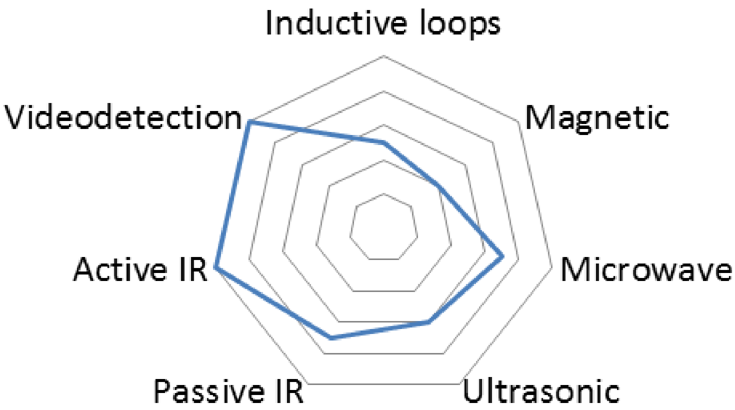

Figure 20: Relative cost comparison for different types of sensors, Source: (15)

DETECTION			
Technological option	**Pros**	**Cons**	**In/ Off roadway**
Induction loop	Reliable, widely deployed, insensitive to weather conditions	Expensive implementation and maintanance, 5 year lifespan, decrease pavement life	In-roadway
Magnetometer	Can be installed in or on pavement, can operate on battery power with wireless connection, insensitive to weather conditions, mechanical durability, low cost	Close proximity reqiured, installation requires pavement cut or tunneling under roadway	In-roadway
Pneumatic tube	Low cost solution, quick and easy installation, maintenance	Temperature sensitivity, vandalism	In-roadway
Piezoelectric	Precise vehicle differentiation, weight and axle measurement	Multiple detectors needed, sensitivity to high temperature and traffic stress	In-roadway
WIM	Precise vehicle differentiation, weight and axle measurement	Lane closure for instalation, depends on the type of used WIM sensor, high cost	In-roadway
Ultrasound	Flexible, can be installed over right-of-way, next most common to loop detectors, easy to install	Can be affected by extreme wind and temperature, degraded occupancy measurement on freeways with vehicles travelling at moderate to high speeds	Off-roadway
IR - passive	Can be configured to process multiple zones	Weather sensitivity	Off-roadway
IR - active	Can detect multiple zones	Weather sensitivity	Off-roadway
Video	Can be configured to detect up to 4 zones. Can use existing equipment, easy to add/ modify detection zones	For best performance it must be placed 50 feet above pavement. Lighting variations also impact system performance, high instalations and maintenance cost	Off-roadway
Microwave	Can detect up to eight zones, not weather sensitive	Inccorect measurement during congestion, wrong reflection of the signal due to unexpected reflections of the wave	Off-roadway
Acoustic	Multiple lane operation, passive detection	Slow moving detection is not accurate, cold temperature sensitivity	Off-roadway

COMMUNICATION		
Technological option	**Pros**	**Cons**
Wireless	Cheaper to install	May have security issues, not as reliable
Cable	Cheaper to install	Lower bandwidth
Fiber	Most secure and highest bandwidth	Expensive

Table 7: Comparison of detection & communication technologies, source: (1) (14)

5 System requirements

<u>General:</u>

- The system should be modular, extendible by another supplier.
- The system shall detect the occupancy of parking spaces in the on street environment even in the adverse conditions, e.g. heavy rain or presence of fallen leaves or snow on a parking space.
- The system shall provide output data in the standard format.
- The system shall have an interface for the administration.
- Every parking space is equipped with detection of vehicle presence.
- The system shall provide parking occupancy data to the central system (server) operated by the client as well as locally to VMSs usually situated at the entrances to the parking area.

<u>Instalation:</u>

The vehicle presence detectors are installed at the dedicated parking spaces. After their physical installation the detectors are calibrated.

<u>Operational:</u>

The system shall be configurable and shall enable the remote supervision.

- Configurability
    - e.g. deactivation during the road (street) closure – extend the lifetime of the detector battery
    - possibility of changing detectors' parameters during the system operation
- Independence on the grid
    - Battery
    - solar panel + accumulator
- Remote control
- with detailed information on the status of all the system's parametres
- possibility of a preventive action, e.g. at the end of the battery lifetime
- system shall provide the possibility of firmware upgrade without the necessity of civil construction actions.

Maintenance:

To fulfil the maintenance requirements the system shall have the possibility to exchange the detectors' batteries, the detectors' wrapping to enable a later reinstallation of the detector.

Lifetime:

For public procurement it is recommended that the supplier guarantee the minimum lifetime of 7 years for the system, even if the detectors' batteries (or detectors themselves) are replaced during this period.

Reaction time

The system shall recognize the vehicle presence on a particular parking space typically up to 8 seconds. The minimum configurable value of the time after parking to the VMS or web value change is 5 seconds.

Reliability

- Detection:

The reliability of detection is based on the type of detection technology. For on street parking magnetic or infrared detection is used. The system shall be robust enough against interference elements – ferromagnetic matters presence, rain, fallen leaves or snow. The type of detection technology should regard the parking spaces conditions.

- Detection information availability:

The system shall ensure the possibility of redundancy in routing when collecting data from detectors. It has to have the confirmation mechanism and a back-off for multiple attempts to transfer information. The system shall keep its functionality even during internet connectivity failure. Local VMS can use information from local detection, i.e. locally available information provided by a local system control element.

The minimum of 95 % reliability of the provision of parking occupancy information is recommended. The proper validated methodology to specify this has to be worked out based on the system performance and user needs (e.g. in SFpark 83 % reliability has been found and was perceived as sufficient by the municipality.

Extendibility

The system shall be extendible in a simple way; this means that it shall enable adding other components without the necessity of complex reconfiguration of the existing system.

It also enables to orchestrate different detection systems in different places/streets from different suppliers into one parking system.

Modularity

The system shall be modular and compatible with other systems through the use of standard communication protocols on various levels of communication and through publicly available API.

Communication security

- against disturbance (enables to change to another channel within the band)
- against replay
- against eavesdropping
- for RF communication (shared keys and block cipher according to the industry standard)
- for API, data (https)

Data:

- data format DATEX2 according to CEN TS 16157-6 (ParkingExtension version 1.0) and the other DATEX2 specifications (series CEN TS 16157)
- csv for import to SW for the purpose of an analysis
- availability (live data; historical data;stored on a backed-up server)

Administration web interface:

Web interface should provide information about:

- parking spaces occupancy
- battery status
- detector status
- detector functionality status
- identification of a parking area
- type of dedicated parking space
- id of a specific parking space
- actual time.

Communication:

The table shows basic communication requirements of the parking detection system.

Communication regime	• Server interrogates an equipment (request/response) • The equipment always answers but never sends data itself (without request)
Frequency	• Mostly it communicates in 100 – 300 ms • The equipment does not have its memory, it only sends back the actual status (e.g. the barrier is up)
Use cases	• For connection to the parking facility control system • For connection to other embedded equipment (e.g. automatic barrier to automatic parking terminal)
Protocol – format	• Proprietary binary protocol (header, body, check sum)
Communication (request/response)	• Request on the date and time (without parameter) • Setting up the data and time (time in ISO format) • Request on the status (without parameter) • Status of payment with cash (tickets) • Status of payment with cards • Status of the printer • Status of the reader • Occupancy on the external display • Traffic lights at the entrance to the facility • Status of the barrier • Setting up the barrier (open, close, blocking) • Request on the version (without parameter)
Protocol – necessary	• Setting up the date and time • Statuses of all the peripheries/field equipment (printer, reader, barrier, etc.)

Table 8: Parking systém communication requirements

6 Summary

Each ITS-based parking management solution is different, requiring a carefully chosen architecture that meets the needs of the various stakeholders. Factors that should be considered when deciding among these options include:

- Availability of mounting space for detectors
- Operational environment in which the components will be used
- Communication channels.
- Electrical power supplies.

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