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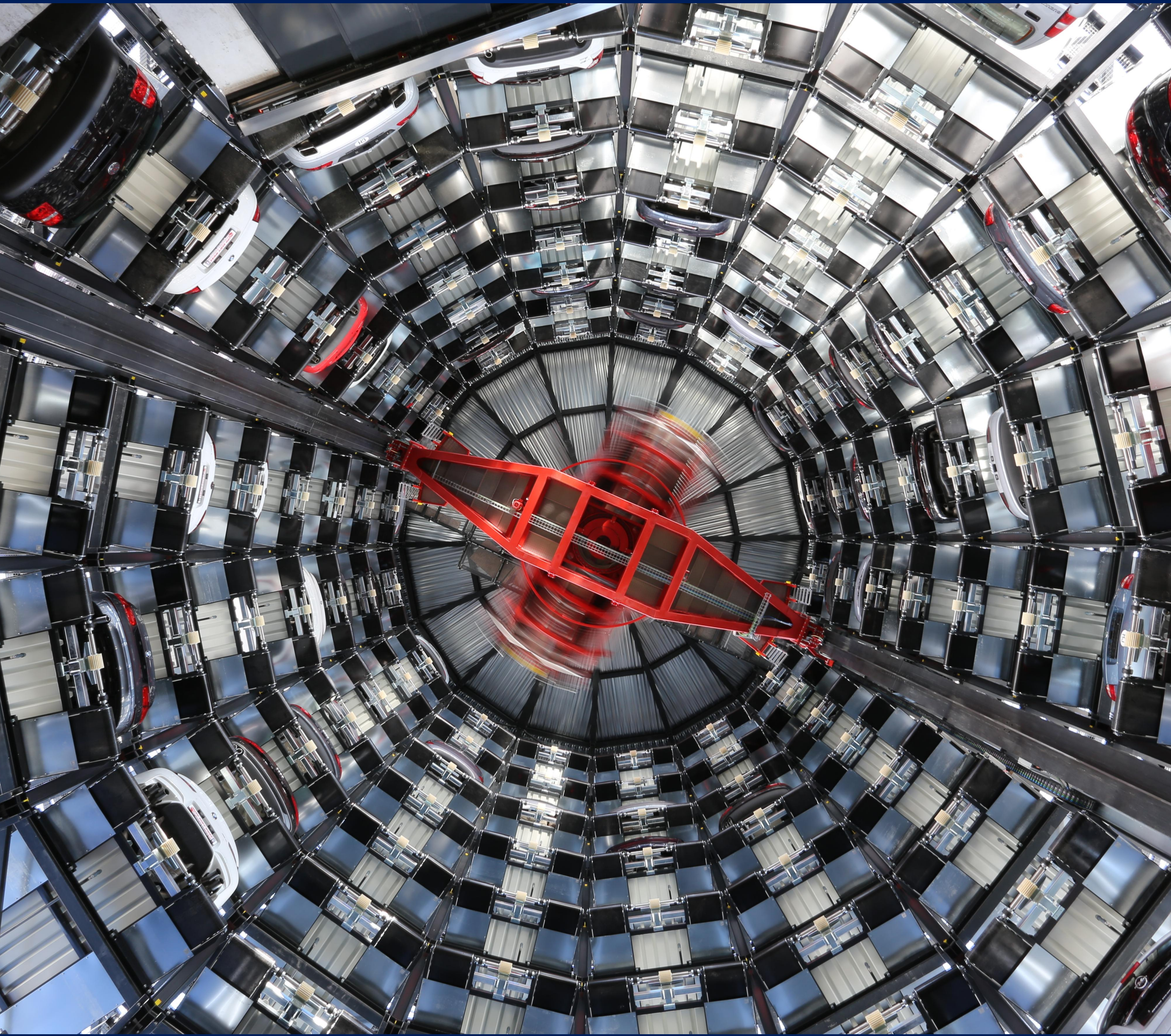

Design Guide

Automated Vehicle Storage & Retrieval Systems

Contents

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1. INTRODUCTION

For developers, architects, consultants and planners to enable them to:

- have an appreciation of the principles of Automated Parking Systems (APS)
- understand what types of system best suit specific types of application
- have an overview of the relevant design standards
- capture the application performance requirements
- draft a complete APS system specification
- understand related construction and building services dependencies

2. HOW APS WORKS

Vehicle Entry

- Enter in the same way you do a conventional parking facility:
    - Enter the building at a predesignated position(s), generally the perimeter of the building is at ground level.
    - Automatic doors open to allow the vehicle to park.
    - Unlike conventional parking, the vehicle does not have to drive around the building to find a space.
    - There can be a number of entry points dependent on the parking facility size.
    - Sometimes the entry point is also an exit point, with the type of use being controlled by the traffic management system.

- Parking Lobbies
    - On entry the car enters a parking lobby where there are visual instructions on parking.
    - Typical dimensions of lobbies are between 4.6 & 5m (16’) wide and 6.6 to 7m (23’) deep.
    - The driver parks the car within designated tramlines on the floor, ideally assisted by an automatic guidance system that finally positions the vehicle.
    - Lobbies should be well lit, secure, with CCTV surveillance and a floor guidance system that positions the car in the lobby with the need for driver intervention.

-
    - Visual display screens instruct the driver on the parking process, ideally with graphics.
    - Once positioned, the driver applies the hand brake, turns the engine off, exits the car and locks the vehicle.
    - The driver and passengers exit the lobby.
    - Well-designed systems should then automatically check that the handbrake has been applied and confirm to the driver that everything is okay.
    - The automatic doors close behind the vehicle.
    - The user is given a unique reference for the vehicle in a form dependent on the ticketing system type.

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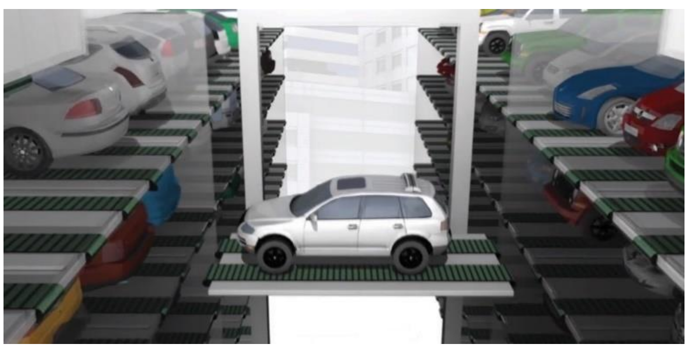
- Vehicle scanning
  - o Once the automatic doors have closed, the most advanced systems scan the vehicle with laser sensors that create a 3D image of the exact vehicle dimensions.
  - o The system software matches the size of the vehicle to an available space (maximizing the parking density).
  - o Less sophisticated systems only check for a maximum vehicle size, as they do not have the ability to vary the parking space size.

- Vehicle parking
  - o The vehicle is transported from the parked position by an electro-mechanical or hydraulic device (pallet, robot or conveyor) to the designated parking position matching the vehicles pre-scanned dimensions.
  - o The types of transport mechanisms vary, depending on the system manufacturer and level of performance required (see later).



- Vehicle retrieval
  - o The client enters their unique vehicle ID or ticket at the exit lobby.
  - o The system software recognizes the vehicle ID, the position in which the vehicle is parked and the chosen exit lobby (if there are multiple exits).
  - o The client is told where the vehicle will exit.
  - o The electro-mechanical vehicle transport mechanism goes to the parking position, picks up the vehicle and returns it to the exit lobby.
  - o The automatic doors open and the car is available.
  - o The client enters the lobby, unlocks the car, loads the vehicle and exits.
  - o Note: A well-designed system should enable the driver to exit the lobby without having to manually reverse the vehicle.

3. WHEN & WHEN NOT TO USE APS

- Use it where one or more of the following is applicable:
  - o Development and developed land values are at a premium
  - o There is a restriction on the amount of space available
  - o Saved space could be used to generate additional incomes
  - o A conventional system cannot fit
  - o There is a need for the parking to be close to the destination

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- o There is a need for a high ROI chargeable parking facility
- o Planning permission is difficult to get approval for
- o Sustainability is a key requirement of the local development plan
- o There is a requirement for an ecological, sustainable and economic solution
- o The security and protection of vehicles is a priority

- Where not to use:
  - o Where open ground or on street parking is readily available
  - o Where development and developed land values are relatively low
  - o Where parking space is available next to the prime destination(s)
  - o Where there is a very high peak in parking facility demand over a very short period
  - o Where planning regulations are relatively easy to obtain
  - o Where hourly car parking charges are relatively low

4. TYPES OF SYSTEMS AVAILABLE

- Overview
  - o Technology - consider the impact of the chosen transport technology on achieving the overall design goal of an Automated Parking System (APS).
  - o The primary design goal for an APS is reducing the size of parking spaces, thereby saving space.
  - o Other factors are performance, user convenience, environment, economy and reliability.
  - o This document shows that most factors are inter-connected with one another and that the chosen transport technology has a strong impact on all of them.

- Different Transport Technologies
  - o Picking up the car in the entry box, moving it via lift/shuttle system and delivering it to the designated space can be done in different ways, namely, with different transport technologies. Currently three different pickup and discharging technologies can be distinguished.

- Conveyor Belt Systems
  - o The car gets moved by conveyor belts that are themselves installed in the entry / exit box, on lifts and shuttles, and on all parking spots.

- Robot Systems
  - o The pickup & discharge process is done by a robot that moves under the car, attaches itself to the wheels and moves it from entry box to lift/shuttle and parking spot.

- Pallet Systems (incorporating Puzzle Park)
  - o The user parks the car in the entry box on a pallet. The parking system then moves the pallet together with the car through the inside of the garage.

- Transport Technologies Development
  - o Pallet Systems
    - Did a good job of introducing large-scale fully automated parking systems to the marketplace back in the`80s and`90s. Such systems work relatively reliably and are relatively easy to use, especially compared to existing puzzle parking and paternoster systems. Pallet solutions are used in Asia predominately and by some other APS manufacturers today.
    - Over the last few years, most providers of APS technology started avoiding pallets, as there is significant room for improvement with non-pallet systems, ranging from higher space efficiency to the freedom of design, higher speed, reduced maintenance efforts, return potential and no decline in performance caused by handling empty car pallets.

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In addition, pallet-based systems require a duplicate transport system to control and store the spare pallets when not being used, which increases costs and can slow down operation of the system.

o **Conveyor Belt Systems**

- Outperform alternative transport technologies in terms of all relevant criteria for smart APS design, with few exceptions. Next generation APS will most likely apply conveyor technologies.

o **Robot Systems**

- Are the most well-known forms of "non-pallet technology". While robots have many advantages over Pallet Systems, they show major disadvantages compared to Conveyor Belt Systems in many of the most common applications.
- Great care should be taken in the design phase as they employ more complex control and movement mechanisms (conveyor and pallet), potentially introducing more operative risk.

5. APS PERFORMANCE BY SYSTEM TYPE

- **Speed**
  - o The time required for the parking & retrieval of cars is critical to the viability of an APS.
  - o Speed is usually the deciding factor in whether a certain APS qualifies for a certain application or not. Vehicle retrieval time, i.e. the time it takes to get the car out of the system, is particularly important together with the ability of the system to empty the parking facility.
  - o Designers should normally be looking to achieve set performance standards for the specific application (see section 6).

- **Reliability & Maintenance**
  - o Reliability and maintenance costs are interconnected.
  - o The technology needs to enable the parking system to work close to 100% of the time.
  - o Designers should choose the simplest and best proven technology available for their application (see Comparable System Performance Chart page 5).

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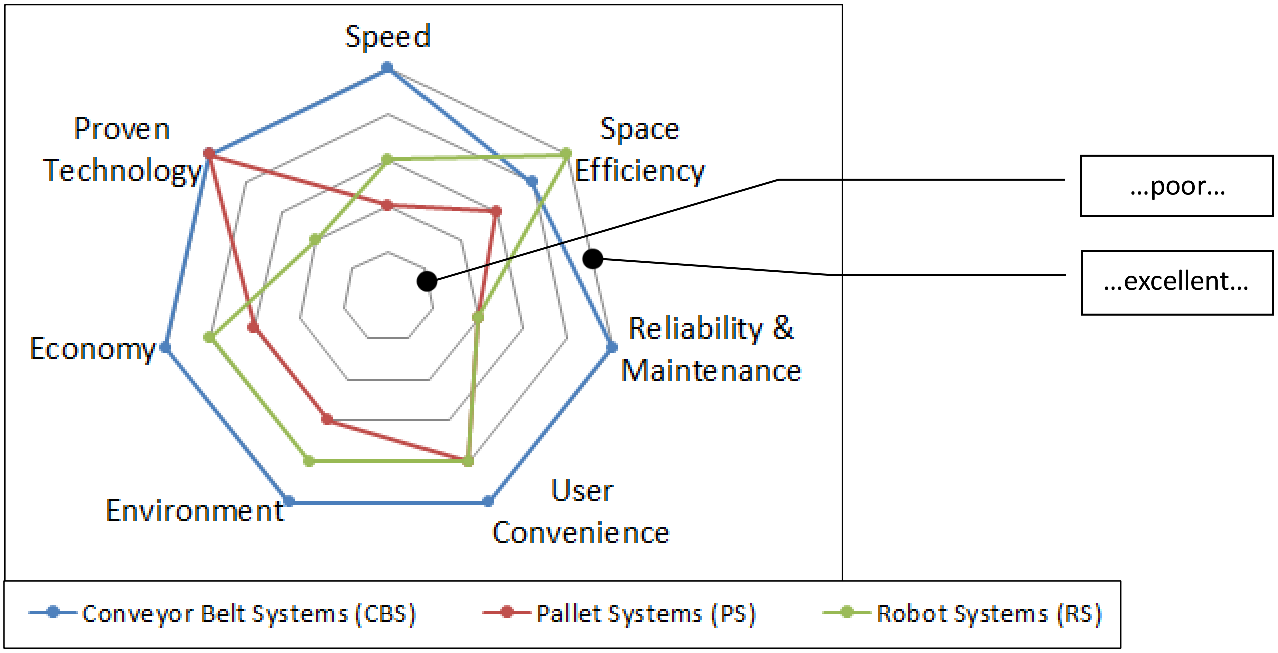
- **Comparable System Performance Chart**



- **Comparable System Performance Tables**

	Conveyor Belt Systems (CBS)	Robot Systems (RS)	Pallet Systems (PS)
Speed	The time required for the parking & retrieval is critical to the viability of any automated parking system. Speed is usually the deciding factor in whether an automated parking system qualifies for a specific application or not.		
Speed	CBS is one of the one of the fastest transport technologies available and suitable for all applications given their good design. Allows for vehicle retrieval times of less than 60 seconds, with few moving parts and mechanical movements.	RS speed performance is acceptable dependent on the application requirements (see Design section).	PS is the slower of the three system type options and is only suitable for applications where the performance requirements are minimal. This is due to the delays required at pick and release of each car due to the transport mechanism type.
Space Efficiency	Any automated parking system should save space and time, but there is room for optimization beyond saving maneuver area, ramps and passenger lifts. Depending on the application, space saving requirements can be quite different, dependent on the system's ability to recognize the real dimensions of the car and adjust the parking space to match them.		
Space Efficiency	CBS allow for distinguishing vehicle height, length and width enabling multi-level depths & compact parking.	RS allow for distinguishing vehicle heights & lengths and enable multi- level depths & compact parking.	PS cannot distinguish between large and small cars.

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	Conveyor Belt Systems (CBS) cont.	Robot Systems (RS) cont.	Pallet Systems (PS) cont.
	Using the automated parking system should be as easy, convenient and safe as possible. Waiting times need to be sufficiently low as well.		
	CBS cut the waiting time to a minimum. Users simply park their cars on a flat conveyor surface with high tolerances.	RS require lower tolerances to allow the alignment of the robotic arms with specific anchor points relative to the vehicle. What's more, the RS system has to move under the vehicle, locate the wheels and make secure contact which can affect performance times adversely.	PS allow for high parking tolerances, but the parking action can be noisy as the pallets run small wheels.
Proven Technology	Is the technology well established in the market? Are there valid references and experiences?		
	Conveyor system technology has been well established over many years and in many industry applications where large heavy components are required to be transported rapidly, safely and accurately.	RS technology relies on there being a minimum distance between the car and the slab below. Care should be taken to ensure that this can be achieved when parking traditionally low profile vehicles (high performance sports cars are a typical example).	PS have been well established for over 20 years.
Reliability & Maintenance	Reliability and maintenance costs are interconnected. The technology needs to enable the parking system to work as close to 100% operability as possible with a good design, requirements capture, and in-built redundancy.		
	CBS is the simplest, easiest, most failsafe and least expensive technology to maintain. Sand, water, ice, freezing and hot temperatures have no detrimental effects on performance. The conveyor systems basically clean themselves. They use industrially proven technology with simple mechanical and electrical components and fewer moving parts.	RS utilizes the newest technology for the parking application and subsequently there are few records of systems reliability levels currently available (but some examples of failures). This can be mitigated by checking the suitability of the application.	PS maintenance is higher than other systems due to the number of dynamic load bearing components (wheels and wheel bearings on the pallets etc.).
Environment	All automated parking systems provide measurable advantages over conventional systems as recognized in UK, American, Australian and European ecological and sustainability standards.		
Economy	Costs of ownership, including maintenance costs, parking fees, and occupation rates determine whether an automatic parking system is just economically viable or a true positive cash generator.		
	CBS, thanks to their high performance, simplicity and reliability, provide good financial returns in nearly all applications.	RS allow for high returns if the requirements capture and strict maintenance regimes are enforced.	PS are usually too slow and have higher running costs to provide high enough returns on investment. There are also some technical restrictions on system size.

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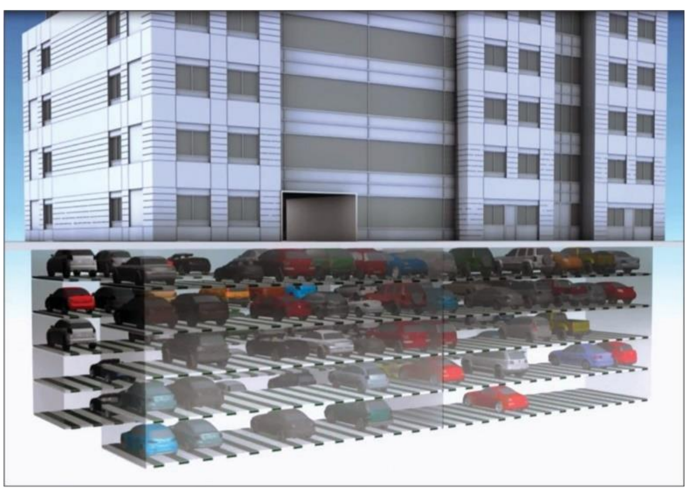
6. DESIGNING A SYSTEM

Important steps in the design process include the following requirements capture, which any reputable manufacturer will need before offering design advice or a budget cost:

- **Number of Parking Spaces**
- **Location**
  - o Ideally a map of the surrounding area should be available, clearly indicating site boundaries, entrance/exit points and road configuration around the installation.
  - o The ground area available should be indicated and defined in terms of area and shape.
  - o Traffic studies incl. peak hour flows should be taken – the issue being, can cars enter and leave the parking facility without any adverse effect on the existing or planned road networks?
  - o The automated parking system may be capable of a high throughput of vehicles, but if the surrounding road network cannot cope with the increased volume at peak times then limitation becomes the surrounding infrastructure, not the parking system.
  - o Local country specific planning regulations and strategic transport plans should be reviewed and checked to ensure that the direct and indirect effects of the parking facility installation will comply.



- **Layout concept:**
  - o Aboveground or below ground
  - o Stand alone or integrated into a building (provide overall plan)
  - o New or integration/replacement of existing building
  - o Maximum height allowed at the site
  - o Façade and roof construction
  - o Any special architectural requirements

- **Performance**
  - o How many cars are moving in and out of the parking facility per hour at peak times
  - o Maximum emptying time requirements

- **Parking Lobbies**
  - o The number and position of the entry/exit lobbies has an important influence on system performance and redundancy. Ideally, they should be as near the center of the building side profile as possible

- **Users**
  - o Parking use: public versus private and short term versus long term usage.
  - o Commercial application of parking: entertainment (cinema, theatre), sport arena, retail, universities, hospitals, offices, residential

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7. PERFORMANCE CRITERIA

- Before contacting any potential suppliers for the APS system, the designer must decide what level of performance is required from the system. Requirements vary dependent on the primary usage of the system and any special influencing factors particular to the client's requirements. Typically, the benchmarks are the time required to empty the parking facility and the average time taken to retrieve a single vehicle.

- To be able to calculate what performance level is required, traffic flows, densities and timing are critical, just as they would be for a conventional design. Typically, a traffic survey or forecast needs to be completed and the client closely consulted as they may have special requirements (prioritization of users, special peak demand requirements etc.).

- It is proven that this is a critical element. In the past, systems have generally failed, because they did not carry out a comprehensive requirements capture and agree to it with the client. Unlike conventional designs, the performance levels of the APS systems vary depending on which technology is used. It is vital that the performance requirements are carefully assessed and agreed with the client and suppliers early in the design process.

- However, there is some guidance available as to what typical system performance is required for different application under the German VDI standards which is a good starting point. The table below shows these recommendations.

Automatic Parking VDI Category	Emptying Time Requirement
Entertainment	0.8 to 1 hour
Retail	1 to 1.8 hours
College & Hospital	1.8 to 3 hours
Residential	2 to 3.9 hours

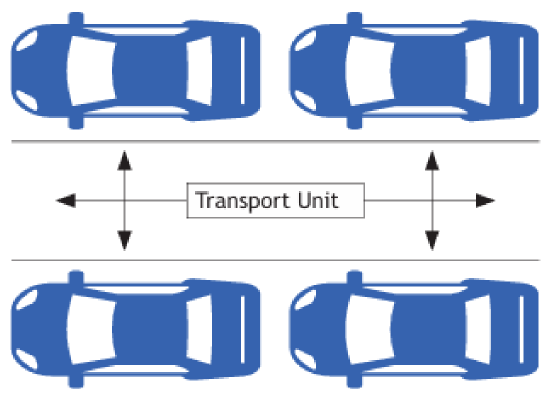
Also consider that the chosen solution & its performance have an impact on the system capacity and the ROI of the system.

8. CONFIGURATION OPTIONS

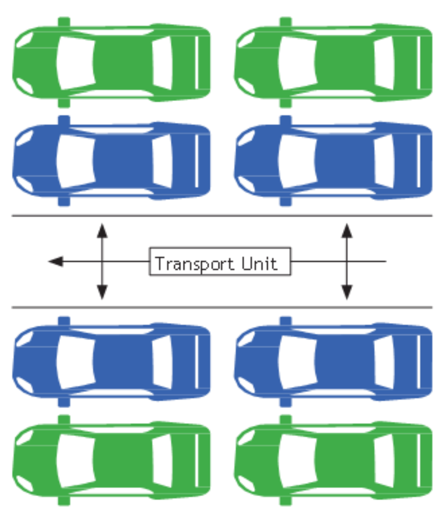
- One of the many unique advantages of automated parking systems is that the normally high parking density can be increased even more by changing the parking configuration.

- This is because APS systems offer the ability to double park cars either in longitudinal or transverse directions. As the cars are transported by an electro-mechanical system operating at low tolerance and high speed, cars can be quickly double parked and retrieved with a minimal delay.

- For example, sketched below is a typical standard configuration with parking on a transverse axis:

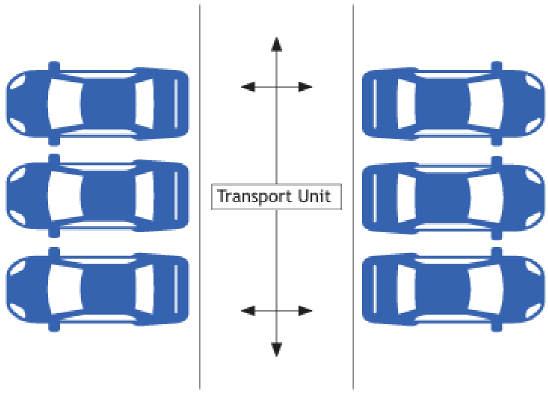


Now consider the same example if double parking is utilized, as it is in the sketch below:

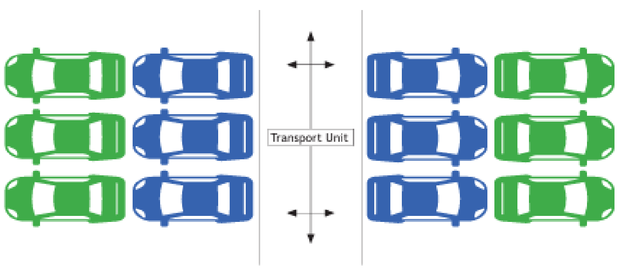


It can be seen that the parking density increases.

- Consider the same principle for a longitudinal configuration below:



Again, add double parking and see the effect on density below:

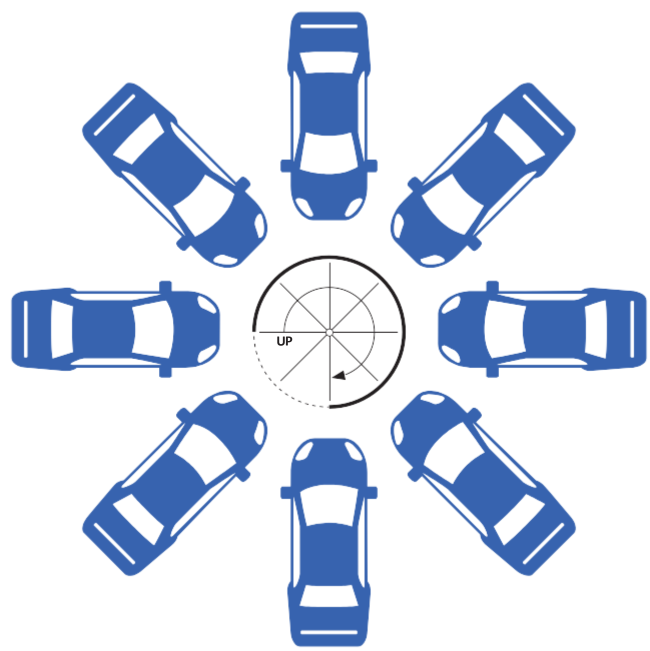


- Dependent on the parking system provider and the technology they use, there can be a reduction in system performance (parking and emptying) because of the additional action of unparking the double-parked car, so check with the chosen supplier first. Typically, double parking can affect the system performance for occupancy rates of over 75% for unparking only.

- Some of the more advanced suppliers have software controls that automatically unpark the double-parked cars as either of the other spaces are vacated (during the quieter operating times) or if the driver sends a notification (by text message) in advance of when they wish to pick up their car. The system unparks the car and places it when it's nearly pickup time.

- The effect of this is to greatly reduce any delays caused by the parking configuration but to increase the par- king densities – a real advantage if the available land is restricted and/or the size of the building profile is a critical issue for planning approvals.

- Consider the options of a tower configuration (or shaft if below ground) like the one below:



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- Parking towers or shafts offer high speed vehicle transportation and the possibility to fit parking spaces in areas where neither transverse nor longitudinally configured systems offer the best parking density.
- They are particularly effective where the client wishes to display the vehicles, increasing the impact and prestige of the facility (such as premium car dealerships).

- Checking the functionality of the proposed APS provider's system(s), dependent on the application for this level of functionality, could bring real advantages for both the designer and the end user.

9. INSTALLING AN AUTOMATED PARKING SYSTEM

There are generally 7 main installation phases for all automated parking systems:

i. **Preliminary Phase:** Clear determination of the project environment and structure (traffic management, etc.) in order to define the detailed project plan, including selecting the system configuration design detail, highlighting critical interfaces to other services.

ii. **Construction Phase:** Drawings of the structure (excavation and building) for the parking facility, building the supporting structure (steel, concrete, wood) for the parking facilities, and installing the building safety elements.

iii. **Installation Phase:** Delivery and installation of the Skyline Parking components in the building. First the mechanical components are installed followed by electrical and electronic components.

iv. **Commissioning Phase:** Testing all components individually and the whole system.

v. **Completion Phase:** The building, building safety, quality and reliability are completed according to the contract conditions.

vi. **Release under Control:** The parking facility is opened up to a specific group of users with direct support from the APS provider.

vii. **Approval and Acceptance Phase:** The parking garage is fully in operation and the system is generally accepted by the customers and approved.

- Because installation of any automated parking system is a specialist subcontract, it is important that the key roles are recognized and included in the project plan at the pre planning stage including the APS provider. Typically, this would include the following:

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- **Client Project Manager:** This representative from the customer side organizes all the responsibilities specified in the contract and makes any requested decisions arising during the project within 3 working days.

- **APS provider design office:** This office gives support to the whole project group directly involved with the APS installation, including interfaces to other trades (construction, general mechanical and electrical services etc.).

- **Client Construction Project Manager:** This person is responsible for all structural aspects from planning to the end of construction (including steel work).

- **APS provider Safety Project Manager:** This person ensures that everything complies with local standards/laws.

- **APS provider Logistic and Installation Project Manager:** This person is responsible for ordering, shipping and installation of Skyline components and documentation of the mechanical components.

- **APS provider Automation Project Manager:** This person is responsible for the development and functionality of all electrical components, wiring, automation, process control, user control, operation and documentation of the automation.

10. BUILDING REQUIREMENTS

- Most automated parking systems are installed on a steel framework, which may form the final building load bearing structure (if it is a dedicated stand-alone parking facility) or may be within a concrete structure above or below ground (normally if the parking is a part of a mixed development i.e. parking shared with residential, commercial or other uses as the primary purpose).

- Whatever the construction type, there are some critical elements that are particular to automated parking system installations that need to be taken into account:

i. Foundations

- Whether a dedicated load for the APS or a part of the overall building structure, the APS will add additional loading. Expert guidance should be taken from the chosen supplier as the steel frame configurations vary to suit, as does the load factor.

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- However, typically the steel frame would be ST37 (S235 Rj2) and the loading per automatic parking space typically between 4.1 tons up to 4.8 tons (all elements including the max. vehicle weight of 2.5 ton) for a budget calculation.

- As an example, a typical parking facility of 172 spaces over 10 floors would require a minimum foundation thickness of 250mm (10in), a concrete plate (C30) and the capability of withstanding a minimum load of 30 Newton/mm sq.

ii. Steel Structure (frame and levels)

- All construction projects consist of a series of broad phases. While there may be considerable overlap in activity between the phases, automated parking system (APS) installations using steel frames require special consideration.

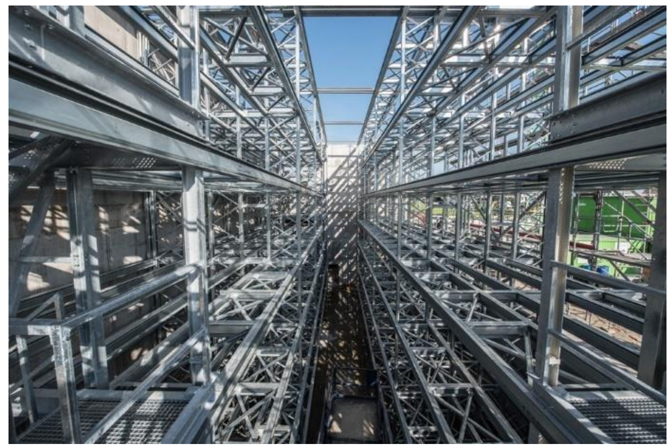
- While the APS structural steel phase is normally shown as a single phase that follows foundation work, in actuality considerable pre- erection work consisting of shop drawings, material ordering and fabrication is conducted simultaneously with the site work and foundation phases.

- A well-integrated automated parking system project schedule will have fabricated steel ready for erection by the time the foundations are completed.

- Careful coordination between the main contractor, the general steelwork contractor and the APS provider is essential to ensure an efficient overall construction plan. The main contractor, general steelwork contractor and APS provider will need to agree on an erection sequence. Site layouts for construction operations will need to be considered.

- It is essential that there is early input and consultation between the general steelwork contractor and the specialist APS provider installation and design team. This will allow the main contractor to prepare an effective overall project schedule.

- Costs for steel structures are commonly available but care should be taken to ensure that the special loading and bracing requirements of the APS provider are considered. For example, tolerances for deflection under load are far more onerous than those for normal steel structures.



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iii. External Walls/Cladding/Roof

- Obviously where the steel frame APS structure is within an overall concrete building/frame, this is not an issue. Where the parking facility is a dedicated steel structure, the frame will require cladding.

- As a basic guide, for simple cladding without any special treatment, the guide cost would be approximately 100 euro per m sq. and for roofs, 135 euro per m sq.

- It is presumed that wind loading etc. would be pre calculated and agreed with all interested parties prior to finalization of the automated parking system frame design.

iv. External Doors

- The quality, speed and reliability of the entrance and exit doors are critical to the performance of the systems, i.e. if they are unreliable or slow to operate, the entire system's performance will suffer.

- Ensure firstly that the APS provider is including door provision and secondly that they are of sufficient quality to ensure that they do not become the single point of failure.

v. Ventilation

- As the general public does not enter the parking facility and the vehicle engines are not running when being parked, there is no need for normal venting, which would be applicable for a conventional parking facility above or below ground.

vi. Smoke Extract/Control

- These are no more onerous requirements than those for conventional parking solutions. Guidance should be taken from the responsible local and country authorities, as would be normal practice. This should include the normal provision of:

  - Extraction units
  - Fan units
  - Supply and extract ductwork including fittings, dampers, etc.
  - Grilles, filters, etc.
  - Fire dampers
  - Valves and fittings
  - Instrumentation and system control
  - Sound attenuators
  - Insulation

- If we consider general guidance for smoke clearance.

  Such systems are not intended to assist in means of escape in case of fire, but to assist fire fighters by providing smoke clearance.

  Even a casual inspection of the requirements shows that these methods cannot be expected to do more than limit smoke density and speed smoke clearance once the fire is extinguished.

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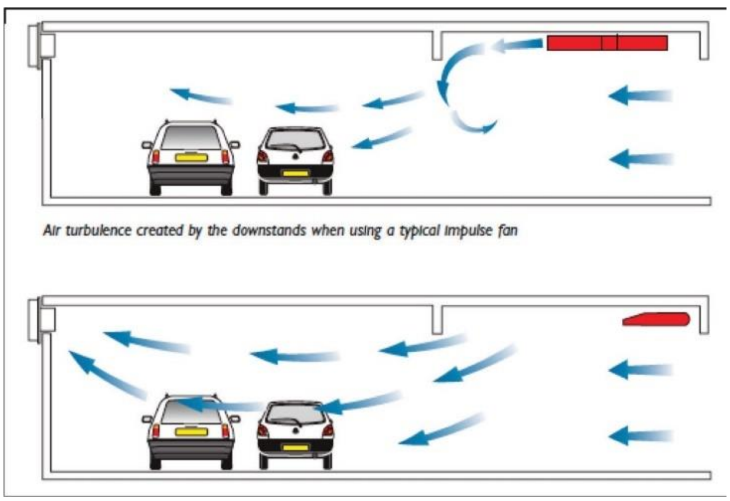
Where impulse fans are used, they are in a layout engineered to ensure there are no areas where it would be possible for fumes to build up due to lack of air movement.

In most parking facilities only a single large extract point is required, located as far as possible from the main air inlet openings. This method satisfies the requirements of both approved documents.

These systems are suitable for use in sprinkler protected parking facilities. Close coordination is needed to maximize the benefits of both sprinklers and ventilation.



Air turbulence created by the downstands when using a typical impulse fan

vii. Electrical Mains and Sub Mains Distribution

- Provision should be included for a suitably rated 3 phase supply to the automated parking system. The guidance should be from the APS provider for the particular system design and type being proposed, as the requirements vary markedly.
- The distribution of the supply from the control gear and main distribution board to the various items of equipment should normally be under- taken by the APS provider due to its specialist nature.

viii. Lighting Installation

- Because the public do not enter the parking area there is no requirement for any normal lighting provision within the parking area.
- However, there is a requirement for suitable task lighting for maintenance purposes and available switched sockets for maintenance purposes.

ix. Specialist Lighting Installation

- Because the public do not enter the parking area there is no requirement for any emergency lighting provision within the parking area, other than that on any designated maintenance/engineering access routes for authorized personnel.

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x. Local Electricity Generation Systems

- Emergency power supply generators will be required to ensure that the parking system can operate in the event of a mains failure. This can either be a part of the general load calculation for a general site backup facility or provided by a dedicated generator, rated to suit the calculated loading of the particular APS being used.

xi. Fire Risk Assessment

- There are no specific standards for automated parking systems, although there are many for conventional multistorey parking facilities. The fire risk is dramatically reduced in APS as the public and their vehicles do not operate in the parking area.

- Conventional parking facilities, because of the use of non-combustible materials, are considered a low fire risk. The same applies to APS as the materials used are generally at least as non-combustible (steel and concrete foundations if not a part of an existing concrete structure).

To keep the fire risk in perspective, Building Research Establishment (BRE) in the United Kingdom confirms:

> *"The number of fires in parking facilities reported by UK fire and rescue services represents a very small percentage of all fires in the UK (i.e. the number of all fires were 426,200 in 2006 – hence fires in parking facilities were less than 0.1%).*
>
> *The majority classification of fires in parking facilities in buildings generally (but also for purpose-built parking facilities) is "accidental". However, when fires reported as being "malicious" or "deliberate" are added together as "non-accidental" then these form the substantial majority."*

Consider that malicious, non-accidental and deliberate fires are not possible within an APS as the public have no access, and the risk is diminished even further.

xii. Fire Suppression Systems

- Even so, our recommendation is that the basic requirements of the German APS standard VDI 4466 is used as a minimum as follows:

> *"In so far as the building is used solely as an automated parking system, walls and ceilings only need to be made from non-flammable materials.*

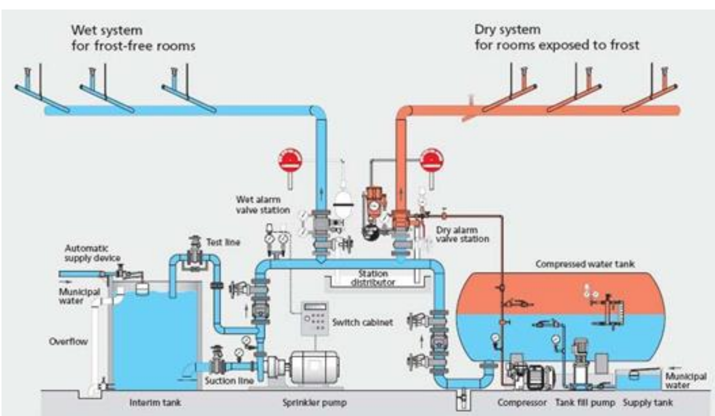
As the public do not enter the parking area, there are no requirements in terms of emergency exits. This also applies with regard to the formation of smoke breaks. Fire breaks must, however, be provided and the accessibility for the maintenance teams to each parking deck has to be considered.

An automatic extinguisher system (e.g. sprinkler system) must be provided for the effective fire protection of an automated parking system with more than 20 parking spaces.

The extinguisher system should be designed for rapid and selective fire extinguishing for fire spread prevention with simultaneous alarm to the fire brigade.

Environmental pollution by fumes should also be reduced to a minimum."

Typically, dependent on the design standards being applied, there would be between 2 and 3 sprinkler heads per car space on a pro rata basis considering the overall building area (see the below example for a tower system).



Systems would be a combination of air and water, with the delivery pipework between designated valve sets to the sprinkler head running dry with a compressed air feed. From the monitored valve sets to the sprinkler pumps and tank feeds would be wet.

Running the distribution pipework dry has many advantages including reduced maintenance costs, less risk of seepage from joints and immunity against freezing temperatures.

The system would be zoned by use of the monitored red valve stations, with the distribution pipework for a defined area being controlled by a single valve set.

Should there be a drop in air pressure in the pipe-work (meaning a sprinkler head is activated) the valve switches from an air to a water feed. The drop in water pressure between the valve set and the sprinkler pump then activates the pump/s.

The sprinkler heads then deliver a predesigned flow of water to the sprinkler head according to the applicable standards for the country and rating of the specific risk.

Typically, a system designed to comply with local country regulations would have a build cost per head of approx. 300 euro. This would include a proportion of the total costs for all elements.

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xiii. Means of escape

- o Because the public do not enter the parking area there are no issues regarding means of escape, greatly simplifying the fire strategy for the facility.
- o However, the requirements for a safe means of escape for maintenance workers within the par- king area should be assessed and taken in account in the final design solution.
- o This may include specific access, egress and emergency lighting provision. These limited requirements should be drawn up in consultation with Building Control, the fire Brigade and the APS provider.

11. TRAFFIC FEASIBILITY & IMPACT STUDIES

- If a separate traffic feasibility study is required, it should include the external road system. The traffic study provides the flows required for the site study and identifies key requirements.
- For example, in urban areas with high parking facility flows, the siting and design of entrances and exits may be cri- tical. The traffic feasibility study should also establish the capacity.

- Many new developments are of a size or type that gene- rates additional journeys on the adjoining transport infrastructure. This additional demand may necessitate changes to the highway layout or to public transport services.
- Wherever possible, opportunities should be taken to provide direct access to public transport and to pedestrian/cycle infrastructure, thus helping to modify the total transport impact.
- The developer will be required to provide a full and detailed assessment of how trips to and from the development might affect the highway network and/or public transport facilities.
- The transport impact assessment should be an impartial description of impacts and should include both positive and negative aspects of the proposed development.
- Transport impact assessment addresses two related issues:
  - o The effects of additional traffic on the safety and efficiency of the existing network (volume/capacity)
  - o The effects of additional traffic in terms of noise, pollution and visual intrusion (environment).
- Traffic impact assessments are now usually required from developers in support of a planning application, the primary responsibility rests with the developer, not the Local Authority. Standard formats for assessment are available and may be required.

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- Before undertaking a full Traffic Impact Assessment (TIA), a scope analysis should be carried out by the developer, in conjunction with the country planning and highway authority, to agree the key aspects.

- This analysis study should set out details of data to be collected, the area of analysis, key junctions to be considered, the methodology to be adopted and the years for assessment. Such a study will provide a basis for assessing the level of resources that will be required to undertake the TIA.

- It will also be invaluable to all involved and should ensure that work is not undertaken unnecessarily and that resources are directed to those aspects requiring the most attention. Before further time and resources are devoted to an application for detailed consent, approval in principle for a particular type of development is often sought by way of outline planning consent.

- The access arrangements for a site are one area of technical analysis where outline conceptual designs may not be sufficient to determine the practicality or safety of a scheme. An outline design often contains insufficient information to enable a highway authority to enter into an agreement with a developer, relating to the costs and layout of the access, and therefore needs to be treated with caution.

- If appropriate agreements are not determined at the outline stage, it may not be possible to reach a satisfactory outcome at the detailed application stage. Consequently, even with an outline application, access details may need to be provided.

- The hierarchy of decision-making and responsibility for obtaining consents and planning permissions must be agreed within the project team and the client.

12. SITE FEASIBILITY REQUIREMENTS

- At this stage, the functional design appropriate to the site and parking requirements is prepared. This process may involve preparing trial designs in accordance with the client's brief and traffic requirements.

- Proposals for new developments will include layouts of access roads and car parking. Pedestrian access, facilities for cyclists and the design of public transport infrastructure, such as bus stops and shelters, should also be considered in detail.

- Where highway authorities require independent safety audits in support of proposals for new highway works associated with development proposals, they should be undertaken in accordance with relevant guidelines.

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- Where parking space is to be provided, the following points should be considered when preparing a development plan

  - Accessibility and convenience. The location of parking and loading areas should be close enough to the building or land they serve to reduce the likelihood of drivers parking indiscriminately to avoid walking. Acceptable proximity may be affected by the nature of the walk involved. A longer walk may be acceptable in a safe and pleasant environment with easy gradients and good lighting. As a guide, 400m (1300ft) is a generally accepted maximum walking distance.

  - Disabled persons. Because the parking lobbies are used by both able and disabled users, the design is common and meets the standards for the more onerous access requirements.

  - In addition, because the cars are parked remotely from the users, a space premium in a designated number of parking positions for disabled persons is not required to meet national standards.

  - Good standards of visibility must be maintained at all times, particularly when parking facility access joins a main road. It is generally necessary to ensure that queues of vehicles waiting for access do not extend back to the main road.

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13. OPERATOR RESPONSIBILITIES

- Some basic support for the parking facility users on a day-to-day basis is required to deal with issues such as lost tickets, how to operate the system etc. Generally, this can be provided by telephone assistance local to the parking lobby area with the ability to provide physical on-site support by exception.

- These requirements may be more important in the early days after system handover to the client. A sensible precaution would be including for this level of day-to-day operational support for the first 3 months' usage from the APS system provider.

- Inevitably, with public access to the parking entry and exit lobbies, these need to be regularly inspected and checked for litter, dirt, contamination, left items etc. CCTV can be used to remotely monitor the condition of the lobbies, enabling the most efficient use of cleaning resources.

- Periodic physical cleaning will be required, both lobbies themselves and checking for any dirt accumulation on the vehicle sensing lenses.

- In addition, routine attendance to the ticketing machines and ticket bins will need to be carried out.

- Regular examinations of the APS should be scheduled to enable a systematic and detailed examination of the lift and all its associated equipment by a competent person.

- Its aim is to detect any defects which are, or might become, dangerous, and for the competent person to report them to the duty holder and, if appropriate, the enforcing authority.

- To determine the extent of the thorough examination, the competent person will assess the risks.

- A thorough examination may include some testing, if the competent person considers it to be necessary. The competent person will normally determine what tests are required, taking account of the relevant guidance and standards and duty holders are recommended to insist on this approach.

- Thorough examination may also be supplemented by inspection. Inspections should be carried out at suitable intervals between thorough examinations and may be done 'in-house' by a competent, trained employee.

- Inspections would normally include visual and functional checks, e.g. the alarm interlocks operate correctly, etc.

- Thorough examination should not be confused with preventive maintenance, although they have some elements in common. Preventive maintenance usually involves replacing worn or damaged parts, topping up fluid levels and making routine adjustments to ensure risks are avoided.

- A thorough examination may act as a check that maintenance is being carried out properly but is not intended to replace it.

- Thorough examination should include the following:
  - o overload detection devices
  - o electrical devices (including earthing, earth bonding, safety devices, selection of fuses, etc.)
  - o landing and lobby doors and their interlocks
  - o any worm and other gearing
  - o main drive system components
  - o all detecting, measuring & safety sensors
  - o governors
  - o safety gear
  - o any suspension chains
  - o braking systems (including buffers and over speed devices)
  - o any hydraulic connections

- The role of the duty holder is of vital importance. As the duty holder, you are responsible for ensuring that the vehicle lift system is safe to use and that it is thoroughly examined at regular agreed intervals.

- These responsibilities include:
  - o selecting and instructing the competent person to ensure that the system is examined at statutory intervals (every 6 or 12 months) or in accordance with an examination scheme drawn up by a competent person
  - o keeping the competent person informed of any changes in the lift operating conditions which may affect the risk assessment
  - o making relevant documentation available to the competent person, e.g. manufacturer's instructions and maintenance records
  - o acting promptly to remedy any defects
  - o ensuring that all documentation complies with the regulations and record keeping

- Selecting a competent person who is aware and involved in the normal monitoring of the APS performance is vital

- A competent person is someone who has sufficient technical and practical knowledge of the system to be able to detect any defects and assess how significant they are.

- It is also important that the competent person is sufficiently independent and impartial to allow them to make an objective assessment of the APS system.

- For this reason, it is not advisable for the same person who performs routine maintenance to carry out the thorough examination, as they are then responsible for assessing their own work.

- Our recommendation is that routine maintenance (see later) is always carried out by an external company, suitably accredited, qualified and experienced in the type of system being used.

- Ideally this would always be the system manufacturer or local approved partner.

14. SUSTAINABILITY

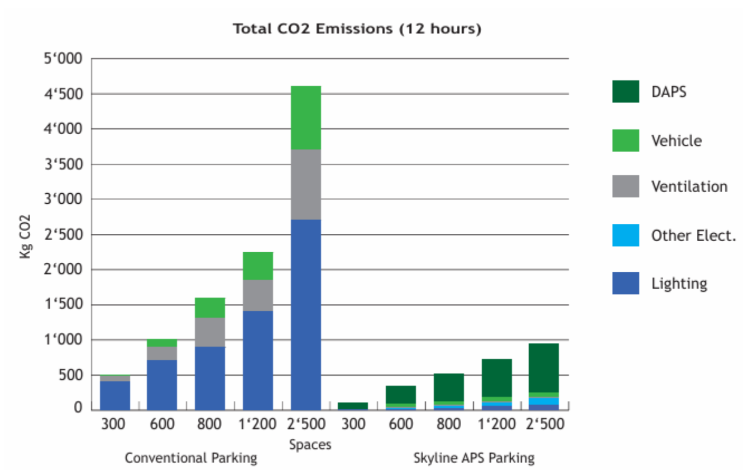
A key planning consideration for anyone responsible for corporate governance and shareholder interests.

- Reduced CO_2 emissions

Operational CO_2 associated with the operation of automated parking systems and CO_2 relating to the emissions from vehicles travelling round a multi-story parking facilities have been used in this comparison.

Over the survey period it was calculated that automated parking systems provide savings of between 84% and 86% on total CO_2.

The installation of low or zero carbon technologies would provide significant savings in both CO_2 and energy costs for both the automated and conventional scenarios.



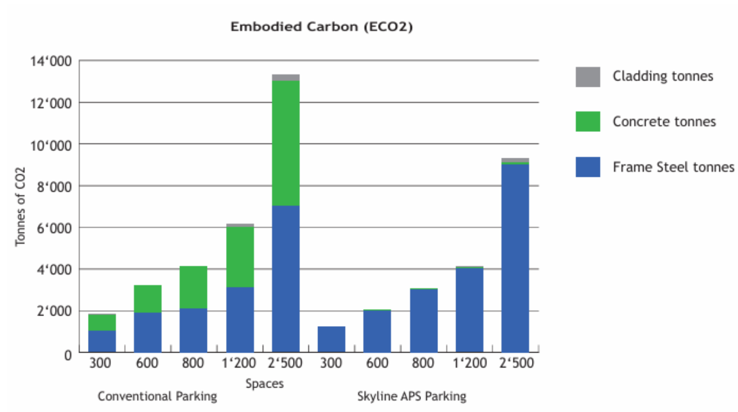
However, the vehicular emissions would remain for the conventional scenario.

The vehicle CO_2 emissions rise to over 1800kg in a 2,500 space parking facility over a 24 hour period.

In comparison, automated parking systems **do not produce any CO_2** in relation to the vehicles using the parking facility.

The embodied carbon (ECO_2) associated with both scenarios is also an important consideration.

Whilst automated parking systems use significantly more steel than conventional ones, the ECO_2 associated with the concrete required for a conventional parking facility far outweighs ECO_2 from the steel.

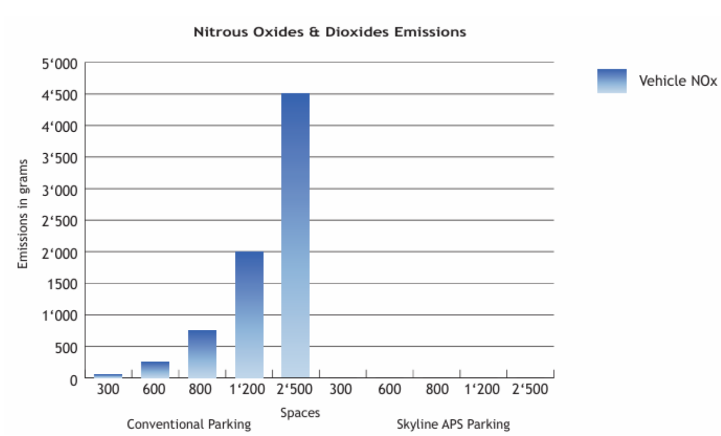


- Zero Nitrous Oxides/Dioxides & PM10 emissions

There are zero NOx and Particulate Matter pollution levels for Intelligent Parking Systems as vehicles do not drive around the parking areas to find or exit a space.

However, conventional parking facilities promote considerable emissions as vehicles enter and exit the facility.

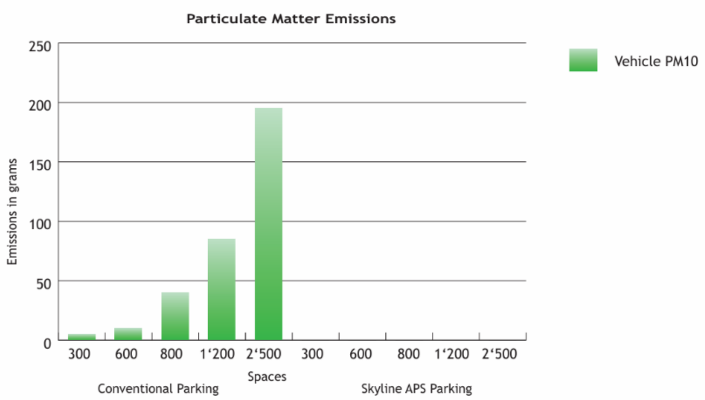
A 600-space conventional parking facility with average occupancy rates emits approx. 200 grams of NO & NO_2, combined with PM10 emissions.



Data relating to the vehicles themselves was taken from a Highways Agency report 'The Role of the High- ways Agency in Local Air Quality Management, 2003'; Part 3 'What effect would it have on air quality?'.

The Kyoto Protocol developed in 1997 sets several binding targets for the reduction of greenhouse gases of which N0x is one. A proportion of the N0x emissions from vehicles take the form of nitrogen dioxide ($N0_2$).

There is evidence that high levels of NO_2 and N0x can, over long periods, result in "severe irritation to the lungs, thereby making asthma sufferers particularly susceptible".



PM10 particulates are those that are of 10µm or less in diameter. PM10 is a primary pollutant emission for which there are no safe concentrations when considering human health. The size of the particle allows them to become lodged in the respiratory system. This can give rise to serious health implications including asthma, cardiovascular issues and even lung cancer.

- Improved country-specific sustainability ratings and building credits

Again, on the basis that if you must have a parking facility it should have as minimal an effect on the environment as possible, a key advantage of Intelligent Parking Solutions is that they enable sustainability credits that a conventional parking facility will not.

There are typically 12 categories of credits that can be obtained varying from Reduction of CO_2 Emissions through to Construction Waste Management.

These credits will have been independently assessed by independent country based accredited professionals and organizations.

Again, this is a major benefit when submitting plans to the local authority for approval.

Examples of typical categories are as follows:

✓ Construction Activity Pollution Prevention

The reduced footprint of automated system (30 – 50 % smaller) will assist the scoring of this credit by facilitating:

- A reduction in precipitation run
- A reduction in soil loss as a result in run-off
- A reduction in air pollution

✓ Site Selection

Automated systems could assist in the scoring of this credit by reducing the building footprint, therefore increasing the distance between the development and any sensitive receptors. Preferences should be given to the sites that do not include sensitive site elements and restrictive land types.

✓ Low-Emitting and Fuel-Efficient Vehicles

The use of automated systems would significantly enhance the achievability of this credit.

An automated parking system can provide specific spaces for these vehicles and charging points for electric vehicles.

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Parking Capacity

As above, automated systems would significantly enhance the achievability of this credit, as it requires the provision of ‘preferred parking’. This credit considers carpools and vanpools which could be given preference in the automated parking system design.

Maximize Open Space

The automated systems will significantly assist in the scoring of this credit by reducing the building footprint, providing an opportunity to use the additional space as open space and promoting biodiversity.

Storm water Design, Quantity Control

Automated systems will assist in the scoring of this credit by reducing the amount of impervious surfacing, in turn reducing surface water run-off. This will also reduce the costs associated with providing sufficient attenuation measures.

Light Pollution Reduction

Automated parking systems will assist in the scoring of this credit by significantly reducing the amount of light pollution. The limited requirement for lighting within the systems means that it would be considerably easier to meet the conditions required by this credit.

Minimum Energy Performance

Given the significant reductions in energy between the automated systems and conventional parking facilites, it would be easier to achieve this prerequisite.

Optimize Energy Performance

The use of an automated car parking system would provide a significant reduction in the ongoing energy consumption of the development. As such a greater number of credits may be achievable for this issue.

Building Re-use

Credits are awarded where a development re-uses a percentage of the existing materials in situ. The use of an automated parking system would allow the required parking spaces to be installed into the existing structure allowing credits to be achieved.

Construction Waste Management

The use of automated systems over the conventional parking facility would assist in the targeting of this credit. The use of automated systems would significantly reduce the amount of construction waste - the systems are prefabricated making this credit easier to achieve.

Materials Reuse

Given that most automated parking systems are predominantly constructed from steel, it would be straight-forward for a high proportion of the steel to be made from recycled materials assisting in the achievement of this credit.

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15. SYSTEM DESIGN STANDARDS

- Because of the disparities in requirements on automated parking, high importance should be attached to country specific and international regulations and norms. The following general regulations and norms are of importance:

- European Standard Concerning Design and Safety - **EN 14010** Safety of machinery - Equipment for power driven parking of motor vehicles - Safety and EMC requirements for design, manufacturing, erection and commissioning stages

- Recommendations for Car Parking Facilities - **EAR 23** The German parking guidelines

- Directions for Application - **VDI-Richtlinie 4466** Automatic parking systems - Basic principles

- Directive 2006/46/EC machinery directive.

- The EAR 23 and the VDI direction are going beyond the minimum legal requirements on automated parking systems and include specific demands for planning and installation.

- These papers show the actual state of the art and act as a valuable orientation tool for customers and planners as well as for the manufacturers themselves.

- But at best these documents give basic guidance as to the general requirement or a detailed requirement but only for a specific function. For an overall system specification, the best document has to be VDI 4466.

16. MAINTENANCE REQUIREMENTS

- There should be at least two major maintenance visits per year. In addition, there may be more frequent tasks listed. These tasks will also be performed during the larger maintenance session. In between these sessions, these tasks can be performed by the competent person.

- During major service visits the following tasks are performed as a minimum.

  o Greasing & replacement of worn parts
  o Retightening of screws and bolts where necessary incl. preventive repair work whenever necessary
  o Testing of the movement of the transport belts
  o Testing of the movement of the transport system

- Detailed system maintenance requirements should always be obtained from the system manufacturer aligned to the system warranties and guarantees.

- Requirements vary greatly depending on the system type and provider so specific guidelines must be obtained in that regard.

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17. FREQUENTLY ASKED QUESTIONS

Question	Answer
How is my car parked?	The transportation system moves the car from the entry ramp to the lift, from here to the selected floor and now the vehicle is put into the correct parking lot. Technically, all transport operation is executed only touching the car's tires.
How many cars can be stored in an automatic parking installation?	Between 60 and 5000 spaces.
How can you store so many cars on such a small footprint?	Automatic Parking Systems (APS) do save a lot of space compared to conventional ones as automatic systems do not require any driving ramps, elevators or walkways for drivers. Also, the APS allows parking lots of different sizes by varying parking floor heights (low, medium and high) and dimensions (narrow, wide-short, long). This leads to a better use of space, because the parking lots correspond to the different car sizes.
Is there any danger of my car getting damaged?	No. APS solutions are safe, not only for the user, but also for the cars – there is no danger of damage. Our products are designed to worldwide safety standards and each scenario and probability is tested and studied. Also, there is no risk of vandalism or damage to the cars as the public do not need access to the parking area.
How do I get the right car back?	Each ticket contains an identification number which is directly linked to the car.
Can I call when I want my car back?	Yes, most providers can provide various ways to allow remote requests and guarantee a higher customer benefit.
What if I get the wrong car back?	This is not possible. However, if someone finds your ticket and gets your locked car, they cannot enter and the car and is put back after a few minutes. In addition, there is normally video surveillance and/or number plate recognition systems.
How long do I wait for my car?	The waiting time for a well-designed system should be around 60 seconds but you need to check the performance data for the specific supplier to confirm this is possible.
Is there a waiting room?	Yes, good designs will include a lounge with visual display screens showing your vehicle being moved to the exit lobby.

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Question (cont.)	Answer (cont.)
When I get my car back can I just drive away?	Yes – the cars are delivered to the exit lobby ready to drive away in a forward direction. No maneuvering is necessary.
Where do I get my car back?	You will be guided to the correct exit lobby. After the payment process at the checkout (if applicable) the machine will tell you which exit lobby your car is in and where to go. Your route will be very well signposted.
After having pre-ordered my car – what happens if I am late?	The car can be picked up from the exit lobby or a space nearby during a fixed time period. After that time, your car is returned to the main car parking area automatically by the car parking system. You can then request it again when you arrive as normal.
How much time do I have to drive away?	As soon as you have entered the exit lobby, there is no time restriction. You can load or unload your car at your own pace.
Is there enough time to load and unload the car?	Yes, absolutely, there are no time restrictions. You can load or unload your car at your own pace.
If it takes a long time for me to load my car, do I block the whole system?	No. Systems should be designed with more than 1 entry/ exit lobby and dedicated loading/unloading zones as required.
Can my car be damaged through vandalism?	No, this is not possible. Nobody besides maintenance people have access to the parking levels. In addition, good designs should equip installations with video surveillance systems and motion sensors on every deck.
How can the system know where my car is?	The ticket, containing an identification number, provides the system with all the individual car information together with the data from the car-measuring-system (length, width, height and weight) in the entry lobby, which includes all the related information needed for the car. The software tracks every single car and stores the data in case of ticket loss. The good design should ensure that there is a video surveillance and a number plate recognition system.
How reliable are automatic parking systems?	Very reliable when they are correctly designed and sourced from reputable manufacturers. Check the accreditation and performance characteristics for the system first – these vary greatly by manufacturer.

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Question (cont.)	Answer (cont.)
In the unlikely case of a system failure or breakdown – can the cars parked inside be taken out manually?	Yes, there is normally manual process which overrides the automatic process. However, machines still need to work. In larger parking facilities, there is usually redundant transport systems included in the design so that a failure of one car shuttle will not affect the system.
What if my car catches fire?	The design should include an automatic sprinkler system in each car parking bay which operates and extinguishes or contains the fire until the site-based or local authority fire service can attend. Automatic parking facilities are safer than conventional because the public will never be near the potential source of the fire, i.e. the parked car, and not all conventional parking facilities have sprinklers.
Cars are parked closer together, is there any increased risk of a fire?	No, there is a reduced risk of a fire starting because the majority of the few fires in parking facilities are started maliciously or accidentally in waste materials left by the public in the car parking area. Also, current building regulations are exceeded with sprinklers in the car parking area, meaning the structure is far better protected than in a conventional parking facility.

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