Case Study Building Specification: Electric Vehicle Charging in High-Rise Car Parks

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Introduction

This case study evaluates performance-based fire safety strategies and challenges associated with integrating electric vehicle (EV) charging infrastructure into an existing multi-story car park serving residential and commercial occupancies. The scenario represents a realistic and evolving issue across Asia and globally, as governments and private owners accelerate the shift toward EV adoption while working within aging infrastructure.

The analysis emphasizes the evaluation of fire risk from EVs and practical trade-offs between safety and cost, and constraints of the existing building construction. The project requires the application of performance-based design principles to determine acceptable solutions under constrained conditions.

Objective

New building legislation mandates EV-ready charging stations for car parks, requiring 100% for residential occupancies and 20% for commercial occupancies. To comply with current regulations, the building owner intends to modify an existing car park as follows:

1. Install EV charging stations at 50% of the parking spaces (a minimum of 300 of the existing 600 bays).
2. To increase car park capacity, a new car stacker will be constructed with integrated EV charging. The proposed location would be along the existing exterior wall adjacent to the existing vehicle entrance (adding 72 car park bays).

The proposed upgrades face regulatory and engineering concerns from the Fire Services Department and insurers. These stakeholders have proposed limiting the number of charging stations unless fire and life safety upgrades are implemented. This case study will examine the feasibility of the owner's request and identify the necessary measures to ensure safe implementation. This will include the distribution of the charging stations and car stackers aboveground and underground.

Existing Building Description

The project stakeholders have reviewed the car park and identified the following features and concerns:

- The 7-story car park consists of three (3) underground and four (4) aboveground levels. Vehicle entrances and exits are provided at the highest underground level and the lowest above-ground level.
- Floor-to-ceiling clear height is typically 2.8 meters above the finished floor.

- A 2-hour fire compartmentation with normally-open fire shutters separates the above and below-ground levels. No additional compartmentation is provided at other levels.
- On each aboveground level, one (1) car park wall adjacent to the shopping plaza is solid. Three (3) exterior walls are 50% open for natural ventilation.
- Vertical circulation occurs via a corkscrew/ramp configuration. Parking spots are along the perimeter of landings at each level, as well as along the sloped vehicle ramps.
- Two (2) stairwells are provided with a 2-hour fire-resistance rating and 90-minutes opening protection, providing compliant means of egress for an existing building.
- Each stair contains a manual dry standpipe requiring a fire department pumper truck to supply water from an existing municipal fire hydrant providing a static pressure of 3.5 bar, and flowing pressure of 3,800 Liters/minute at 1.4 bar.
- The aboveground levels are <u>not</u> protected with an automatic sprinkler system. An outdated fire sprinkler system is installed in the underground levels, designed to 5 mm/min over 140 square meters, with no recent maintenance records. The sprinklers are standard response (RTI ≥ 80 [ms]½) and intermediate-temperature operating at 79°C (175°F). A 25 m^3 water tank supplies the sprinkler system via a fire pump. Tank infill is via 100 mm municipal piping.
- The existing fire alarm system provides bell-only notification (no voice communication or visual alarm notification appliances). The underground levels do <u>not</u> provide detection and are only activated by the fire sprinkler system. The aboveground levels are provided with fixed-temperature heat detection with an activation temperature of 57 °C (135 °F) and up to 15 meters spacing.
- Smoke detection is provided in the elevator lobby to close the lobby doors and recall the elevator. It is noted that most doors on hold-open devices are held open with door wedges.
- The car park is connected to adjacent occupancies. While the existing car park is constructed of concrete, the adjacent and above façade is constructed of glazing:
    - Above: a mixed-use facility consisting of 3 floors of medical/dental clinics, 10 floors of offices, and a 10-story residential apartment tower. The structural slab at the interface consists of 140 mm of concrete, with all pipe and duct penetrations grouted in place. PVC drain piping is used for upper-floor drainage.
    - Adjacent: on the wall opposite to the natural ventilation, the car park is attached to a shopping plaza, separated by a 2-hour fire-rated barrier according to as-built drawings. Access doors are provided on one (1) underground level and three (3) aboveground levels.

Figures 1 and 2 provide a sketch of the existing facility:

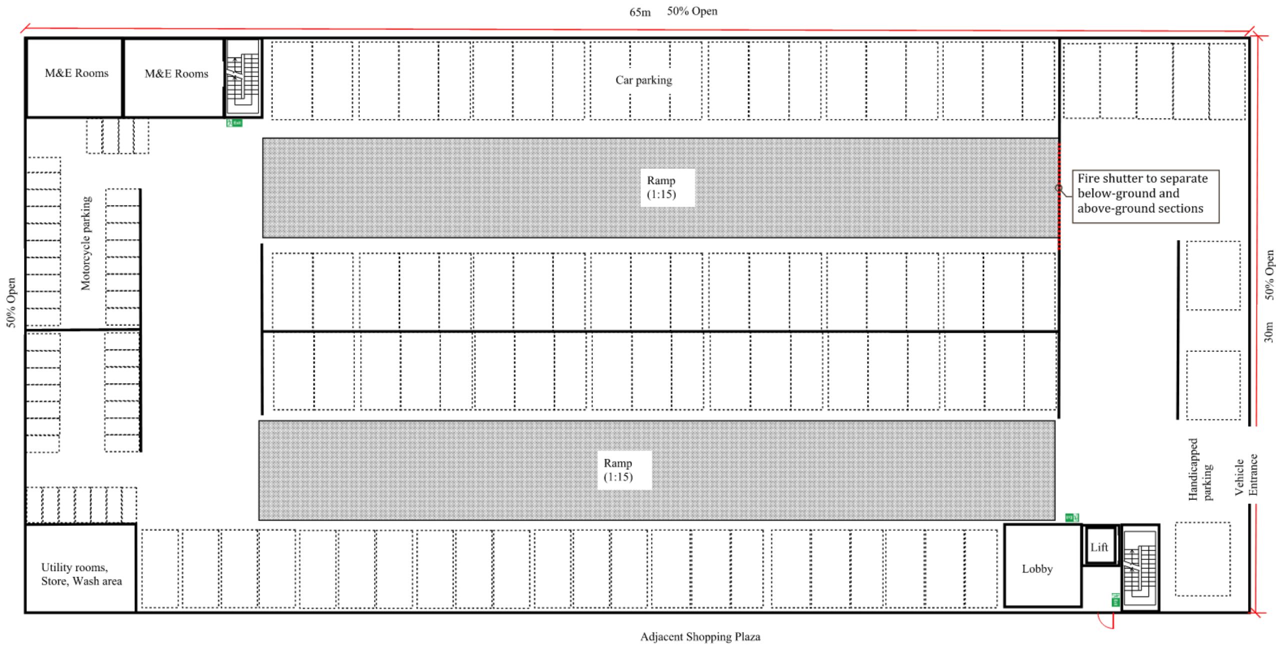

Figure 1 Typical Layout Plan (Ground Level)

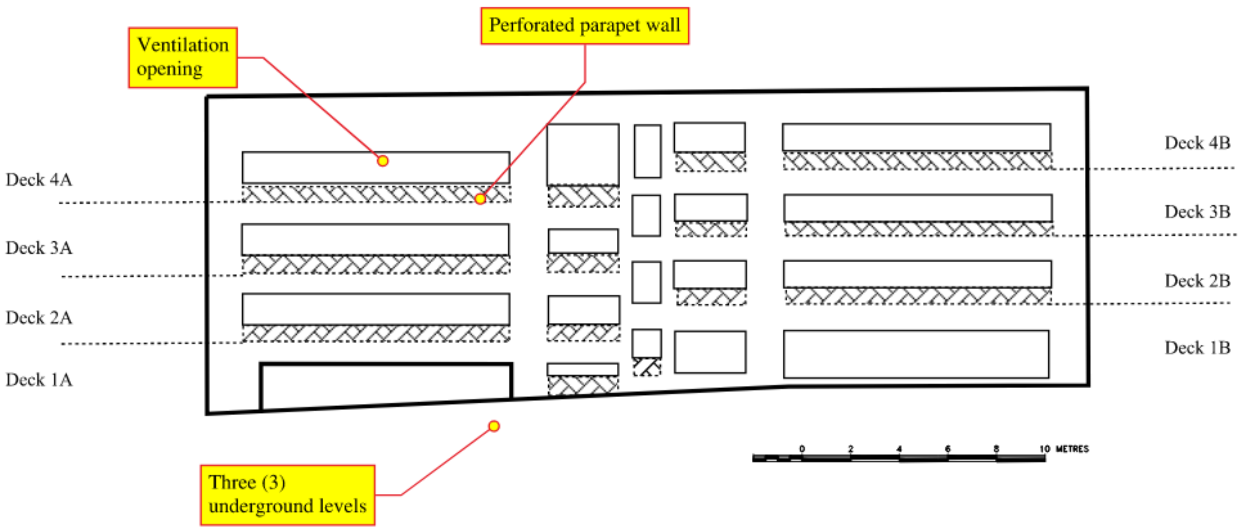

Figure 2 Elevation View

New Car Stacker Description

A preliminary feasibility study by the building owner indicates that car stackers with integrated EV charging could be installed for the four (4) story aboveground portion of the facility adjacent to the existing car park entrance, creating 72 additional parking spaces (2 stacks, each 4 tiers high, and 9 vehicles per tier). Figure 3 indicates the proposed car stacker location.

Stakeholders have observed that similar car stacker installations are typically separated from adjoining spaces by 2-hour fire-rated construction. In this case, such separation would reduce the wall's existing 50% open condition, potentially affecting ventilation and code compliance.

Overall design:

- Total stack enclosure height: 10 meters
- Enclosure dimensions: 15 meters x 22 meters
- Design vehicle mass per bay: 2,500 kg
- Setback from existing wall: 600 mm

Module geometry (per bay):

- Clear pallet size (usable): 2.00 m W × 5.10 m L (solid)
- Pallet overall (including side beams/rails): 2.30 m W × 5.30 m L
- Pallet structural depth: 0.12 m (steel deck + rails)
- Vertical clear per vehicle slot: 2 meters clear + 0.15 meters (underside clearance to pallet)
- Inter-pallet service gap: 0.10 m

Figures 3 and 4 provide a sketch of the proposed car stacking facility:

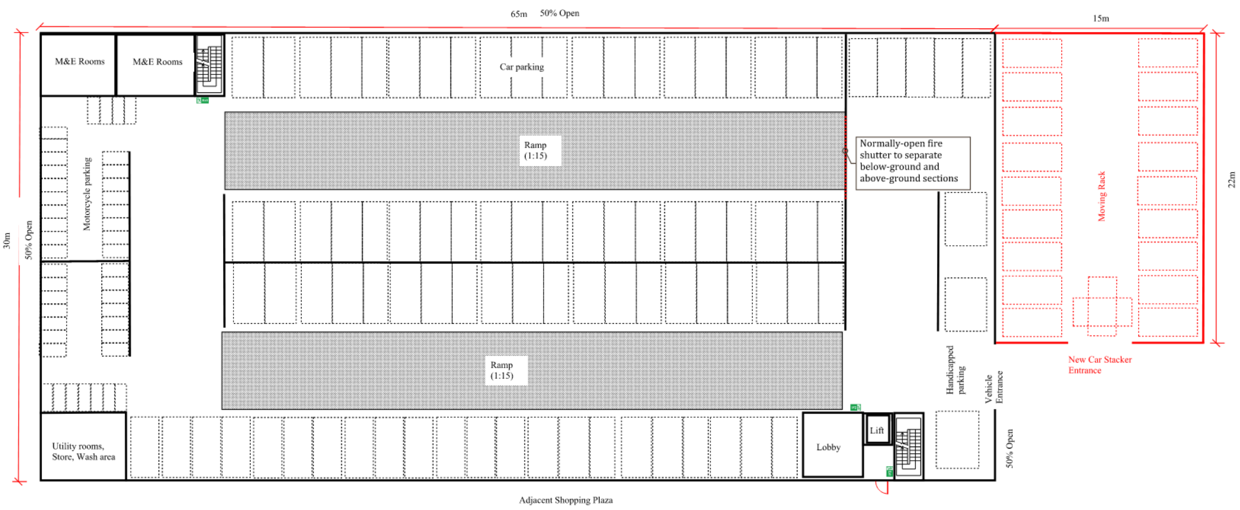

Figure 3 New Car Stacker Configuration Plan (Ground Level)

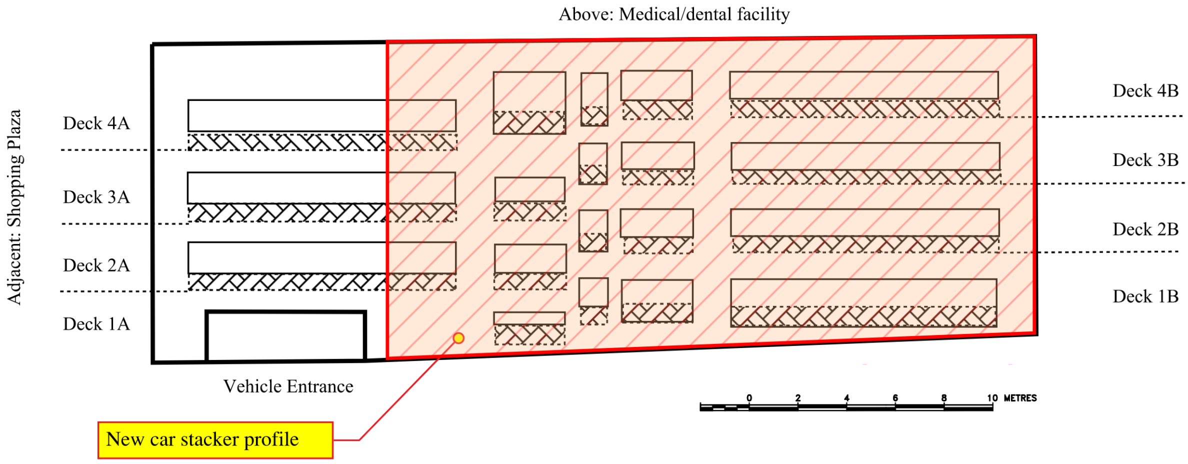

Figure 4 New Car Stacker Configuration Plan (Section View)

Fire and Safety Life Safety Goals

The fire and life safety analysis should examine the phased deployment of EV chargers and car stackers, and evaluate the corresponding fire protection requirements. The goal is to identify a scalable strategy that maximizes benefits while maintaining an acceptable level of risk.

The Owner would like to determine:

1. *No upgrades:* The number and location of EV charging stations and car stackers that can be safely installed at present, without changes to the existing building and fire/life safety systems.
2. *Full upgrade:* The measures required to safely enable EV charging stations for 50% of existing car bays, if any.
3. *Car stackers:* The measures required to install the car stacking facility with integrated EV charging safely.

Key considerations might include, but are not limited to:

- Fire load and heat release rate (HRR) from electric vehicles, especially during thermal runaway events.
- Impact of car parks on sloped ramps.
- Impact of EV charging on egress times, tenability, and smoke/heat spread.
- Capability of existing suppression and detection systems to handle EV fires.
- Firefighter access and response challenges in semi-open and underground environments.
- Viable options for upgrades to the existing building, such as improved detection, smoke curtains, compartmentation, sprinklers, mechanical ventilation, fire-

fighting, and emergency response planning. Alternatively, confirming that the existing building provides sufficient fire and life safety protection.
- Fire and life safety requirements of car stackers and assessment of any alterations to the wall's existing 50% open condition.
- Fire and life safety related to adjacent and above occupancies, if any.

Project Report Requirements

The design and analysis of the building needs to be documented in a holistic fire safety strategy report and presented at the conference. Equal emphasis needs to be given to the building fire safety design and fire safety strategy, as well as the methodology for assessment to verify the performance.

The report should highlight all the key fire safety design decisions and fire protection measures chosen, and their rationale.

The report should also detail the performance-based fire safety engineering methodology utilized for the assessment of the building and its provisions.

All relevant assumptions made as part of the supporting analysis, all relevant inputs, all relevant performance criteria utilized, and the data, research, and/or engineering expert judgements utilized as part of each performance-based methodology should be identified.

The report should also include the following:

1. A summary and description of all assumptions, limitations and design simplifications utilized as part of the analysis, including a discussion of any assumptions that would directly impact the concluding fire safety design strategies.
2. A discussion of the selected acceptance/performance criteria utilized for each part of the analysis. The teams are encouraged to consider risk (or risk tolerance) as part of the criteria selection process.
3. A summary of all calculations, modelling, data, etc., utilized to support the fire safety design strategies. Relevant details of each can be provided as long as they clearly demonstrate and support the concluding fire safety design strategies.
4. A summary of the concluding fire safety design strategies with a discussion of how the performance of the fire safety design can be maintained over time.