"Preventing the Next Luton": A Novel Risk-Based Approach to Fire Safety and Operational Resilience in Airport Car Parks

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Abstract

The 2023 Luton Airport car park fire, which destroyed over 1,300 vehicles and caused £20M in losses, highlighted vulnerabilities in Multi-Storey Car Parks (MSCPs) and the limitations of UK regulations that prioritize life safety over operational resilience. This study introduces a sector-first, risk-based framework methodology designed to identify and prioritize enhancements that mitigate the operational, financial, and reputational impacts of severe fire events. The approach was applied to nine MSCPs across two UK airports, combining desktop analysis, on-site inspections, impact-based assessments, fire engineering evaluations, and global benchmarking. Findings indicate that all MSCPs would benefit from targeted improvements, including upgrading fire detection systems, retrofitting fire collars to drainage systems, improving compartmentation at building interfaces, and evaluating sprinkler systems through cost-benefit analysis. These enhancements, aligned with evolving vehicle technologies and international best practices, offer significant reductions in disruption risk with relatively modest investment. The proposed framework shifts the focus from regulatory compliance to proactive resilience, providing a replicable model for aviation infrastructure and other complex environments. By adopting this structured methodology, stakeholders can strengthen fire safety strategies, protect passenger experience, and safeguard operational continuity in the face of emerging fire challenges.

Keywords: multi-storey car parks; airport fire safety; risk-based assessment; operational resilience; fire detection systems; compartmentation; sprinkler evaluation; vehicle technology; international best practice; fire engineering.

1 Introduction

The 2023 Luton Airport [1] car park fire destroyed over 1,300 vehicles, caused approximately £20 million in property losses, and disrupted more than 150 flights. This was not an isolated event in the UK; a similar incident on New Year’s Eve 2017 at Liverpool’s Kings Dock MSCP [2] engulfed around 1,400 vehicles and resulted in damage exceeding £20 million.

These incidents highlighted vulnerabilities in Multi-Storey Car Parks (MSCPs). While UK regulations primarily focus on life safety, guidance on mitigating wider operational, financial, and reputational risks remains limited. As neither the Liverpool Kings Dock fire nor the Luton Airport fire resulted in loss of life, industry and government responses have been relatively limited, with few, if any, significant changes to design standards and building codes of practice.

Although car park fires are extremely rare, evolving vehicle characteristics, including increased size, higher fire loads, and electrical risks have raised potential hazard. The overall risk remains low when compared to the vast number of vehicles using car parks daily, but the consequences justify attention for car park owners and operators seeking to reduce business continuity and property protection risks.

The objective was to develop a standardized framework for assessing fire safety improvement opportunities for different MSCPs built at different times, under varying client specifications and legislative requirements, incorporating diverse structural materials and fire safety provisions.

2 Methods

2.1 Framework development

The methodology applied a structured, risk-based approach to evaluate the extent to which inherent safety systems within each MSCP can reduce this impact, focusing on both the likelihood of a large-scale fire and its wider operational, financial, and reputational impacts.

The methodology included:

- Desktop analysis of construction and existing fire safety systems
- On-site inspections to verify regulatory compliance
- Impact-based assessment to prioritize enhancement options
- Fire engineering analysis to evaluate resilience improvements
- Industry benchmarking to align with global best practice

The methodology draws on *PAS 9980: Fire Risk Appraisal of External Wall Construction and Cladding of Existing Blocks of Flats – Code of Practice [3]*, combined with on-site inspections and desk-based studies. This enabled an impact assessment, ranging from high to low, to be created based on the car park's fire safety strategy, construction type, and active/passive fire protection measures.

Although PAS 9980 focuses on risk rather than impact, the principles which form the basis of its methodology for assessing risk can be applied and used to build a suitable framework.

2.2 Impact assessment methodology

Risk-based benchmark criteria for car park fire safety (*key considerations*) were generated by the assessors based on assessing historical fire data from the client as well as UK standards for the design and refurbishment of new car parks such as BS 9999 [4], wider industry guidance [5-9] and international guidance [10].

The assessment considered the following as *key considerations*:

- **Fire Performance**: Likelihood and speed of fire spread, based on materials, components, and fire/life safety systems.
- **Firefighting Access and Facilities**: Ability of fire and rescue services to respond effectively, and factors influencing intervention success.
- **Means of Escape**: Potential harm to occupants and impact on evacuation, considering design features and hazards.
- **Fire and Smoke Spread**: Development and escalation of fire/smoke to adjoining infrastructure (e.g., terminals, airfield), including internal features such as drainage.
- **Building Configuration and Features**: Structural or operational elements that may increase fire loading, ignition sources, or hinder firefighting efforts.

For each *key consideration* a series of *common impact factors* were developed and used for the assessment. These common impact factors are given in Table 1 below.

Using the information obtained from the literature review each *common impact factor*, (such as fire resistance of the structure) was then assessed for its potential positive, neutral, or negative influence on fire safety and its contribution. For example: work commissioned by the Building Safety Regulator in the UK [11] identified that "*ceiling height is an influential factor in determining fire severity, with modest increases resulting in reductions in the probability of extended fire spread and lower time equivalence values*", the same research also noted the internal air speed was also a mitigating factor, so *common impact factor*: *A.3 Factors Impacting Likelihood of Flashover*, sets an arbitrary positive value where ceiling are in excess of 3 m and there is a large (over 50%) amount of open ventilation.

However, despite using an arbitrary numerical value in this example, numerical values have been avoided, as far as practical, by the assessors, to allow a qualitative type of assessment. Where numeric values were given, these are only intended to be indicative as to the possible influence the factor might have in a risk-based assessment.

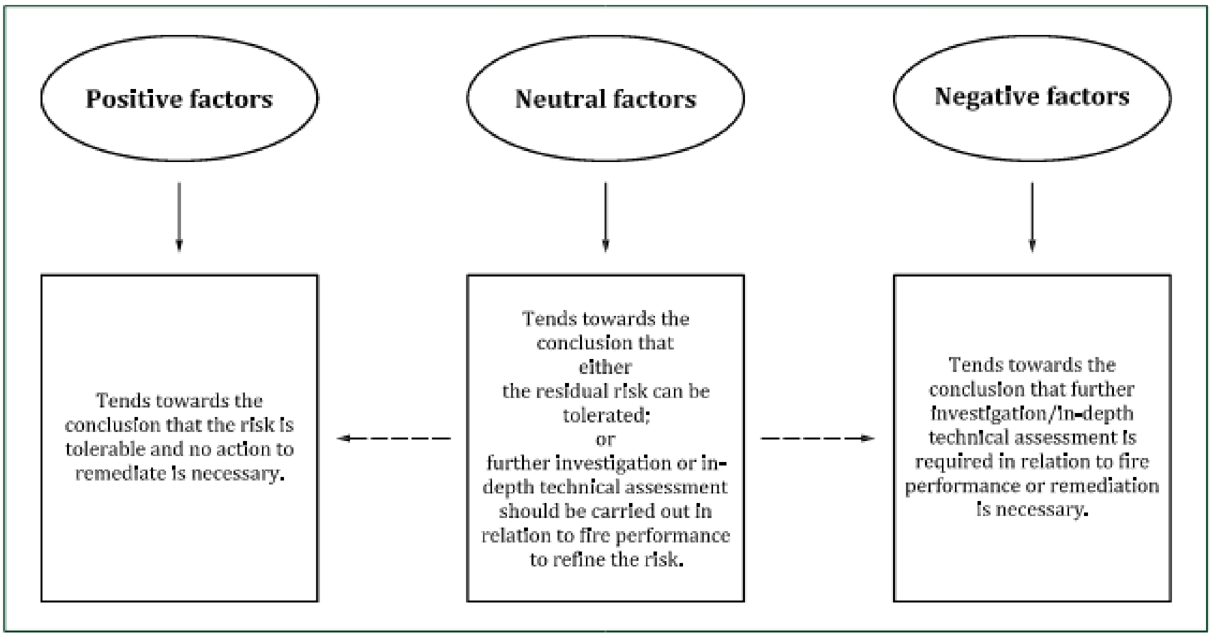

Figure 1. PAS 9980 Figure 5 – Possible outcome of impact factor weighting

Figure 1, extracted from BS 9980, gives guidance for assessors in how to assess whether a common impact factor trends towards positive, neutral or negative.

The relevance of the *common impact factors* can vary within different buildings or even within different parts of the same building. Consideration is given by the assessor as to how significant such variations are when assessing the fire impact on the building.

No single *common impact factor* gives a definitive answer on impact. Whether an entry is considered positive, negative or neutral is purely indicative of the potential influence it might have. Careful judgement is needed when using these *common impact factors* to determine the actual relevance of each factor and its significance in the context of the building under consideration.

Table 1. Fire Safety Key Considerations and Common Impact Factors

	Key Considerations & Common Impact Factors	**Classification Criteria**
A	**Fire Performance**	
A.1	*Fire Resistance of Structure*	**Negative** -No FR or sub 30 minutes fire resistance to structure or floors **Neutral** - 30 minutes fire resistance **Positive** - 60 mins (plus) fire resistance to structure (columns, beams and floors)
A.2	*Structural Materials*	**Negative** - Timber or composite materials (including floors) **Neutral** - Steel and concrete floors **Positive** - Concrete structure.
A.3	*Factors Impacting Likelihood of Flashover*	**Negative** - Any ceiling height and limited opening to elevations (e.g. <50% total elevation area) **Neutral** - Low ceilings (<3m) and open sides >50% elevation **Positive** - Open deck or high ceilings (>3m) and open sides >50% elevation

A.4	*External Materials (Cladding)*	**Negative** - External wall materials, components/systems and configurations that are combustible, but with no knowledge of fire behaviour or known poor behaviour. **Neutral** - External wall materials etc. that are combustible, but with adequate fire performance. **Positive** - Predominantly non-combustible external wall materials
A.5	*Fire Loading / Stored Materials*	**Negative** - Storage of materials within the car park or open storage in close proximity externally. **Neutral** - Materials stored in separate fire rated stores **Positive** - No materials stored
A.6	*Attachments*	**Negative** - Features such as brise soleil incorporating combustible material, photovoltaic (PV) installations, illuminated signage / advertising. **Neutral** - Attachments of limited combustibility or combustible attachments (e.g. advertising) of limited extent **Positive** - No attachments or non-combustible attachments
A.7	*External Surfaces Classification*	**Negative** - BS 13501 [12] Class D or worse **Neutral** - BS 13501 Class B or C **Positive** - BS 13501 Class A
A.8	*Structural Inspections*	**Negative** - No regular structural Inspections are undertaken **Neutral** - n/a **Positive** - Structure is regularly assessed and maintained in accordance with the ICE guide "*Recommendations for the Inspection, Maintenance and Management of Car Park Structures*"
B	**Firefighting Access and Facilities**	
B.1	*Vehicle Access*	**Negative** - No or minimal vehicle access **Neutral** - Adequate vehicle access **Positive** - Good vehicle access
B.2	*Façade Access Restrictions*	**Negative** -Parked vehicles or security barriers blocking access to facades **Neutral** - No obstructions to roadways or easily removeable barriers **Positive** - n/a

B.3	*Fire Fighting Lifts*	**Negative** - No FF lifts in building >18m **Neutral** - No FF lifts in building <18m **Positive** - FF lifts any building height
B.4	*Rising Mains*	**Negative** - No rising mains **Neutral** - Dry rising mains **Positive** - Wet rising mains
B.5	*Suppression*	**Negative** - No suppression system **Neutral** - Water mist suppression system or partial sprinkler protection **Positive** - Full BS EN sprinkler system
B.6	*Smoke Ventilation*	**Negative** - No smoke ventilation **Neutral** - Natural smoke ventilation **Positive** - Mechanical smoke ventilation
B.7	*Manual Fire Fighting Measures*	**Negative** – None provided or limited installation **Neutral** - Extinguishers located and installed to BS 5306-8 **Positive** - Fire extinguishers located / installed to BS 5306-8 including specialist extinguishers for car fires
B.8	*Hydrants*	**Negative** - No obvious fire hydrant **Neutral** - Fire hydrant within 90m of entry point to building **Positive** - Multiple fire hydrants in close proximity to the building
C	**Means of Escape and Warning**	
C.1	*Occupancy*	**Negative** - n/a **Neutral** - Members of public & staff **Positive** - Staff only
C.2	*Evacuation strategy*	**Negative** - n/a **Neutral** - Phased evacuation **Positive** - Simultaneous evacuation
C.3	*Travel Distances*	**Negative** - Extended travel distances **Neutral** - Code compliant travel distances **Positive -** Minimal or short travel distances
C.4	*Escape Route*	**Negative -** No protected lobbies and/ or open stairs **Neutral** - Unventilated protected lobbies to stairs **Positive** - Direct access to outside and / or ventilated lobbies to staircases.

C.5	*PRM Evacuation*	**Negative** - No PRM evacuation facilities **Neutral** - Refuge lobbies **Positive** - Evacuation lifts and refuge lobbies
C.6	*Fire Alarm and Detection*	**Negative** - No fire alarm and detection **Neutral** - Manual fire alarm and detection **Positive** - Comprehensive automatic fire alarm and detection
C.7	*Signage and Emergency lighting*	**Negative** - Insufficient escape signage and / or emergency lighting provided **Neutral** - Sufficient escape signage and emergency lighting provided **Positive** - PAVA combined with live feed CCTV, signage and emergency lighting
D	**Fire and Smoke Spread**	
D.1	*Connectivity to Terminal*	**Negative** - Direct door / opening connection to terminal **Neutral** - Link bridge connection to terminal **Positive** - No direct connection to terminal
D.2	*Compartmentation*	**Negative** - Inadequate compartmentation **Neutral** - Adequate compartmentation **Positive** - n/a
D.3	*External Wall / Cladding Connectivity*	**Negative** - Car park and terminal connected by materials with unknown or poor fire performance. **Neutral** - Car park and terminal connected by materials with adequate fire performance. **Positive** - Not connected or connected by predominantly non-combustible materials
D.4	*Drainage*	**Negative** - Plastic and / or aluminium drainage **Neutral** - n/a **Positive** - Plastic drainage with crush collars / cast iron drainage
D.5	*Ramps and Openings*	**Negative** - Sloping floors or level floors but open ramps and / or unbunded openings (lightwells) **Neutral** - Open internal ramps and other bunded openings (lightwells) or no other openings. **Positive** - External ramps / spiral ramps discharging to external point

D.6	*Cavity barriers and fire stopping*	**Negative** -Inadequate or missing fire stopping and cavity barriers **Neutral** - Cavity barriers / fire stopping present. **Positive** - Cavity barriers / fire stopping present and provided with third party certification.
D.7	*Fire Doors*	**Negative** - Doors to protected routes either not fire doors or missing / substantially damaged. **Neutral** - Minor maintenance issues to fire doors that have been reported / recorded. **Positive** - n/a
E	**Building Configuration and Features**	
E.1	*Building Height*	**Negative** - Over 18m **Neutral** - 11m to 18m **Positive** - <11m
E.2	*Potential disruption to airfield / apron*	**Negative** - Proximity of car park to airfield / apron such that smoke plume could disrupt operations **Neutral** -Car park located sufficiently far from airfield / apron to not disrupt operations **Positive** - n/a
E.3	*Potential disruption to critical infrastructure / buildings*	**Negative** - Carpark sufficiently close to adjacent critical infrastructure that fire spread, or smoke egress could occur. **Neutral** - Buildings / infrastructure located sufficiently remote. **Positive** - n/a
E.4	*EV Charging*	**Negative** - EV charging present within the car park **Neutral** - EV Charging present outside the car park **Positive** - No EV charging present
E.5	*Parking arrangements*	**Negative** - Nose to tail (contract) parking **Neutral** - Predominantly standard sized parking bays **Positive** - Predominantly extra sized or disabled bays
E.6	*Collision Reduction Measures*	**Negative** - Poor sight lines and / or no collision reduction measures **Neutral** - Good sight lines and some collision reduction measures **Positive -** Speed controls, providing good sight lines and lighting, sufficient space to turn and park vehicles, bays suited to current car dimensions, providing a one way system and providing rubber pads to columns

E.7	*Routine Inspections*	**Negative** - No routine inspections by a responsible organisation and / or no reporting mechanism for faults **Neutral** - Routine inspections by a responsible organisation with a reporting mechanism for faults **Positive** - Onsite team undertaking regular & documented inspections with reporting mechanisms.
E.8	*Security*	**Negative** - No security strategy **Neutral** - Passive security strategy (e.g. fences and post event CCTV etc.) **Positive** - Active security strategy including visible patrols and live feed capable CCTV.

For each group of *common impact factors* forming a *key consideration*, the overall decision whether a *key consideration* is trending towards positive, neutral or negative is attached to the number and significance of the impact factors:

- The dominance of positive factors supports a low impact conclusion, indicating a high probability of meeting fire safety criteria.
- A dominance of negative factors supports a high impact conclusion, indicating likely failure to meet criteria and justifying remediation.
- Neutral or mixed factors may suggest a medium impact, but this must be based on evidence and not assumed by default. Where uncertainty exists, further fire engineering assessment may be required.

Importantly, the number of factors does not equate to quantification; rather, it strengthens the evidence base for the assessors to make the determination on how each group influences the overall fire impact position on the high-to-low scale. This prevents the addition of multiple lower risk impact factors obfuscating the importance of a higher risk impact factor within a *key consideration*.

Once the *key considerations* and *common impact factors* were agreed by all members of the assessment group and validated through peer review, the next step involved gathering comprehensive information about the buildings and their construction, covering both *key considerations* and *common impact factors*, such as:

- What materials, components and systems have been used and how they are configured on or within each building. This includes identifying the type of structure, provision of fire compartmentation and fire stopping (e.g. cavity barriers) or their absence in locations where they would normally be expected.
- The scope for a fire involving the building to circumvent the compartmentation in the building and any other relevant factors (e.g. proximity) that might influence the ability of fire to spread.

This information was gathered by a combination of a review of all relevant and available documentary evidence and visual inspection of the building. A comprehensive desktop review of all available documentation, including as-built drawings, maintenance records, and structural details was undertaken to establish a baseline understanding of the car park's age, design, and previous interventions. The subsequent onsite inspection for each MSCP was systematic and covered all critical components such as the structural frame, decks, expansion joints, drainage systems and cladding, to ensure that each *common impact factor* (and therefore *key consideration*) was addressed. Site measurements as well as photographic and video evidence were taken to provide an auditable record.

Following the site surveys and subsequent data analysis, each MSCP was evaluated against the *common impact factors*, and an appropriate classification was assigned for each impact factor. Based on these classifications, an assessment outcome (e.g. positive, neutral or negative) was then applied to each *key consideration*, which then generated an overall *impact profile* for each car park (from high to low). Providing an *impact profile* for each car park enabled a comparative analysis across facilities.

The results of the site survey and data analysis were screened against the pe-defined classification criteria by at least two independent assessors to minimize bias. Disagreements were resolved through discussion, with the input of a third assessor where required. Each decision was documented against each individual *common impact factor* in the form of assessor's comments, which were recorded within the assessment report and saved for audit purposes.

2.3 Assessment of enhancement potential

Estimating the current *impact profile* for each MSCP provided a basis for determining whether further enhancements were required to reduce potential business impacts.

Enhancement options were categorized as:

- Potential fire safety enhancements: enhancements with significant impact reduction (e.g., shifting from medium to low) such as active fire suppression.
- Additional measures: Measures that improve safety but have limited effect on overall impact (e.g., collision risk reduction, supplementary first-aid firefighting equipment for airfield responders).

Once potential fire safety enhancements and additional measures were identified, the assessors would then re-run the assessment with the alteration of relevant *common impact factors* to reflect the benefits if the enhancements and measures were included. This would provide a revised *impact profile*.

While outside the scope of this study, the client was then able to take each potential fire safety enhancement and additional measure, provide a cost for the work and make an informed decision on whether the costs associated with the work were worth the cost of the enhancement or additional measure.

3 Results

The outcome of the assessment positioned the fire *impact profile* of the individual MSCP on a relative scale from low to high. A low impact indicates acceptable construction, while a high impact reflects an unacceptable situation, such as:

- Extremely rapid external fire spread.
- Secondary fires causing widespread disruption or property loss.
- Fire or smoke compromising escape routes beyond the car park (e.g., adjoining terminal).
- Inability of fire and rescue services to prevent severe disruption or loss.

For confidentiality reasons, a complete assessment of the results cannot be disclosed in this manuscript. However, older MSCPs often displayed vulnerabilities such as insufficient compartmentation, exposed steel structures, and drainage systems that could promote vertical fire spread. In contrast, newer facilities generally achieved lower impact ratings but still benefited from targeted enhancements. Common improvement themes included upgrading manual fire detection to automated systems for faster emergency response, retrofitting fire collars at drainage penetrations, and assessing sprinkler installations through cost–benefit analysis where conditions allowed.

Findings for an exemplar car park are presented in Table 2 and Table 3, and a brief overview is given below.

Table 2. Fire Safety Key Considerations and Common Impact Factors for an Exemplar Car Park

	Key Considerations & Common Impact Factors	Classification	Assessors Comments
A	**Fire Performance**		
A.1	*Fire Resistance of Structure*	**Neutral**	Fire Strategy report states 30 minutes to floors and 60 minutes to office. Visual inspection appears to indicate intumescent to all beams and columns. Likely 30 minutes fire resistance provided to beams and columns.
A.2	*Structural Materials*	**Neutral**	Steel columns and beams, with metal deck and concrete floors
A.3	*Factors Impacting Likelihood of Flashover*	**Neutral**	2.94 m floor to slab height measured onsite. Openings in elevations in excess of 50%.
A.4	*External Materials (Cladding)*	**Positive**	Predominantly non-combustible wall materials
A.5	*Fire Loading / Stored Materials*	**Neutral**	Storage provided onsite predominantly in the office compartment.
A.6	*Attachments*	**Neutral**	Minimal attachments (signage) of limited combustibility.
A.7	*External Surfaces Classification*	**Positive**	Generally Class A materials
A.8	*Structural Inspections*	**Neutral**	New building and structural assessments are not required yet.
B	**Firefighting Access and Facilities**		
B.1	*Vehicle Access*	**Positive**	Good vehicle access with 100% perimeter access.
B.2	*Façade Access Restrictions*	**Neutral**	Good access around the site.
B.3	*Fire Fighting Lifts*	**Neutral**	No firefighting lifts found onsite

B.4	*Rising Mains*	**Neutral**	Dry rising mains identified on site and detailed in Fire Strategy report
B.5	*Suppression*	**Negative**	No suppression system is provided.
B.6	*Smoke Ventilation*	**Neutral**	Natural smoke ventilation provided by opens sides to the car park.
B.7	*Manual Fire Fighting Measures*	**Negative**	No extinguishers located in the car park. Provision within the office.
B.8	*Hydrants*	**Positive**	Hydrant provision to the site.
C	**Means of Escape and Warning**		
C.1	*Occupancy*	**Neutral**	Predominantly staff only but public access for the drop off with a higher than usual volume of public at time of inspection than other car park public areas.
C.2	*Evacuation strategy*	**Positive**	Simultaneous evacuation
C.3	*Travel Distances*	**Negative**	Fire strategy notes extended travel distances of approximately 62m.
C.4	*Escape Route*	**Neutral**	Unventilated protected lobbies provided
C.5	*PRM Evacuation*	**Positive**	Disabled refuges and evacuation lifts to all cores noted in fire strategy report and refuges and lifts found in sample core survey onsite.
C.6	*Fire Alarm and Detection*	**Neutral**	Fire strategy and onsite inspection found manual call points in car park and L1 in the associated offices. Insufficient coverage to give a neutral rating
C.7	*Signage and Emergency lighting*	**Neutral**	Sufficient signage and emergency lighting provided.
D	**Fire and Smoke Spread**		
D.1	*Connectivity to Terminal*	**Neutral**	No direct connection to terminal but direct connection to adjoining car park which is subsequently connected to other assets. Scored neutral.

D.2	*Compartmentation*	**Negative**	No compartmentation between offices and car park.
D.3	*External Wall / Cladding Connectivity*	**Neutral**	Link bridge comprises of metal cladding panels with adequate fire performance so neutral score conservatively provided.
D.4	*Drainage*	**Positive**	Cast iron drainage provided.
D.5	*Ramps and Openings*	**Positive**	While internal ramps provided onsite, the floors slope away from the ramps to collection points.
D.6	*Cavity barriers and fire stopping*	**Positive**	Fire stopping evident and some certification remained intact onsite enough to confirm third party assessment.
D.7	*Fire Doors*	**Neutral**	Generally in good condition onsite.
E	**Building Configuration and Features**		
E.1	*Building Height*	**Neutral**	Fire strategy notes 15.3m which is identified onsite by the assessors
E.2	*Potential disruption to airfield / apron*	**Neutral**	Car park 124 m from the apron / airfield so minimal risks of fire spread.
E.3	*Potential disruption to critical infrastructure / buildings*	**Neutral**	110m to railway and not in close proximity to the terminal. Direct connection (with no compartment) to adjoining car park but risks of fire spread to high value asset considered to be low.
E.4	*EV Charging*	**Positive**	No EV charging present onsite. EV vehicles and hybrids found onsite.
E.5	*Parking arrangements*	**Negative**	Generally contract parking including self-parking by public.
E.6	*Collision Reduction Measures*	**Neutral**	Minimal collision reduction measures (Hi-Viz strips to columns), good site lines but minimal evidence of speed control to non-public areas.

E.7	*Routine Inspections*	**Positive**	Onsite team and regular inspections.
E.8	*Security*	**Neutral**	Passive security measures.

The same structured approach applied to common impact factors was used for evaluating key considerations. Each weighting and corresponding value for the key impact factors was assessed against predefined criteria by at least two independent reviewers to reduce bias. All decisions were documented, and any variations were recorded with justification to ensure transparency. An illustrative example of this assessment process is presented in Table 3 below.

Table 3. Key Considerations for an Exemplar Car Park

Key Consideration	Assessment	Assessors Comments
Fire Performance	Positive	Both assessors observed consistent trend toward positive.
Fire Fighting Access & Facilities	Neutral	Both assessors did not observed a consistent trend toward positive or negative.
Means of Escape & Warning	Positive	Both assessors observed consistent trend toward positive.
Fire and Smoke Spread	Positive	Both assessors observed consistent trend toward positive.
Building Configuration and Features	Neutral	Although slightly more positive indicators were noted, the presence of EV and hybrid vehicles combined with mixed staff and public “nose-to-tail” parking patterns shifts the overall assessment to neutral in the view of both assessors.

To allow easy interpretation of the data, and to allow the potential for risk mitigation measures to be more easily identified, the findings from each *key consideration* were overlaid onto the high-to-low impact scale to establish the overall position. This determines how the building’s fire impact aligns with the benchmark.

The scale was expressed as three graded outcomes, high, medium, and low, arranged in a continuum from left (high) to right (low). While not quantified, the position reflects relative severity: the far left of high indicates the greatest impact, decreasing progressively toward low.

The process begins with a baseline assumption of high impact due to vehicle presence in the MSCP, with the position adjusted toward low as further mitigating information is evaluated.

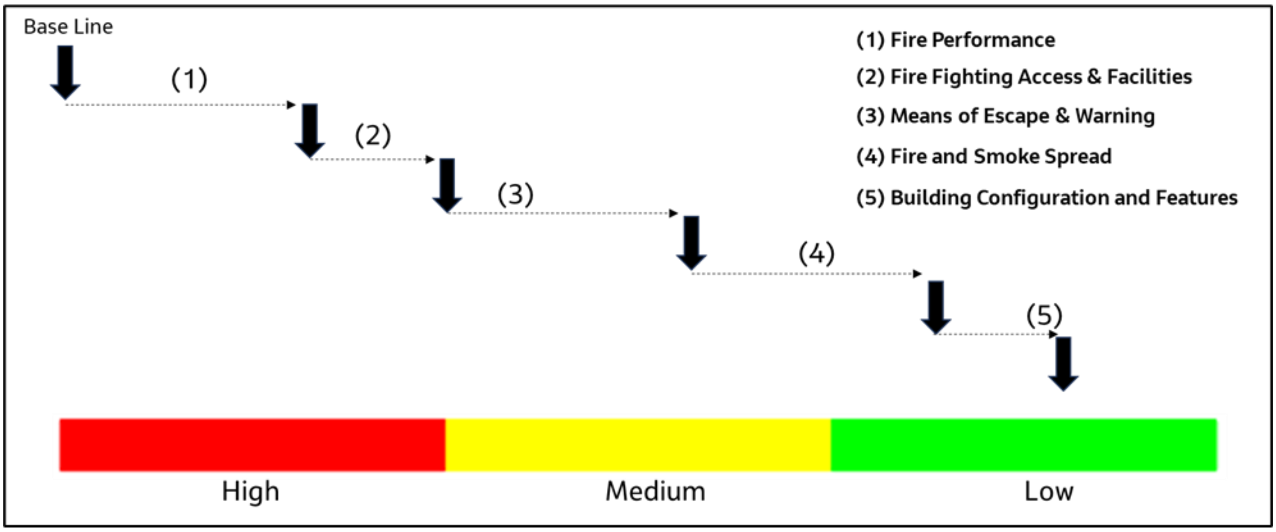

Figure 2. Impact Profile for Exemplar Car Park

In this exemplar, the risks of a catastrophic fire event were considered by the assessors to be ‘low’. However, the potential for a new fire door to separate the exemplar car park from an adjoining car park was identified. The effect of the proposed enhancement, on the relevant key impact factors, was assessed against predefined criteria by the two independent assessors, and a revised *impact profile* provided.

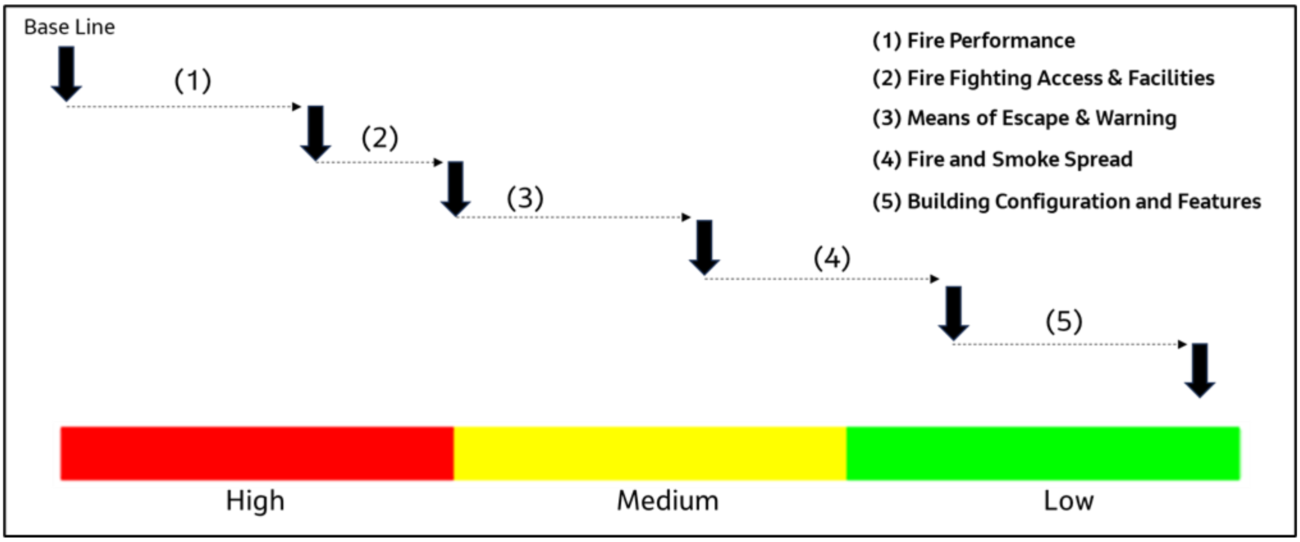

Figure 3. Impact Profile for Exemplar Car Park with Additional Fire Door

4 Discussion

This study underscores the need for a proactive, risk-based approach to fire safety in multi-storey car parks (MSCPs), particularly within airport environments where operational continuity is critical. While UK regulations primarily address life safety, recent large-scale fires such as Luton (2023) and Liverpool Kings Dock (2017) demonstrate that compliance alone does not mitigate severe business disruption. The proposed framework, adapted from PAS 9980 principles, enables comparative assessment of impact levels and prioritization of enhancements beyond statutory requirements.

The results, while broadly confidential, highlighted significant differences in fire resilience between older and newer MSCPs. Older facilities frequently exhibited vulnerabilities such as inadequate compartmentation, exposed steel structures, and drainage systems that could accelerate vertical fire spread. These deficiencies align with observations from previous incidents, including the Luton Airport and Liverpool Kings Dock fires, where rapid fire growth and structural exposure contributed to extensive damage and operational disruption.

Conversely, newer MSCPs generally achieved lower impact ratings due to improved design standards and incorporation of passive fire protection measures. However, the analysis demonstrated that even these facilities were not immune to risk, particularly in relation to evolving vehicle technologies and the absence of active suppression systems. This finding reinforces the need for a proactive approach that goes beyond regulatory compliance, focusing on operational resilience and continuity.

Common enhancement themes, such as upgrading manual fire detection to automated systems, retrofitting fire collars at drainage penetrations, and evaluating sprinkler installations through cost–benefit analysis, were identified as practical interventions. These measures offer substantial reductions in disruption risk with relatively modest investment, making them attractive options for asset owners seeking to balance safety improvements with financial constraints.

The results also underscore the importance of integrating fire safety strategies with broader risk management frameworks. By adopting a structured, risk-based methodology, stakeholders can prioritize interventions based on impact rather than prescriptive compliance, ensuring resources are directed toward measures that deliver the greatest resilience benefit. This approach is particularly relevant in high-value, operationally critical environments such as airports, where fire-related disruption can have cascading effects on passenger experience and commercial performance.

Future work should explore the influence of emerging factors, such as electric vehicle charging infrastructure and alternative fuel technologies, on fire risk profiles. Additionally, the development of performance-based design guidance would support the evolution of best practice in this sector.

Overall, this structured methodology provides a replicable model for enhancing resilience in complex infrastructure, bridging the gap between regulatory compliance and strategic risk management.

5 Conclusions

This study demonstrates that while MSCPs generally comply with life safety regulations, significant gaps remain in addressing operational resilience. Recent large-scale fires have shown that the consequences of such events extend beyond property damage, impacting business continuity and reputation. The proposed risk-based framework provides a structured approach to assess impact levels and prioritize enhancements, enabling stakeholders to move beyond compliance toward proactive risk management. Targeted measures, such as automatic fire detection, improved compartmentation, drainage upgrades, and cost-benefit evaluation of sprinklers, offer substantial reductions in disruption risk with relatively modest investment. By adopting this methodology, operators can safeguard critical infrastructure, maintain operational continuity, and set a benchmark for fire safety in complex environments.

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