



# ANALYSIS OF THE CONDITIONING FACTORS FOR THE ACCESS OF ELECTRIC PERSONAL MOBILITY VEHICLES TO PUBLIC TRANSPORT

SUMMARY  
DOCUMENT



AUTORITAT DEL TRANSPORT METROPOLITÀ - ATM

## 1. Motivation and objective

On November 17, 2022, an electric scooter exploded inside a train of the Baix Llobregat line of Ferrocarrils de la Generalitat de Catalunya (FGC), in the Metropolitan Area of Barcelona, leaving 7 people affected by the smoke (4 hospitalized). The rapid response of the users, who were able to move away from the deflagration and activate the alarm mechanism, and of the driver, who stopped the train between two stations and extinguished the fire, was decisive in the management of this incident, which caused significant material damage to the carriage.

In view of these facts, on November 21, 2022, the operation working group of the Public Transport Emergency Coordination Committee in the field of the ATM (Metropolitan Transport Authority) met, with the presence of representatives of the fire brigade of the Generalitat, and the temporary prohibition of 6 months of access of scooters and other electric PMVs (personal mobility vehicles) to public transport vehicles and facilities was agreed. During this period, the ATM undertook to carry out research in order to develop a Proposal to regulate the access and safety of personal mobility vehicles to public transport, as well as to promote the promotion of parking of these vehicles at public transport stations.

This document, prepared in collaboration with Institut Cerdà's Crisis Management Service, summarises the main aspects analysed and the reasons that led to the decision to permanently ban electric PMVs from public transport within the ATM area. With this decision, the principle of preventive safety that governs operators prevails, with regard to the protection of users, personnel working in the public transport service and its facilities.



Figure 1. State of the FGC wagon where the incident took place.

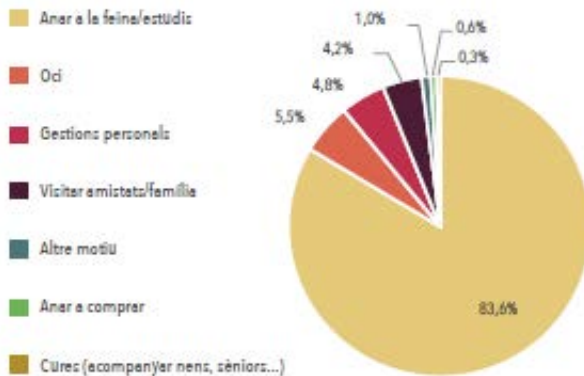
## 2. The role of micromobility in sustainable mobility and the impact of prohibition

The PMVs they have been boosted at different levels by their role in active and sustainable mobility and the Mobility Master Plan 2020-2025 (ATM) foresees significant growth between 2020 and 2025 (70% for bicycles and 136% for PMVs). In terms of volume, the ATM estimates that at the beginning of 2023 there were 144,000 journeys with PMV per day throughout the Integrated Metropolitan Mobility System of Barcelona (SIMMB), of which only 10% corresponded to multimodal journeys, combined with public transport (about 8,300 daily users).

With regard to mobility affected by the prohibition, the characterization of travel shows that most:

- are metropolitan (they could not be done unimodally with a scooter),
- are for work or study reasons (in 83.6% of cases),
- They combine with public transport to cover medium and long distances (journeys of about 50 minutes, with scooter stages of 20 minutes on average).
- They would switch to sustainable modes (walking, cycling or public transport) and only 9% would opt for the car.

### Quin és el motiu d'aquest desplaçament?



### Amb quin mitjà de transport substituirà el patinet?

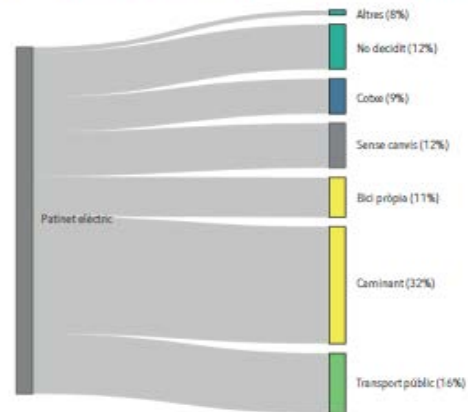


Figure 2. Characterization of PMV displacements. Source: UAB-GEMOTT.

Knowing these characteristics, since the temporary ban agreement, the ATM has worked with municipalities and operators to guarantee the presence of PMV car parks in public transport stations, adding new car parks or adapting existing ones to accommodate PMVs. It has been sought that users can continue doing part of the journey (first or last mile) with their PMV, reducing the need to travel the entire journey accompanied by the vehicle.

### 3. Evolution of cases and international benchmarks

The fire of a scooter in an FGC train has been the first case of deflagration of PMV in the transport network in Spain; however, in recent years and parallel to its popularization, the cases of deflagration of lithium-ion batteries in these vehicles have been increasing. The data collected by the Fire Brigade of the Generalitat de Catalunya and by the Barcelona Fire Brigade corroborate this trend, with a growth of more than 50% between 2020 and 2022 in Catalonia (excluding Barcelona) and that has more than doubled in the city of Barcelona in just one year (2021-2022).

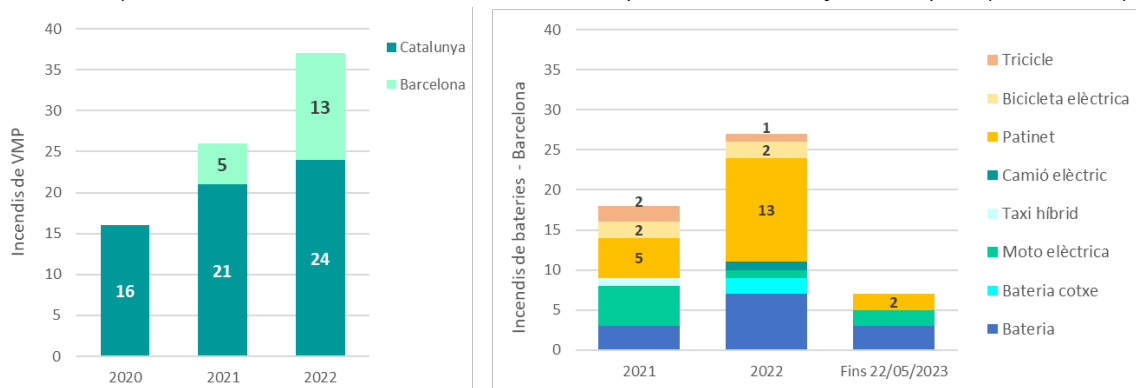


Figure 3. Scooter fires to Barcelona (\*data not available per 2020) and to the rest of Catalonia. Font: Bombers de la Generalitat de Catalunya and Bombers Barcelona.

Internationally, only 4 cases have been identified where the restrictions applicable to PMV access to public transport respond specifically to the risk of battery deflagration:

- In London, the fire of 2 PMV in the Underground led to a ban on the use of privately owned PMVs in public spaces and throughout the public transport network.
- In Hamburg, PMV has been banned from entering U-Bahn trains, a line with older rolling stock, with compartmentalized cars, in August 2023.
- In New York, electric PMVs are allowed as long as certain conditions are met (prohibition of charging, homologation of batteries, maximum sizes and weight...)
- In Singapore, a PMV record was established and compliance with a safety standard for electrical devices was required, in addition to maximum size, weight and speed. To ensure compliance, every 2 years it was necessary to pass a technical inspection of the vehicle.

#### 4. Main risk factors

To conclude whether there are measures that can be taken to minimize the risk, it is necessary to understand what elements intervene in which a fire can be triggered (conditioning factors of the probability of deflagration) and the vulnerabilities or elements involved in the capacity to contain or limit the impact, once the risk is manifested.



#### The phenomenon of *Thermal Runaway* and triggers

According to technical studies, if lithium-ion cells and batteries are handled correctly, the risk of a fire occurring is very low. However, certain characteristics of personal mobility vehicles make the batteries that power them more easily subjected to handling conditions or abusive demands than other vehicles.

The main risk elements identified in the case of electric PMVs are:

- Software modifications to increase performance or power, which can alter battery control and management parameters, as well as allowing the use of the PMV at speeds outside its design range.
- Battery overload or over-discharge, use of second batteries (external, standards lower than the original or different characteristics), inadequate storage...
- Physical damage, linked to the position of the battery at the bottom of the platform, which makes it more prone to vibration and shock, greater exposure to moisture.

The danger of these deflagrations is due to the phenomenon by which fire occurs (*Thermal Runaway*) is an extremely fast degradation process in which exothermic chemical reactions are catalysed that generate fire (up to 700°C), smoke, emission of gases of which some components can be very dangerous for people's health (mainly carbon monoxide (CO), carbon dioxide (CO<sub>2</sub>), methane, ethane, ethylene, H<sub>2</sub> and, in some studies, traces of hydrogen fluoride (HF), fragmentation and explosion.



Figure 4. State of the PMV on fire. Source: FGC.

### Lack of guarantees of the regulation applicable to PMVs

In January 2022, the Manual of characteristics of PMVs prepared by the General Directorate of Traffic (DGT) was approved, which will require a traffic certificate to PMVs to guarantee compliance with the technical requirements required by national and international regulations. These requirements regulate physical, mechanical aspects of the electrical system (moisture resistance, power control and shutdown, anti-tampering, battery protection, etc.) and will allow limiting the circulation of vehicles that do not comply with the CE marking<sup>1</sup>, that do not include mechanisms to prevent handling or measures to prevent battery degradation, among others.

However, the transitional regime for its application extends until 2027 the requirement of a traffic certificate for all PMVs, so that the applicable regulation does not provide, at present, sufficient guarantees to assume that PMVs in circulation meet the safety criteria defined by the DGT, in line with other European regulations.

### Vulnerabilities given by the characteristics of the transport system

The consequences of the deflagration of a battery will depend largely on the environment where it is produced and public transport has some characteristics that make the impact very high:

- High density of travellers in certain time slots, which may prevent you from moving away from the fire;
- Presence of tunnels, especially in underground railway modes, which makes evacuation (both fumes and passengers) more complex;
- Greater vulnerability of people with reduced mobility (PRM) and children in pushchairs in a situation of deflagration and need for evacuation;
- Existence of automatic metro lines, in which the detection and response time or the ability to assist people during the evacuation can be affected.

<sup>1</sup> The CE marking does not require certification of the product in designated laboratories if the manufacturer declares that its product complies with the regulations. For this reason, the Consumer Agencies verify, through random sampling, the safety of the products present in the market, proceeding to their withdrawal and communicating an alert for the European market.



Figure 5. Metro Tunnel

In railway modes, as required by Law 4/2006, of 31 March, on railways, it is necessary to have self-protection plans for railway infrastructures in which risks and measures are assessed to deal with any incident, minimizing damage to people. The review of existing protocols, in order to assess their suitability, allows us to conclude that the different railway operators contemplate the risk of fire in their Self-Protection Plans, detailing the prevention and containment measures necessary to address it. However, there are aspects that influence the mitigation capacity of the potential impact of the fast degradation, explosion and fire from an electric battery:

- Ventilation management, which varies depending on the operator and the series and age of the cars. The active management of smoke, which allows it to be confined or evacuated from the wagon, according to needs, is a differential element in the management of this risk.
- Indications for evacuation also vary, introducing differences in reaction time and management of the initial moments of deflagration. In general terms, in networks with tunnel circulation, and reduced travel times between stops, priority is given to the arrival of the train at the next station, contemplating evacuation to the tunnels only in case of emergency. On the other hand, in external circulation networks, the immobilization of the vehicle and the opening of doors are foreseen (with special attention to the risk of being run over).
- The type and volume of cars, ranging from compartmentalized vehicles to the open composition (worm-type connected wagons), make the horizontal evacuation capacity, essential to minimize damage in the first moments of the incident, highly variable, but not possible when vehicles are quite full, which happens in most hours of service.

## 5. Analysis of measures to regulate PMV's access to public transport

Having analysed the causes involved in the phenomenon of *Thermal Runaway*, and knowing the characteristics of the transport system that could aggravate the severity of the consequences, the following 7 measures related to PMV access to public transport have been analysed:

### 1. ACCESS RESTRICTIONS AT PEAK TIMES OR ACCORDING TO OCCUPANCY

<b>Objective</b>	Minimize the severity of the consequences (burns, smoke) if the fire occurred in a vehicle with a high level of occupancy					
<b>Proposal</b>	<ul style="list-style-type: none"> <li>Prohibition of access to the slots from 7:00 a.m. to 9:00 a.m. and from 5:00 p.m. to 7:30 p.m. on weekdays, with the possibility of extending them as considered by each operator.</li> <li>Power of each operator to limit access in situations where occupancy is considered too high (of the order of 3 pax/m<sup>2</sup>), as is already the case with bicycles.</li> </ul>					
<b>Estimation</b>	Reduces probability		Reduces impact		Improves coexistence	
<b>Limitations</b>	Having analysed the current requirements of the different operators (growing demand, expansion and displacement of high occupancy slots), the prohibition of access should be extended to many other time slots, making it notably difficult for users to understand and comply with or leading to the establishment of prohibition slots that occupy practically all the time of provision of the service.					

### 2. SPECIFIC AREAS INSIDE VEHICLES

<b>Objective</b>	Do not interfere with the evacuation of travellers in the event of an incident					
<b>Proposal</b>	<ul style="list-style-type: none"> <li>Railway mode: specific location in the space provided for bicycles, respecting the priority of PRM and baby seats if shared.</li> <li>Road mode: transport in the hold, whenever available; alternatively, in the space for bicycles or area of coexistence with PRM and baby seats, respecting the priority of the latter. Where there are none or are occupied, they must be located in areas of easy access and exit, which do not interfere with evacuation. Maximum of 2 units per vehicle.</li> </ul>					
<b>Estimation</b>	Reduces probability		Reduces impact		Improves coexistence	
<b>Limitations</b>	The proposal does not address the principle of removing the risk from the most vulnerable, with the aggravation that both PMR and children would be more exposed to deflagration and smoke emission. Therefore, a sufficiently safe location for electric PMVs has not been found in the public transport system as a whole. In addition, placing the PMVs together could facilitate the triggering of a chain reaction in case of deflagration of one of the vehicles.					

### 3. LIMITATION OF THE NUMBER OF PMV PER VEHICLE

<b>Objective</b>	Ensure that the concentration of gases emitted in a <i>Thermal Runaway</i> does not exceed safe health limits in acute exposures <sup>2</sup> .					
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<sup>2</sup> The calculation has taken as a reference the Liters of gas emitted by various types of battery (using the two most common) and its composition (BATTECH study) and the thresholds for each gas provided by the Public Health Agency of Catalonia, based on the consultation of the reference sources.

<b>Proposal</b>	Taking as a reference the volume of the most critical wagon (smaller volume) of each of the operators <sup>3</sup> and considering a uniform distribution of gases throughout the wagon, maximum numbers of between 1 and 2 PMV per wagon are obtained, depending on the operator. In the case of train units with connected carriages, this number can be recalculated based on their actual volume.					
<b>Estimation</b>	Reduces probability		Reduces impact		Improves coexistence	
<b>Limitations</b>	It is necessary to have more specific studies on the composition of fumes (the values used correspond to experiments in inert atmospheric conditions) and that help clarify the kinetics of the reaction and propagation of gases. In addition, the diverse typology of rolling stock adds complexity when establishing common access conditions.					

#### 4. MAXIMUM SIZE LIMITATION

<b>Objective</b>	Improve coexistence with other users (although it is true that the size of the batteries is an indicator of risk and the transport of large elements can hinder evacuation).					
<b>Proposal</b>	Limit to a maximum folded dimension of 160 cm x 70 cm.					
<b>Estimation</b>	Reduces probability		Reduces impact		Improves coexistence	
<b>Limitations</b>	This size already exceeds the size that is allowed in some regulations and a rather complex volume control would be necessary.					

#### 5. BATTERY CHARGE

<b>Objective</b>	Limit a possible overheating of the battery, associated, among others, with the charging process. In addition, the charging conditions that occur in public transport (vibration, temperature variations...) can cause destabilization in the battery.					
<b>Proposal</b>	<ul style="list-style-type: none"> <li>• Prohibition of loading of PMVs to vehicles and passing the fare barrier at railway stations, either by plugging it directly into an outlet or through an external device, thus reducing the likelihood of a fire occurring.</li> <li>• In the facilities (lobbies) loading is prohibited as long as it is not done with the measures that prevent the incident from affecting the rest of the spaces.</li> </ul>					
<b>Estimation</b>	Reduces probability		Reduces impact		Improves coexistence	
<b>Limitations</b>	Difficulty knowing when the PMV is being charged with a second battery if it is in a bag.					

#### 6. IDENTIFICATION OF VEHICLES CERTIFIED BY THE DGT

<b>Objective</b>	Reduce the chances of <i>Thermal Runaway</i> by conditioning access to public transport to guarantees of good condition of the PMV.					
<b>Proposal</b>	Introduction of a Technical Inspection of Personal Mobility Vehicles that are not yet certified by the DGT as a requirement that determines their access to public					

<sup>3</sup> The analysis has been carried out only by the railway mode, considering that in buses the conditions for smoke evacuation are more favourable because they circulate on the surface, there is ease to stop and the opening of doors is fast.



	transport, as is done with other vehicles. An annual inspection would verify that they have not been tampered with or that they present defects that generate a risk to themselves and to other people and property, both when they are driving and when they are loading or stopped disconnected, as shown by the fire brigade statistics.					
<b>Estimation</b>	Reduces probability		Reduces impact		Improves coexistence	
<b>Limitations</b>	Taking into account that the DGT has already established certification mechanisms and the official elements of identification of vehicles, it is considered that this system cannot be doubled, which over time could generate confusion among the owners of PMVs. It is considered that it is necessary to ask the responsible administration to apply an annual inspection of PMVs, which certifies their good condition not only at the time of commercialization but through their use.					

## 7. FOLDED ACCESS

<b>Objective</b>	Improve coexistence with other users, avoiding excessive occupation of space, as well as possible falls and trips.					
<b>Proposal</b>	Folded access of all PMVs to public transport, assimilating the treatment that multiple operators give to folding bicycles.					
<b>Estimation</b>	Reduces probability		Reduces impact		Improves coexistence	

## 8. OTHERS: CASES AND INSURANCE

<b>Objective</b>	Limit the consequences of a fire.					
<b>Proposal</b>	Require the transport of the scooter in a fireproof case, which stifles the thermal effect and delays the spread of smoke. Require compulsory insurance to access public transport.					
<b>Estimation</b>	Reduces probability		Reduces impact		Improves coexistence	
<b>Limitations</b>	Taking into account the lack of commercial alternatives at affordable prices for users and the added difficulty of carrying out their inspection, this aspect has been ruled out. There are currently regulatory initiatives underway and a bill by the Spanish Government, in which it will be proposed to create a group to analyse its obligation.					

## 6. Global assessment and conclusions

In this work, the risks of PMV access to public transport have been analysed. Having delved into the set of measures, based on the search for best practices, reference regulations and numerous meetings with the different agents involved, accompanied by those responsible for Civil Protection and the fire brigade of the Generalitat de Catalunya and the Barcelona City Council, a proposal has not been formulated that gives, Currently, sufficient guarantees for PMV access to public transport safely, as an acceptable level of risk is not reached within self-protection plans, contingency protocols and risk analysis, in the metropolitan public transport system and especially in the railway system.

Therefore, it is concluded that scooters and other electric PMVs should not be allowed access to public transport, at least until the conditions governing their marketing and circulation provide sufficient safety guarantees against deflagration.

In order to promote intermodality between electric PMVs and public transport, it is recommended to continue evolving the options for parking these vehicles, increasing the available spaces where significant occupancy is detected and improving safety conditions.

Finally, it is necessary to promote the awareness of users about the dangers of battery fires, ensuring that they know the recommendations regarding the driving, charging and transport of batteries is the first step to prevent their deterioration that could lead to a fire, whether on public transport, in homes or outside.

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