A PROPOSED NEW APPROACH TO LIGHT RAIL SAFETY MANAGEMENT IN SPAIN AND OTHER COUNTRIES

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Highlights

- Critical review of regulatory framework for LRT safety management in Spain.
- Comparison of LRT safety management in different European countries.
- The French LRT safety management approach is presented with a critical review.
- Approach to improve LRT safety in any country, following the French model.
- National LRT safety management database

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ABSTRACT

The light rail transit (LRT) has experienced considerable growth in Spain since 1994; to date, this has led to the installation of more than 200 km of light rail lines and LRT operations in 11 metropolitan areas. Nevertheless, its institutional and regulatory framework have not been developed accordingly. Thus, in this paper, an approach for managing the LRT safety in Spain is proposed. The approach is based on the French model and could be applied to any other country that is interested in improving its LRT safety management.

The paper explains the current situation of LRT safety management in Spain and provides a critical review. A comparison of the situations in several European countries is presented. Moreover, the paper presents details pertaining to the French framework and tool as the most adequate model for managing the LRT safety; a critical review is also included in order to propose ways for improving it.

Finally, the main points of the proposed LRT safety management approach include the following: 1) development of a National Light Rail Safety Act, which would create the National Light Rail Safety Body; 2) implementation of a light rail safety database, which is created through the codification of light rail lines in homogenised sections from the safety point of view and the standardised light rail accident/incident reports, to be filled in by light rail operators directly; 3) management of the database by the National Light Rail Safety Body in order to improve safety based on the conclusions obtained.

Keywords: Light rail safety, Accident report, Safety management

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Finally, the main points of the proposed LRT safety management approach include the following: 1) development of a National Light Rail Safety Act, which would create the National Light Rail Safety Body; 2) implementation of a light rail safety database, which is created through the codification of light rail lines in homogenised sections from the safety point of view and the standardised light rail accident/incident reports, to be filled in by light rail operators directly; 3) management of the database by the National Light Rail Safety Body in order to improve safety based on the conclusions obtained.

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1 INTRODUCTION AND PAPER OBJECTIVES

The aim of this study is to formulate a new approach for managing light rail transit (LRT) safety in Spain as presented in this paper. The proposed approach is deemed applicable to any other country interested in improving its LRT safety management.

In previous decades, several definitions of the LRT have been formulated (TRB, 1978 and Van der Bijl et al., 2018); nevertheless, none of these has attained international consensus. Accordingly, in this paper, the LRT is defined as a metropolitan transit system with the following characteristics (Novales and Bugarín, 2009).

- Railway technology: the vehicles are guided by the contact between steel wheels and steel rails, and traction is usually electric.
- It runs on the surface along its main journey, although it may also run underground or on elevated structures.
- It runs mainly on segregated right-of-way, which means that it is longitudinally physically separated from other traffic by curbs, barriers, and others similar to these, but with grade-crossings for road vehicles, cyclists, and pedestrians (Vuchic, 2007). Nevertheless, there may be certain short stretches where the LRT shares the trackway with road traffic.
- It uses 'light' railcars. This means that the weight per axle is lower than those used in subway trains. In addition, the train length is limited because of the necessity to blend with the streets; this leads to an intermediate system capacity.

The metropolitan areas in Spain where a light rail system is operated are shown in Fig. 1; the opening year for the first line is indicated in parenthesis. They are depicted with a circle if they complement a network with a heavier system (such as a metro or commuter rail); otherwise, a square is used.

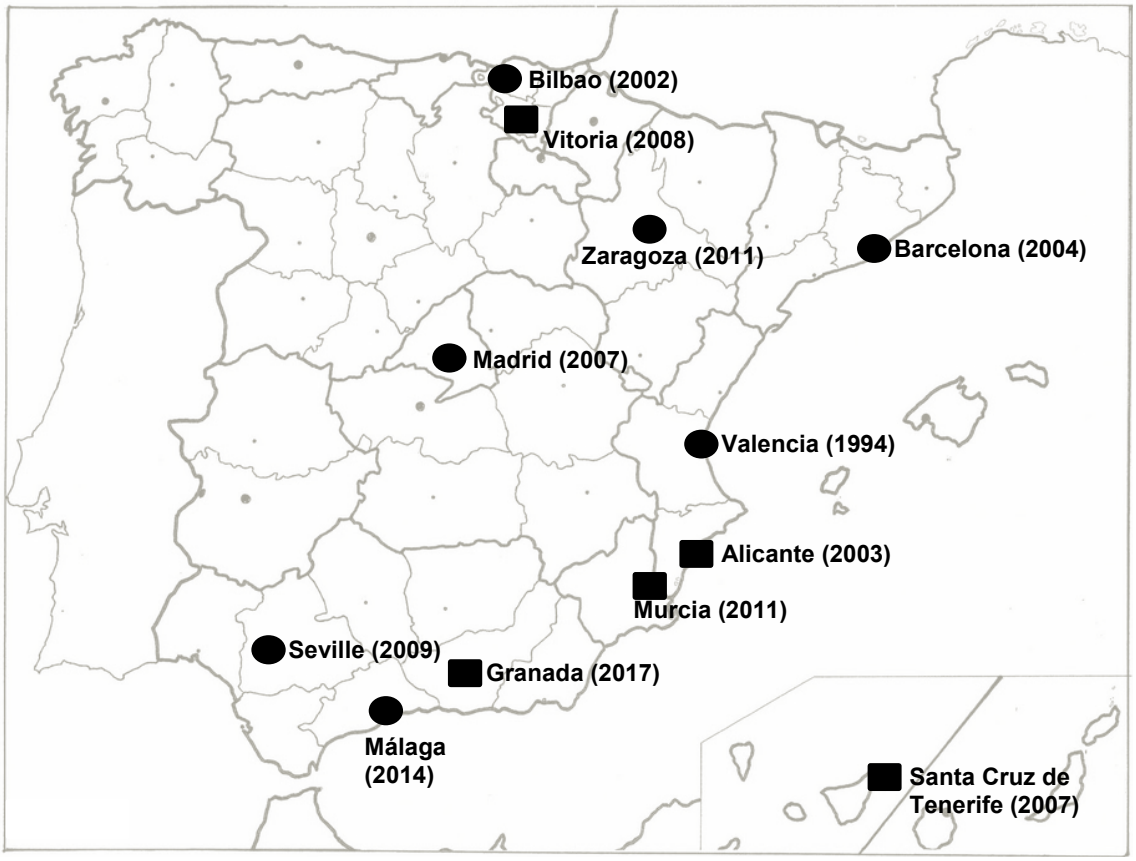

FIGURE 1 Light rail systems currently in operation in Spain

In some of the depicted metropolitan areas (Madrid and Barcelona), there are more than one light rail system. The wider grey lines in the figure show the borders of each regional government in Spain. More information about some of Spain's LRT networks can be found in Novales (2012), Novales et al. (2013), and Muñoz (2014).

In total, there are more than 200 km of light rail lines in operation in Spain including several underground sections, as well as the metropolitan light rail line from Alicante to Benidorm, which is served by tram–train vehicles (Novales et al., 2013).

Nevertheless, the institutional and regulatory framework of the light rail transit in Spain has not undergone a development that is in accordance with the considerable growth of modern LRT networks since it first opened in Valencia in 1994. Therefore, in Spain, there is neither a unique national body that manages the safety of LRT networks nor a general regulation that establishes a method for collecting data pertaining to accidents/incidents and using those data to improve safety, although safety is evidently a priority for LRT operators (Novales et al., 2015). This situation is completely different from the case of France, where the growth of LRT lines in the last decades has been accompanied by the formulation of rules and clear procedures for safety management in guided transport systems in a regulatory framework, as this paper shows.

As stated above, the aim of this study is to propose a new approach for managing the LRT safety in Spain that is applicable to any other country interested in improving their LRT safety management. This paper is organised as follows. Section 2 reviews the regulatory situation of LRT safety in Spain and presents a critical review. Section 3 provides a synthesis of the LRT safety management in some European countries. Section 4 describes in detail the French approach to the LRT safety management; a critical review is also presented. Section 5 discusses recommendations for the improvement of light rail

safety management in Spain and other countries based on the French model; a critical review is also provided. Finally, Section 6 summarises the conclusions of the study.

2 REGULATORY SITUATION OF LRT SAFETY IN SPAIN

This section reviews the regulatory situation of LRT safety in Spain from national and regional points of view.

2.1 National approach

Safety is a priority in railway regulation, in the standards of both Europe and Spain. In Spain, the Regulations on Traffic Safety of the General Interest Rail Network (Ministry of Infrastructure, 2007) with their subsequent modifications[1] implement the Rail Sector Act, Act 39/2003[2] (Head of State, 2003), in relation to rail traffic safety on the General Interest Rail Network. Nevertheless, these regulations explicitly exclude subways, tramways, and light rail systems from their scope.

Meanwhile, the Rail Sector Act, Act 38/2015 (Head of State, 2015), specifies in Article 65 the duties of the National Railway Safety Agency (the national authority responsible for railway safety), but only in relation to the General Interest Rail Network.

Therefore, there is no regulation that is related to light rail and tramway safety at the national level in Spain.

2.2 Regional approach

2.2.1 Catalonian and Andalusian Regional Acts

Both regions of Catalonia and Andalusia have established their own rail acts: Catalonian Rail Act, Act 4/2006 (Catalonian Regional Government, 2006); Andalusian Rail Services Act, Act 9/2006 (Andalusian Regional Government, 2006).

Both Acts have relatively similar contents in relation to tramways and light rail systems, with general references to maintenance and works, as well as other aspects. Both of them remind the priority of tramways and light rail systems over road vehicles and road public transit; in Andalusia, such a priority is over any other individual transport system. The regulations treat railway safety in a rather general way, including the safety of light rail and tramway systems, without specifying the procedure for managing accidents and incidents.

The Catalonian Act specifies that the Catalonian Railway Safety Agency is responsible for the proposal and implementation of the safety regulatory framework and its enforcement. Even though the Catalonian Railway Safety Agency was created by the Catalonian Act 5/2017 (Catalonian Regional Government, 2017), no additional regulation has yet been approved in relation to the management of accidents and incidents of tramway and light rail systems, or information related to them.

Nevertheless, it could be expected that in the near future, both Catalonia and Andalusia might implement new regulations that would specify the manner in which this management should be led as a continuation of the path initiated by their Rail Acts.

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[1] The Regulations on Traffic Safety of the General Interest Rail Network (Ministry of Infrastructure, 2007) where modified by Ministry of Infrastructure (2010), Ministry of Infrastructure (2011), and Ministry of Infrastructure (2015).

[2] The Rail Sector Act, Act 39/2003 (Head of State, 2003), was later repealed by Act 38/2015 (Head of State, 2015)

2.2.2 Valencian Rail Safety Act

The Valencian Rail Safety Act (Valencian Regional Government, 2018) was fostered by the investigation of the subway accident that occurred on 3 July 2006 in Metrovalencia line 1. This Act creates the Valencian Railway Safety Body, as well as the Railway Accident Investigation Commission, as a permanent institution for the technical investigation of rail traffic accidents and incidents.

The Act explicitly includes light rail and tramway lines in its scope. It defines them as those lines that share traffic signs and signals with the road system at intersections, where the priority is assigned at each instance by these traffic signs and signals, or even those lines that share the right of way with road traffic.

This Act stipulates that every rail entity (defined as 'any rail operator/undertaking or rail infrastructure manager') will have a specific department responsible for traffic safety management with a person in charge.

Title V of the Act refers to the investigation and notification of accidents and incidents. Article 51, 'Object and purpose', specifies that every significant railway accident[3] must be subjected to a technical investigation conducted by the Railway Accident Investigation Commission, whereas the rest of the accidents and incidents may not be the object of technical investigation if justified. The aim of the technical investigation is to determine the causes of the accident/incident and the circumstances that led to the mishap, and to formulate relevant safety recommendations when appropriate. Under no circumstances shall the technical investigation deal with blame or liability for the accident/incident. In addition, every rail entity must internally investigate every accident and incident in which it has been involved. This investigation shall not interfere with that conducted by the Railway Accident Investigation Commission to whom they must provide any required collaborations.

In addition, Article 52 specifies that rail entities are required to immediately notify the Railway Accident Investigation Commission of any significant accidents or incidents that occur in their field; reporting less serious incidents remains optional. Any notifications made should be recorded and should proceed according to the procedure established by the Commission; the actions taken pertaining to an accident or incident, as well as the necessary preventive and corrective measures to ensure that it does not occur again, must be reported.

Accordingly, with the implementation of Article 52, it becomes possible to create an accident/incident database filled with data provided by rail entities. These data can then be processed by the Valencian Railway Safety Body to determine appropriate measures for improving safety.

Finally, Section 2 of Annex 1 of the Act establishes the indicators that must be considered when evaluating the safety of light rail operations.

The accident-related indicators include the following.

- Total and relative (in relation to tram-km·10^6) number of accidents broken down as follows.
  - Collisions: among trams; with an obstacle on the structure gauge, including a catenary; with vehicles, including bicycles, in an authorised or outside an authorised crossing (with or without victims)
  - Derailments

[3] Significant railway accident: an accident that results in at least one person killed or seriously injured, extensive damage (over €150,000) to rolling stock or infrastructure (or facilities), or serious railway traffic interruptions (at least 1 h).

  - Injury to people by a moving rolling stock: collision with a pedestrian in an authorised or outside an authorised crossing; falls inside the tram.
  - Injury to people by a standing rolling stock or without the involvement of a rolling stock: injury to people when boarding or alighting, including door trappings; falls onto the tracks
  - Severe fire/smoke: in a rolling stock; in the infrastructure
  - Other events
- Total and relative (in relation to tram-km·10^6) number of seriously and slightly injured people and fatalities, as a whole and by the type of accident, with the following breakdown: passengers; employees; users of authorised crossings; other people
- Total and relative (in relation to tram-km) number of attempted/successful suicides

The indicators related to incident and accident precursors (or near misses) are as follows:

- Total and relative (in relation to tram-km·10^6) number of incidents with the following breakdown.
  - Light rail signals passed at danger
  - Road signals passed at danger
  - Forcing open switch points (or run through the turnout), which may be a consequence of a tram proceeding beyond its permitted movement as authorised by a tramway signal
  - Obstacles on structure gauge not leading to collision: internal obstacles; external obstacles (including animals on tracks); pedestrians or people using light personal mobility vehicles (bicycles, motorcycles, scooters, and skates) on tracks
  - Infrastructure failures: broken rail; defect in track alignment; tram signal failure; road signal failure; catenary failure
  - Rolling stock integrity failures: broken wheel; broken wheelset; structural failure
  - Emergency braking actions: on-purpose emergency braking; dead-man emergency braking because of the absence of activation or cycle breach; emergency braking because of door failures, alarm-handle, and other situations
  - Non-significant fire/smoke

The Act establishes that these indicators may be changed through a decree, which allows certain flexibility to their modification. This may be desirable in the event that new circumstances render the introduction of additional indicators advisable.

2.3 Critical review of regulatory situation of LRT safety in Spain

2.3.1 Innovative approach of Valencian Rail Safety Act

The Valencian Rail Safety Act includes certain innovative features that are discussed in this section.

Firstly, the inclusion of a list of standardised indicators pertaining to accidents, incidents, and near misses is an important improvement in relation to the regulations implemented by most European countries (although in this case, it is only enforced at a regional level). The COST Action TU1103 '*Operation and safety of tramways in interaction with public space*' has only identified four European countries that have

nationally adopted standardised indicators: France, Ireland, Switzerland, and Poland (Fontaine et al., 2015).

The detailed study of near misses is not particularly common in light rail networks; however, such an investigation is highly advantageous for this type of system because it is common knowledge that the occurrence of accidents is just the 'tip of an iceberg' (Yang et al., 2012; Jones et al., 1999). This is evident from the statement of Zhang et al. (2016) that 'there is a broadening base of serious accidents, non-serious accidents and near misses, in such a way that preventing accidents involves focusing on the lower levels, or precursors, and paying more attention to near misses'. The objective of reporting near misses is to learn lessons from these events in order to reduce the number of incidents (including accidents and near misses) because they share some common causes. Moreover, most generating mechanisms (causal factors) of an accident sequence are exhibited by near misses (Gnoni and Saleh, 2017). Therefore, the lessons learned from these events can enhance safety performance (Jones et al., 1999; Gnoni and Saleh, 2017).

Secondly, the inclusion of indicators relative to emergency braking actions is also an advance step in the Valencian Act compared with the regulations of most European countries. Emergency braking actions are among the most consequential near misses in light rail systems. Their study is crucial because their concentration in a particular zone of a network may be the result of certain flaws in system design or operation (Fontaine et al., 2015; Lewisch et al., 2014). Nevertheless, not every light rail network in Europe makes a systematic registration of emergency braking actions. In the first working phase of the COST Action TU1103 '*Operation and safety of tramways in interaction with public space*' (Fontaine et al., 2014), a study was conducted to determine in which countries such a registration is made. France, Hungary, Ireland, and Spain reported such events, whereas Belgium, the Czech Republic, Germany, Italy, and Switzerland do not register emergency braking events unless they cause additional accidents or incidents (e.g., passenger falls inside the rolling stock).

It is noteworthy that in order to gather coherent information from different light rail networks, a clear definition of the emergency braking concept should be provided (Fontaine et al., 2014). This is also the case for all the other near misses to be registered; this is because employees tend to be confused regarding what a near miss means and what should be reported (Gnoni and Saleh, 2017).

Finally, to achieve a comprehensive registration of emergency braking, the driver must be assured that there will be no negative consequences for filing the report. This assurance is necessary even if the registration is automatic or mandatory; this is because there are cases where the avoidance of emergency brake applications to avoid penalty could compromise safety (Fontaine et al., 2015). This principle can be applied to any of the other near misses that have to be reported because it is always advantageous to make a follow-up with the person who filed the near-miss report and acquire more factual contextual information. Accordingly, to the extent possible, it is important to avoid a punitive approach to near-miss reporting (Gnoni and Saleh, 2017).

2.3.2 Necessity of a national regulation

As explained in section 2.1, Spain has neither a unique national body that manages the safety of LRT networks nor a general regulation that establishes the methods for data collection pertaining to accidents/incidents and managing those data in order to improve safety (Novales et al., 2015). As presented in section 2.2.2, the *Valencian Rail Safety Act* fills this void; however, it is limited to the regional level. Nevertheless, this last act has been passed recently; the detailed procedures for its implementation are still pending.

As elaborated in the following section, the lack of a national regulation is common in most European countries, except for France (Germany has regional regulations). Nonetheless, the authors of this paper deem it advisable to formulate and implement a national regulation for Spain and establish a national body responsible for the safety of light rail systems, patterned after the French approach (presented in section 4). By deriving conclusions from the examination of an extensive accident/incident database fed by all light rail operators, incident trends can be identified, and future accidents can be avoided (Zhang et al., 2016); consequently, the safety of all light rail systems in the country could be enhanced. The database management would lead to a more comprehensive knowledge pertaining to potential risks, corrective measures that have to be implemented in operating systems, and design of new lines or branches. The approach of the *Valencian Rail Safety Act* could be used in part and elevated to the national level.

The implementation of this national regulation is urgent because regional regulations have started to be passed. Harmonising these regional regulations in such a way that data from all light rail operators could be gathered in the most comprehensive and coherent way is a priority. Moreover, the format in which the data are registered should be consistent in order for information gathering to be more beneficial. The current approach of registering LRT accident information that light rail operators in Spain practise are discussed by Novales et al. (2015); incidentally, the reporting techniques of operators vary and do not harmonise.

3 LIGHT RAIL SAFETY MANAGEMENT IN SOME EUROPEAN COUNTRIES

During the first work phase of the COST Action TU1103 '*Operation and safety of tramways in interaction with public space*' (Fontaine et al., 2014), an analysis of light rail safety management in several European countries was conducted. The main conclusion achieved is that this management is highly dissimilar among countries; in general, there is no national body in charge of light rail safety. Even when such a body exists, it is typically only concerned about the investigation of the most serious accidents; no systematic analysis of all mishaps (accidents and incidents) is conducted. In several cases, the light rail agency (operator/undertaking) or the authority on which it depends (council, metropolitan area) is the sole responsible entity for this safety management.

Table 1 is a synopsis of the situation in Belgium, France, Germany, Ireland, and the United Kingdom.

TABLE 1 Light rail safety management in some European countries. Source: authors' elaborations and data from Fontaine et al. (2014).

	BELGIUM	FRANCE	GERMANY	IRELAND	UNITED KINGDOM
National body responsible for light rail safety	NO	YES (STRMTG and BEA-TT)[a,b]	NO	YES (RAIU and CRR)[d,e,7]	YES (RAIB and ORR)[f,g,12]
Regional body responsible for light rail safety	NO	NO	YES (TAB)[c,4]	NO	NO
Responsible for accident/incident report elaboration	LRT operator	LRT operator (reviewed by STRMTG)[1]	LRT operator	LRT operator (and RAIU for certain accidents/incidents)[8]	LRT operator (and RAIB for certain accidents/incidents)[13]
Responsible for accident/incident evaluation	LRT operator	LRT operator (reviewed by STRMTG)[1]	LRT operator (and TAB if considered appropriate)[5]	LRT operator (and RAIU for certain accidents/incidents)[9]	LRT operator (and RAIB for certain accidents/incidents)[13]
Responsible for implementation of improvement measures after accident/incident	LRT operator	LRT operator (reviewed by STRMTG)[2]	LRT operator (review by TAB)[6]	LRT operator[10]	LRT operator (and ORR for certain accidents/incidents)[14]
Responsible for accident/incident record keeping	LRT operator	LRT operator and STRMTG[3]	LRT operator and TAB	LRT operator [11]	LRT operator, RAIB and ORR[15]

a: STRMTG, *Service Technique des Remontées Mécaniques et des Transports Guidés* (Technical Service of Ropeways and Urban Guided Transit)
b: BEA-TT, *Bureau d'enquêtes sur les Accidents de Transport Terrestre* (Land transport accident investigation bureau)
c: TAB, *Technische Aufsichtsbehörde* (Technical Supervisory Authority (TSA))
d: RAIU, Railway Accident Investigation Unit. The RAIU is not strictly responsible for the LRT safety. Their role is to improve railway safety by establishing, to the extent possible, the cause or causes of an accident with the purpose of making recommendations for the avoidance of future accidents (Railway Accident Investigation Unit, 2019).
e: CRR, Commission for Railway Regulation. The CRR's function is regulatory; it does not have an operational function in managing day-to-day safety on the ground. That responsibility lies with various railway organisations. The CRR's function is to ensure that each railway organisation has implemented and is complying with Safety Management Systems (SMS) that conform to legislative requirements; this includes both heavy and light rail (Commission for Railway Regulation, 2019).
f: RAIB, Rail Accident Investigation Branch. This Branch investigates accidents and makes recommendations for improving safety.
g: ORR, Office of Rail and Road (formerly Office of Rail Regulation)
1: The local office of STRMTG receives the information and may require additional data.
2: The local office of STRMTG may require additional information about the proposed action plan.
3: The LRT operator is responsible for recording all data related to each accident/incident in the database. The STRMTG is informed annually (except for serious accidents, which should be reported the soonest) to complete the national database. The STRMTG manages the complete database, a national assessment is made, the data are anonymised, and a national report is sent to the operators and made public.
4: The TAB does not receive information about all accidents/incidents except those that are severe (with seriously injured people or fatalities), have high material damage (more than €100,000) value, or those that are sensational (accidents that may have significant media coverage). The operator is responsible for reporting these events to the TAB.
5: The TAB may conduct a supplementary investigation if considered appropriate (repetition of same type of accident, accident concentration in a specific zone, etc.).
6: The TAB may require the implementation of any additional improvement measures that are considered appropriate.
7: The RAIU investigates every severe accident, defined as 'any train collision or derailment of trains, resulting in the death of at least one person or serious injuries to five or more persons or extensive damage to rolling stock, the infrastructure or the environment, and any other similar accident with an obvious impact on railway safety regulation or the management of safety' (Irish Government, 2014).
In addition, the RAIU 'may investigate accidents and incidents that under slightly different conditions might have led to serious accidents' (Irish Government, 2014).
The railway undertaking 'shall immediately report the accident or incident by the quickest practicable means' (Irish Government, 2014).
8: When the RAIU decides to investigate an accident or incident, the response involves the dispatch of investigators to the site, the investigation of the accident or incident site, and the collection of evidence (Irish Government, 2014).
9: The RAIU also evaluates accidents it has investigated.
10: The LRT operator is responsible for the implementation of formulated measures, and the CRR and RAIU check that any recommendations in the RAIU reports are implemented.

11: All accident/incident reports are registered in the LRT operator's system, i.e., traffic event database (TED). Every accident or incident investigated by the RAIU is registered in its system. No statistics about accidents and incidents are published. The CRR prepares reports on safety statistics considering the general indicators (Appendix 4, Commission for Railway Regulation, 2017).
12: The RAIB investigates every serious accident, defined as accidents that involve deaths, serious injuries to two or more people, collisions, derailments, closure of the line for more than 6 h, or major damage (worth more than €2 million) to trains, infrastructure, or environment. In addition, the RAIB 'may investigate those accidents and incidents which under slightly different conditions might have led to serious accidents' and other types of accidents. The factors considered by the RAIB to decide whether or not to investigate an accident are the severity of the outcome, the potential for the consequences to have been more severe, the potential for new safety learning, and how widely it could be applied, safety trends, and areas of particular safety concern (British Government, 2014).
The operator shall report these events within the prescribed period depending on its severity (British Government, 2005).
13: In the case of serious accidents, the RAIB may conduct its own investigation, dispatch investigators to the site, and elaborate a bulletin (if there are no lessons that can be learned) or a complete report within 12 months. (Fontaine et al., 2014).
14: The RAIB may make recommendations and forward them to the ORR to ensure that the operator takes appropriate action.
15: The operators, RAIB, and ORR keep their own records. No statistics about accidents and incidents are published.

Although a quick scan of the table could give the impression that safety management in France, Ireland, and the United Kingdom (including Germany, at a regional level) are similar, this is not the case. Firstly, the German TABs are regional bodies, which may lead to dissimilar approaches according to different regions. Secondly, even though the RAIB (the United Kingdom) and RAIU (Ireland) consider the accidents of every operator at a national level, France has an absolutely different and a more comprehensive approach based on a unique database. The database is filled with accident/incident data reported by the operators of all LRT networks in France. Starting with the foregoing, the STRMTG gathers extensive information on the mishaps from all networks, as explained in section 4.

Apart from the information listed in the table, it is important to note that in the case of a serious accident, an official investigation is usually conducted parallel to that of the operator or responsible body in order to determine criminal or civil liabilities and deal with compensation claims. The operators are required to provide all pertinent information (for instance, data from the automated event recorder (black box) and CCTV images) to clarify the causes and circumstances of the accident. Finally, serious accidents that occur on urban roads are usually investigated by the police (Lewisch et al., 2014).

4 THE FRENCH APPROACH

In this section, the French approach to LRT safety is explained in detail in order to use it as a model for Spain or other countries that might be interested in enhancing their LRT safety management.

4.1 Regulation

In 2003, the *Décret n°2003-425 du 9 mai 2003 relatif à la sécurité des transports publics guides* (French Government, 2003) that pertain to urban guided transit safety was approved. This Decree has recently been improved and replaced by the *Décret n° 2017-440 du 30 mars 2017 relatif à la sécurité des transports publics guides* (French Government, 2017); the latter maintains the same philosophy and benefits from more than a decade of experience relative to transit safety management.

The aforementioned Decree establishes the safety requirements for starting the operation of a new light rail system or modifying an existing one, as well as the conditions that must be satisfied during the entire operational life of such a system.

Specifically, the Decree establishes the State's responsibility to manage the safety of guided transport systems (including light rail) throughout their service life by means of the Department Prefect, which is designated as the supreme representative of the State. The Prefect may act as follows.

- entrust monitoring visits to the system itself to guarantee that the service is provided under safe conditions (Article 84 of *Décret n° 2017-440*);
- require the operator or transit authority to amend any defect in the system (Article 85);
- require a safety assessment of the system through an accredited organisation (Article 86);
- suspend service if safety is compromised (Article 87).

The Decree also indicates the function of various entities, such as public transport authorities, road managers, and guided transport system operators, in the general frame of safety monitoring (Articles 20–23). In particular, it specifies the obligation of the

operator to establish a safety management system (Article 23) in which people in charge of the internal safety assessment must be independent of the production staff (Article 24).

Finally, this Decree (French Government, 2017) specifies the procedure for reporting accidents and incidents, as well as providing information pertaining to the general safety situation of the system in the absence of events, as follows.

- In the case of a serious accident or incident, the LRT operator activates the safety and response plan and takes immediate necessary measures to ensure the safety of emergency personnel, operating staff, and third parties. The LRT operator must immediately inform the Department Prefect (Article 89) and thereafter the STRMTG and all implied entities. The first report must be sent within 48 h.
- The LRT operator must submit a detailed report to the transit authority and to the Prefect within two months after an event or after it is detected. The report must include an analysis of the identified causes and consequences of the event, the potential risks, the lessons learned, and the measures applied to prevent the recurrence of the same event (Article 89).
- The Prefect may require the LRT operator for the analysis of any important incident related to safety that the latter is aware of. In any case, the Prefect may ask for any supplementary information that is considered appropriate (Article 94).
- The LRT operator has to produce an annual report pertaining to the safety of the system's operation. Specifically, this report must include sections related to the accident rate, internal control, system evolution, and action plan to be implemented for maintaining and improving the system's safety (Article 92).
- The transit authority sends this report to the Prefect including an assessment of the action plan considered. In case of deficiencies in the report, the Prefect may ask for a safety diagnosis through an accredited organisation (Article 92).

In addition to the foregoing, the functioning of the national supervisory body of urban guided transit safety (STRMTG) is also specified by another decree (French Government, 2010).

Article 2 establishes that the STRMTG, under the authority of competent Prefects, performs missions established by the regulations for urban guided transit regarding the following:

1) technical and safety inspections;
2) technical examination of safety files.

Moreover, Article 2 assigns the following missions to the STRMTG:

- implement studies, research, and gather experiences;
- gather data and prepare statistics;
- produce and disseminate documents and recommendations or technical guidelines;
- propose regulatory changes to the national government in relation to urban guided transit.

The creation of a database of light rail accidents and incidents is derived from the mission of making statistics (Fontaine et al., 2015). The details in creating this database are presented in the following sections.

It is important to note that, in concrete terms, this tool is the result of a shared process between the STRMTG and operators, both for its initial implementation and for its up-to-date filing and maintenance. Accordingly, a working group was organised in

2003–2005 to define the database; the group was reactivated twice (2010 and 2017) to modify the tool since it was first convened.

4.2 National database on light rail incidents/accidents

The French database is actually based on the combination of two different databases (Fontaine et al., 2015).

- A ‘network’ database, which contains the physical description of all existing light rail lines. Each line is divided into elementary sections, identified by a number and a code that determines the type of section (pedestrian crossing, intersection, station, or linking section) and contains the main characteristics of its environment and configuration. Accordingly, sections with similar codes are comparable in terms of safety because their designs are alike in all aspects that may have an influence on safety. Section 4.3 explains this codification.
- An ‘events’ database, in which all events (accidents or incidents) that occur in all LRT networks are gathered. A detailed description of each event is recorded based on a standard accident/incident report (explained in section 4.4). The localisation of the event is made by using the number of the section where it occurred; this allows the link between both databases.

The construction and updating of the network database and the recording of events are locally made by each LRT operator; it is yearly forwarded to the STRMTG, which then compiles a complete and exhaustive database of all incidents and accidents that must be reported regarding every light rail system in France.

The STRMTG manages this database and produces statistics. This database is more extensive than one that would have been built based on information from only one LRT network; hence, its statistical robustness is considerably improved. As a result of the homogeneous division and codification of lines in sections, several data related to each type of section are registered, conclusions may be drawn regarding the circumstances or design features of these sections, and links may be established relative to the probability of accidents/incidents.

These statistics are the bases for generating an annual national report about the fleet, the traffic and the operational events of light rail systems for the previous year, and the trends over the previous 10 years. To date, the latest published version is that of 2017; it includes the evolution from 2008 to 2017 (De Labonnefon y Passelaigue, 2018).

The national database is also used to implement a specific analysis and to feed studies regarding light rail safety (for example, pedestrian crossing safety problems and interactions between cyclists and light rail); it then aids in formalising the recommendations in the design guidelines for the construction of new lines or modification of existing ones. Examples of these guidelines are the roundabout design guideline (Lagarde et al., 2017) and that pertaining to the location of fixed obstacles near intersections (Dusserre, 2012).

Nevertheless, the objective is not to make comparisons among the networks. The compilation of the database for each network can be used by its operator as a tool to satisfy its specific requisites. The database may aid in monitoring the safety level trend or identifying black spots where accidents are concentrated. Therefore, readjustments or corrective measures to be implemented in these spots may be derived from the use of this database, always taking into consideration the specific local characteristics. The database is also useful for operators to produce the annual safety report that they are required to submit as explained in section 4.1.

4.3 Codification of light rail lines in homogenised sections

The procedure for codifying the sections of each line, detailed in the technical guideline for light rail line coding and published by the STRMTG (Passelaigue, 2018), is based on the following general principles.

- Each line is segmented in homogeneous sections identified by a 'section' number and a 14-digit code, which allows for the description of both driving directions (V1 and V2), although they can be differentiated if necessary. The code is intended to describe field reality but essentially in terms of safety. The sections can be assigned to one or more operation lines in case several lines merge into one trunk line.
- The reference points are employed to indicate the order of sections in the line. The sections in trunk zones will have different reference points for each line because they are related to the line they describe.
- When line modifications are made, a new sub-section is added so that the former codification is not deleted; modifications are implemented in such a way that the 'memory' of line configurations and accident locations that occurred before the modifications are maintained over time.

The 14-digit code is established as follows.

- The first digit characterises the urban environment where the section is located; the private traffic speed is the main reference (1 for pedestrian zones, 2 for speeds of up to 30 km/h, etc.).
- The second digit indicates the type of section, which can be a station (1), an intersection (3 –9), or a linking section (2). The main aspects considered for the codification of stations and linking sections are the following.
  - Regarding intersections, several types are distinguished: from single road crossings (3) to 'other' intersections (9), intersections with road vehicles turning on tracks (4), roundabouts or circular intersections regulated by traffic lights (5), pedestrian/cyclist crossings (6), neighbouring access (7), and entrances to shared carriageway zones (8).
  - The linking sections refer to segments of lines between intersections or between intersections and stations. These stretches are divided in as many sections as necessary because of changes in any of the following criteria: urban environment and surroundings; position of tramway tracks in the street; type of track separator in relation to adjacent carriageways; regulatory situation of tramway tracks; running conditions of private traffic in relation to the tramway tracks; type of parking (adjacent or not to the tracks); any railway particularity; type of infrastructure; type of right of way (whether it is possible to run on it or not); cyclist lanes; visual obstacles; light rail speed limit.
- For each section, the 10 digits in the code that follow are used to describe its specific characteristics (layout, signage, etc.) with each figure having distinct meaning according to the type of the section; the last two digits indicate the allowable light rail speed.

A detailed explanation of the procedure to code the lines exceeds the purpose of this study. Accordingly, only a table summarising the linking sections is presented as an example to provide a general idea of the main aspects considered. For each of the other

second digits (1 and 3–9), there are other summarising tables that indicate the coding procedure in the guideline.

TABLE 2 Linking section classification. Source: translated from Passelaigue (2018).

2 = linking section	2º	2								
	3º	Position of tramway tracks		1 = lateral	2 = central	3 = bilateral	4 = out of the road/street	5 = other, particular case		
	4º	Type of separator	0 = NA	1 = separator designed as impassable	2 = separator designed as passable	3 = central impassable separator (shared right-of-way)	4 = central passable separator (shared right-of-way)	5 = none	6 = others	
	5º	Regulatory situation of tramway tracks		1 = exclusive for light rail	2 = reserved for light rail and other transit	3 = shared right-of-way	4 = reserved for light rail and others			
	6º	Running conditions of private traffic (adjacent carriageways)	0 = NA	1 = two-way	2 = one-way, light rail to the left	3 = one-way, light rail to the right	4 = particular configuration			
	7º	Parking spots adjacent to light rail tracks	0 = NA	1 = yes; without pedestrian barriers	2 = no	3 = yes; with pedestrian barriers (metal, bushes, etc.)				
	8º	Railway particularities	0 = NA	1 = turnout	2 = single track	3 = bretelle (scissor crossing)	4 = terminal	5 = simple crossing	6 = other cases	7 = split tracks
	9º	Type of infrastructure		1 = on surface	2 = bridge/viaduct	3 = tunnel	4 = underpass	5 = other cases		
	10º	Type of tramway finishing		1 = possible to run on it	2 = impossible to run on it	3 = possible to run on it; with access control (pit, retractable bollard, barrier, etc.)				
	11º	Existence of cyclist lanes		1 = yes; with interaction	2 = yes; without interaction	3 = no				
	12º	Existence of visual obstacles		1 = yes	2 = no					
	13º	Light rail speed	These digits indicate the maximum authorised light rail speed expressed in km/h. Example: 05 = 5 km/h; 25 = 25 km/h							
	14º									

NA = not applicable

4.4 Event database: standardised accident/incident report

In order to homogenise database records, the LRT operators agreed on the use of a standardised accident/incident report.

The use of this standardised shared tool and the training of the persons in charge of filling it out aim to guarantee the gathering of all relevant information in an appropriate and shared manner at the accident/incident site immediately after its occurrence. It is extremely important to determine the causes and circumstances of the accident/incident. Accordingly, this information must be gathered accurately because every detail can be essential for later investigations, and the errors committed at this stage can barely be neutralised in a later phase (Lewisch et al., 2014).

Figure 2 shows the format of the accident/incident reporting frame employed by the French light rail systems.

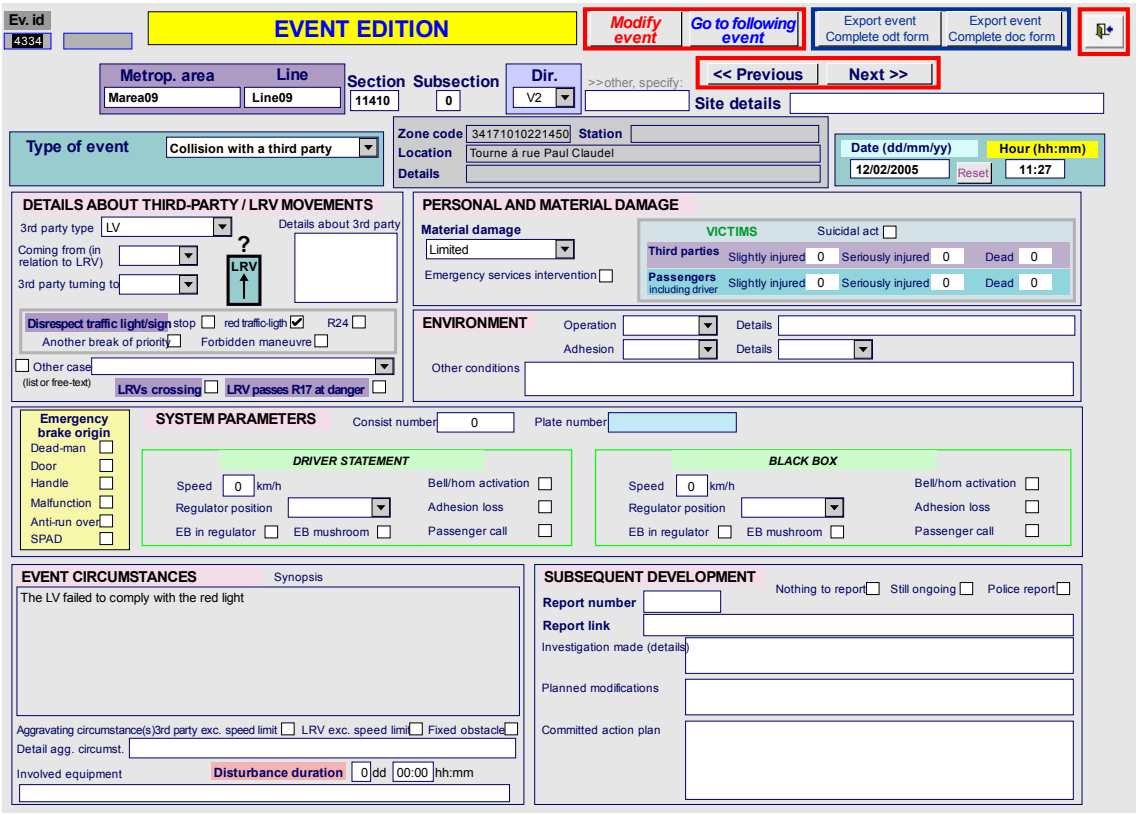

FIGURE 2 Accident/incident report format employed by French light rail. Source: translated from Passelaigue (2015)

The main parts of the report are explained in the guidelines for using the event database (Passelaigue, 2015). A brief summary of these guidelines is presented in this section, where each part is related to a part of the reporting frame shown in Figure 2.

Section identification and event location

The section where the event occurred may be selected from a list in the 'network' database. The fields 'section', 'subsection', 'metropolitan area', and 'line' are automatically loaded; also loaded are 'station' (if applicable), 'location' (pedestrian crossing, for instance), and 'remarks' (if they exist). Thereafter, the driving direction must be selected from a drop-down menu for the following fields to appear. The 'site details' field can be filled in to specify any additional information about the event location.

Type of event

There is a drop-down menu to select the type of accident/incident from the following options: collision with a third party; passenger event; collision with an obstacle on structure gauge; derailment/derailment because of switch problems; collision among light rail vehicles (LRV); event at the end of the line; panic; electrocution; fire/explosion; other events.

Depending on the type of event selected, other fields emerge to be filled in. For instance, for the case 'passenger event', the options are as follows: fall in the LRV; fall from the LRV in line; fall from the LRV at station; fall from the platform; trapping in the LRV; dragged by the LRV.

Moment of event

The date and time of the accident/incident must be registered.

Third party and LRV movements

The part related to 'Details about third party and LRV movements' is only available for event types 'collision with a third-party' and 'other events'. The data include the type of third party involved (drop-down menu), where the third party is coming from in relation to the LRV (drop-down menu), and turn of the third party in relation to the LRV (drop-down menu).

The part 'disrespect of traffic-light/traffic-sign' allows the inclusion of the type of signs violated. Moreover, a drop-down menu is available when the check box 'other case' is clicked; it allows the selection of unauthorised movements made or other circumstances.

There is also a check box for the case that the event involves the crossing of two LRVs, and another for the case of a light rail traffic light passed at danger.

Personal and material damage

The field 'material damage' is a drop-down menu with the following options: limited; significant; none; derailment; unknown.

In the part related to victims, the consequences of the accident/incident must be included in the form of number of third parties and passengers slightly or seriously injured, or killed.

There are two check boxes, one related to the emergency service intervention and the other to suicidal attempts or acts.

Environmental conditions

The fields 'operation' and 'adhesion' are drop-down menus with the options normal and degraded. An explanation can be included about the operational situation in the 'details' field. For the case of adhesion, there is a drop-down menu with the options meteorological and leaves. Finally, the field 'other conditions' allows for the inclusion of explanation of any specific situation that may affect operations.

System parameters

The number of LRV must be included.

The section 'Emergency braking origin' allows registering why the emergency brake activated if it has not been initiated by driver action. The options are dead-man; door opening while running; emergency brake handle activation by a passenger; anti-run over system activation; automatic braking after passing a signal at danger or because of exceeding speed limit. If the activation of the brake resulted from the malfunction of any of the previous elements, then it should be registered as 'malfunction'.

The section 'Driver statement' should be registered as soon as possible after the statement has been made. The data to be registered are the information given by the driver regarding speed before the driver's reaction; regulator position (traction, neutral, and braking); emergency brake activation with the regulator; emergency brake activation with the 'mushroom'; bell/horn activation; adhesion loss; passenger call.

The section 'Black box' includes the same information as the driver statement but obtained directly from the automatic operation parameter recorder. In this case, the speed corresponds to the moment when the crash occurred.

Event circumstances

The field ‘synopsis’ is a free-text field where the circumstances of the event can be explained.

Aggravating circumstances are identified by check boxes: third party exceeding speed limit; LRV exceeding speed limit or speed not according with on-sight driving; fixed obstacle, following the STRMTG guide definition (Dusserre, 2012). The field ‘Aggravating circumstances detail’ can be used to explain these circumstances.

The field ‘Involved equipment’ is a free-text field where the malfunction of safety equipment can be registered.

Subsequent development

There are three check boxes: ‘nothing to report’, if there has been no further investigation; ‘still ongoing’; ‘police report’, if there has been a judicial inquiry. A link to the internal report is included.

Finally, there are three text-free fields for explaining the following: investigations being made, modifications to be applied to the system after the event analysis, and actions to be taken after the event analysis.

4.5 Conclusions and critical review of French approach

As explained in the previous sections, the STRMTG (a national technical public body) has been assigned by the French regulation the task of dealing with the safety of all light rail networks in the country.

One of the main tools for the STRMTG to perform this task is the national database pertaining to light rail accidents and incidents. This database allows having a larger sample of sections of each type than if data were available from only one network; this can be attributed to the shared codification explained in section 4.3. The results are given in the STRMTG’s annual national report; the database is used as the basis of numerous light rail safety studies. Moreover, light rail operators use the database for filling in the reports about accidents/incidents with a standardised model; this systematises information gathering and allows its treatment as a whole at the national level. Accordingly, a more productive statistical analysis can be achieved.

It is important to note that the contents of the standardised accident/incident report in the database imply (similar to any investigation manual) a set of assumptions on how accidents/incidents occur and what factors are important (Lundberg et al., 2009). Therefore, the ‘What-You-Look-For-Is-What-You-Find’ principle can be applied; this means that the assumptions made determine what is actually found (Hollnagel, 2008). In the same way, the identified causes are typically the problems that are fixed during the implementation of solutions according to the principle ‘What-You-Find-Is-What-You-Fix’ (Lundberg et al., 2009). Furthermore, the factors considered in the report are mainly related to the microlevel or sharp end of accidents/incidents, i.e., to equipment, actor activities, and physical processes (Le Coze, 2008; Cedergren and Petersen, 2011).

Nevertheless, it is possible for the STRMTG to examine all reports and to have various professionals with different backgrounds to derive conclusions from the investigation. This is an important aspect because the factors emphasised in investigation reports are usually related to the competencies and experiences of investigators who are inclined to focus on their areas of expertise (Cedergren and Petersen, 2011). Hence, by having different professionals from the STRMTG investigate the accident/incident reports from several LRT networks, a more appropriate solution than that conceived by an LRT operator alone can be derived. This is because with a limited staff and without

clear accident/incident investigation procedures and reports, vital information may be lost; consequently, the conclusions reached by an LRT operator may be biased.

Finally, as previously stated, the management of this database allows the STRMTG to perform other tasks, such as producing reports based on research and experiences, statistical analysis, guidelines and technical references, and proposing regulatory changes in light rail safety at the national level when necessary. These tasks performed by the STRMTG guarantee that apart from the aforementioned microlevel aspects, different professionals of different backgrounds also focus on the blunt end, i.e., the meso-level (organisational aspects, such as management issues) and macrolevel (inter-organisational features, regulatory bodies, inspectorates, associations, and even governments) aspects (Le Coze, 2008; Cedergren and Petersen, 2011). Accordingly, a comprehensive approach to the LRT safety is performed, and a deeper comprehension of accidents and incidents is achieved; this leads to well-based proposals that can improve the entire spectrum of influencing factors.

In order to be as exhaustive and objective as possible regarding this tool, it is relevant to consider the limits of the database and certain problems that users encounter; potential enhancements of the tool should also be conceived.

Comprehending the influence of layouts on accidents is a considerably assertive goal. This is because the codification of the lines is actually heavy in terms of both the number of sections (approximately 17 000 sections for all networks in 2018) and the description of layouts and signage through the 10 digits.

Moreover, it appears that despite the detailed description and precise explanations provided in the codification guideline, there remains room for individual interpretations in deciding how to code sections. Consequently, the same configuration could be codified in various ways from one network to another because each operator is in charge of the creation and maintenance of a certain part of the network database. To resolve this problem, some verification campaigns have been launched in previous years by the STRMTG with the aid of CEREMA (*Centre d'études et d'expertise sur les risques, l'environnement, la mobilité et l'amenagement*, formerly CERTU—*Centre d'Etudes sur les Réseaux, les Transports, l'Urbanisme et les constructions publiques*) and operators on some specific sections, such as roundabouts or turn-on junctions.

In relation to these problems, CEREMA, which is currently working on a similar database for the BHLS (bus with high level of service) systems, is endeavouring to implement a more simple codification approach conducted by a unique office.

Regarding the event database, there are also some possible interpretations concerning what is and what is not to be recorded as an event when the consequences are not severe (no (or even slightly) injured people, no serious material damage); moreover, there can be a lack of precision in terms of localisation of some events (for example, on or near a pedestrian crossing). The use of geographic information system (which is considerably more easily accessible nowadays than 15 years ago) might be useful in this regard as well as for building the network database. This choice has been made by CEREMA for the BHLS database.

However, the main limitation of the database lies in the partial description of events because no information on the causes of third-party behaviour can generally be gathered. Regarding this particular point, the video recording resource from frontal cameras (as used in other countries) would be considerably advantageous; however, their implementation and use remain impeded by legal issues in France.

Despite the various problems, there remains considerable interest both for the operators and the STRMTG to build, maintain, and use such a database.

5 RECOMMENDATIONS FOR IMPROVEMENT OF LIGHT RAIL SAFETY MANAGEMENT IN SPAIN AND OTHER COUNTRIES

From the authors' point of view, it would be highly relevant for Spain to develop a regulatory framework related to light rail safety in accordance with the increase in the number of networks and lines during the last decades. The French setup, which seems to be the most developed system in Europe, might be considered as a pattern that could yield benefits to Spain. It may also be useful for other countries interested in enhancing their light rail safety management.

The main aspects of the regulatory framework to be implemented include the following.

- The development of a Light Rail Safety Act, which could be similar to the Valencian Rail Safety Act in certain aspects, but implemented at the national level. This Act would create the National Light Rail Safety Body, with a similar function as the French STRMTG in relation to light rail safety. It would establish the procedures for light rail accident/incident treatment in a manner similar to that of the French regulation (section 4.1) by considering the following points.
    - Implementation of a light rail safety database. Following the French example, this database would be composed of the following at a minimum:
        - codification of light rail lines in homogenised sections from the safety point of view by considering relevant parameters (section 4.3) but endeavouring to simplify the process in line with the proposals in section 4.5;
        - creation of a standardised light rail accident/incident report to be filled in directly by light rail operators through the database and establishment of the criteria necessary for guaranteeing a homogeneous information treatment in order to conduct statistical studies based on the database (section 4.4), also considering the critical review presented in section 4.5.
    - Management of the database by the National Light Rail Safety Body in order to make statistical analysis and recommendations both for the existing lines and the design of new lines or branches. This will allow the consideration of both sharp and blunt ends of accidents and incidents. This Body should hire professionals with different backgrounds that would lead to a more comprehensive approach for improving light rail safety.

As shown in Novales et al. (2015), most of the LRT operators in Spain use a certain type of line codification, internal form for accident reporting, and information collection. Nevertheless, there is no homogeneity among the operators in these aspects; consequently, it becomes impossible to make fair comparisons among the reported accidents and incidents as well as derive general conclusions on how to improve the situation in the entire country.

By managing the database, expertise is developed. Consequently, the National Light Rail Safety Body could deliver guidelines and technical recommendations; it could become a world reference in relation to light rail safety, in the same way that the French STRMTG and CEREMA already are.

It should be noted that the use and maintenance of an accident/incident database entail certain problems that must be resolved; these have been compiled by Fontaine et al. (2015). The most crucial ones are as follows: the necessity of an initial standardisation work for introducing data to the database; the necessity of additional staff for LRT operators in order to manage and register data both for the initial codification of sections

and registration of data during operation according to standardised criteria. Moreover, the critical review presented in section 4.5 should be considered, especially in relation to the simplification and unified preparation in a unique office of the codification of lines for homogenisation; precision in the localisation of certain events with the use of geographic information system can also be achieved. In any case, the authors presume that the deficiencies of the database are outweighed by its advantages, as explained in this paper.

As previously stated, these recommendations on light rail safety management patterned after the French example could be extended to any country interested in improving its light rail safety management. In fact, the United Kingdom seems to be following this path after the investigation of the overturning of a tram at Sandilands junction; the event, which occurred at Croydon in November 2016, led to the death of seven passengers. The investigation report (Rail Accident Investigation Branch, 2018) provided several recommendations to improve safety. Based on the investigation of this accident, the first recommendation is that the ORR (Office of Rail Regulation) should create a body to enable effective 'cooperation on matters related to safety, and the development of common standards and good-practice guidance'. Among the objectives of this body are the following:

> 'iii. managing the development of safety related design and operational standards, and their subsequent maintenance.
> iv. participation in the development of industry standards and guidance by international bodies.
> vi. gathering data, monitoring and reporting on the industry's safety performance (including comparisons of safety performance on different tramways).
> viii. working with tramways to help plan industry safety improvement'.

It appears that the functions assigned to this body are partially similar to those of the STRMTG and those proposed for the National Light Rail Safety Body presented in this paper. From the authors' point of view, the best approach to satisfy these purposes is to implement a similar safety management system as those previously proposed.

The implementation of this national regulation is an urgent matter for the case of Spain because regional regulations are starting to be passed. The authors presume that the management of LRT safety at a regional level in Spain would not be appropriate because it will imply that the responsibility of each region is limited to a small number of LRT networks: one network each for Murcia, Canary Islands (Tenerife), and Aragón (Zaragoza); two for Basque Country (Vitoria and Bilbao) and Catalonia (the two Barcelona LRTs); three for Andalusia (Seville, Granada and Malaga) and Madrid (the three Madrid LRTs). Consequently, this would defeat the purpose of compiling an extensive accident/incident database.

For the case of other countries, the regional management approach could only be considered if the number of LRTs in each region is sufficiently high; however, it should be managed carefully in order to harmonise all efforts related to safety among all regions.

6 CONCLUSIONS

This paper has presented the current situation of LRT safety management in Spain; a critical review is made, and a new approach based on the French model is proposed. The aforementioned model has been selected because after a comparison of different approaches taken by European countries, the French model seems to be the most adequate and comprehensive solution. Nevertheless, a critical review of this solution is

also presented in the paper; it highlights the model's main drawbacks and the potential ways for improving it in new deployments.

The proposed LRT safety management system is based on the following points: 1) the development of a National Light Rail Safety Act, which would create the National Light Rail Safety Body; 2) the implementation of a light rail safety database by codifying the light rail lines in homogenised sections from the perspective of safety and by standardising light rail accident/incident reports to be directly filled in by light rail operators; 3) the management of the database by the National Light Rail Safety Body in order to improve safety based on the conclusions drawn.

This approach would be useful both for Spain and other countries interested in improving their LRT safety management.

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REFERENCES

Andalusian Regional Government, 2006. *Ley 9/2006, de 26 de diciembre, de Servicios Ferroviarios de Andalucía*, Comunidad Autónoma de Andalucía, Sevilla. https://www.boe.es/buscar/pdf/2007/BOE-A-2007-665-consolidado.pdf (April 30, 2019).

British Government, 2005, *Railways (Accident Investigation and Reporting) Regulations 2005*, British Government. http://www.legislation.gov.uk/uksi/2005/1992/pdfs/uksi_20051992_en.pdf (April 30, 2019).

British Government, 2014, RAIB's response to accident and incident notification, UK Government, London. https://www.gov.uk/guidance/raibs-response-to-accident-and-incident-notification (April 30, 2019).

Catalonian Regional Government, 2006. *Ley 4/2006, de 31 de marzo, Ferroviaria*, Comunidad Autónoma de Cataluña, Barcelona. https://www.boe.es/buscar/pdf/2006/BOE-A-2006-8213-consolidado.pdf (April 30, 2019).

Catalonian Regional Government, 2017. *Ley 5/2017, de 28 de marzo, de medidas fiscales, administrativas, financieras y del sector público y de creación y regulación de los impuestos sobre grandes establecimientos comerciales, sobre estancias en establecimientos turísticos, sobre elementos radiotóxicos, sobre bebidas azucaradas envasadas y sobre emisiones de dióxido de carbono*, Comunidad Autónoma de Cataluña, Barcelona.

https://www.boe.es/buscar/act.php?id=BOE-A-2017-7353&p=20170803&tn=1 (April 30, 2019).

Cedergren, A., Petersen, K., 2011, Prerequisites for learning from accident investigations – A cross-country comparison of national accident investigation boards, *Safety Science*, 49, 1238-1245. https://doi.org/10.1016/j.ssci.2011.04.005

Commission for Railway Regulation, 2017, *Annual Report 2017*, Commission for Railway Regulation. https://www.crr.ie/download/pdf/crr_annual_report_2017_web.pdf (April 30, 2019).

Commission for Railway Regulation, 2019, Commission for Railway Regulation website. https://www.crr.ie/about/ (April 30, 2019).

De Labonnefon, V., Passelaigue, J.M., 2018, *Rapport annuel sur le parc, le trafic et les événements d'exploitation des tramways – année 2017 – évolution 2008-2017*, STRMTG (Service Technique des Remontées Mécaniques et des Transports Guidés). http://www.strmtg.developpement-durable.gouv.fr/IMG/pdf/rapport_annuel_tw_2017_v1_2.pdf (April 30, 2019).

Dusserre, A., 2012, *Guide d'implantation des obstacles fixes à proximité des intersections tramways / voies routières*, STRMTG (Service Technique des Remontées Mécaniques et des Transports Guidés). http://www.strmtg.developpement-durable.gouv.fr/IMG/pdf/GT3-DTW-Obstacles_Fixes_V2b.pdf (April 30, 2019).

Fontaine, L. (chair), Ablasser, G., Bakaba, J.E., Baptista, J., Bertrand, D., Carrasco, N., Carsi, J., De Jong, M., Deutsch, V., Duhoux, M., Gaivoto, C., Gattuso, D., Goch, K., Ignaccolo, M., Inturri, G., Jasinski, M., Kammachi, A., Kupferschmid, J., Langensiepen, D., Lewisch, S., Lohrmann, K.D., Macsinka, K., Malasek, J., Manso, O., Marti, C., Millot, M., Monti, F., Morley, R., Muñoz, A., Naegeli, L., Novales, M., Ortiz, O., Roos, R.J., Rosenberger, M., Schmitt, D., Schröter, R., Schwertner, M., Smit, C., Spousta, J., Sucha, M., Teixeira, M., Tierney, D., Ullmann, M., Vana, M., Van Genechten, R., Vasicek, J., Walmsley, D., Weidmann, U., Yezbek, J., Young, T., Zaidel, D., 2015, *Operation and safety of tramways in interaction with public space. Analysis and Outcomes. Detailed Report*, COST (European Cooperation in Science and Technology). ISBN: 978-2-11-139720-0. http://goo.gl/dX2ycG (April 30, 2019).

Fontaine, L., Teixeira, M., Sucha, M., Bertrand, D., Novales, M., Walmsley, D., 2014, *Operation and safety of tramways in interaction with public space. Public Report, Work Phase 1*, COST (European Cooperation in Science and Technology). http://webarchiv.ethz.ch/ivt/oev/publications/papers/COST_TU1103.pdf (April 30, 2019).

French Government, 2003, *Décret n° 2003-425 du 9 mai 2003 relatif à la sécurité des transports publics guidés*, JORF nº109 11th May 2003, French Government. https://www.legifrance.gouv.fr/eli/decret/2003/5/9/EQUX0300030D/jo/texte (April 30, 2019).

French Government, 2017, *Décret n° 2017-440 du 30 mars 2017 relatif à la sécurité des transports publics guidés*, JORF nº0077 31st March 2017, French Government. https://www.legifrance.gouv.fr/eli/decret/2017/3/30/DEVT1609684D/jo/texte (April 30, 2019).

French Government, 2010, *Décret n° 2010-1580 du 17 décembre 2010 relatif au service technique des remontées mécaniques et des transports guidés*, JORF nº0293 18th December 2010, French Government. https://www.legifrance.gouv.fr/eli/decret/2010/12/17/DEVK1020985D/jo/texte (April 30, 2019).

Gnoni, M.G., Saleh, J.H., 2017, Near-miss management systems and observability-in-depth: Handling safety incidents and accident precursors in light of safety principles. *Safety Science,* 91, 154–167. http://dx.doi.org/10.1016/j.ssci.2016.08.012

Head of State, 2003. *Ley 39/2003, de 17 de noviembre, del Sector Ferroviario*, Jefatura del Estado, Madrid. https://www.boe.es/buscar/pdf/2003/BOE-A-2003-20978-consolidado.pdf (April 30, 2019).

Head of State, 2015. *Ley 38/2015, de 30 de septiembre, del Sector Ferroviario*, Jefatura del Estado, Madrid. https://www.boe.es/boe/dias/2015/09/30/pdfs/BOE-A-2015-10440.pdf (April 30, 2019).

Hollnagel, E., 2008, Investigation as an impediment to learning. In: Hollnagel, E., Nemeth, C. P. & Dekker, S. (Eds.), *Remaining sensitive to the possibility of failure*, pp. 259-268. Aldershot, UK: Ashgate.

Irish Government, 2014, *European Union (Railway Safety) (Reporting and Investigation of Serious Accidents, Accidents and Incidents) Regulations 2014*, Irish Government, http://www.irishstatutebook.ie/eli/2014/si/258/made/en/pdf (April 30, 2019).

Jones, S., Kirchsteiger, C., Bjerke, W., 1999. The importance of near miss reporting to further improve safety performance. *Journal of Loss Prevention in the Process Industries,* 12, 59–67. https://doi.org/10.1016/S0950-4230(98)00038-2

Lagarde, Y., Bertrand, D., Blancheton, M., 2017, *Giratoires et tramways. Franchissement d'un carrefour giratoire par une ligne de tramways. Guide de conception*, STRMTG (Service Technique des Remontées Mécaniques et des Transports Guidés) & CEREMA (Centre d'études et d'expertise sur les risques, l'environnement, la mobilité et l'amenagement). http://www.strmtg.developpement-durable.gouv.fr/IMG/pdf/giratoires-tramways-final-web-2.pdf (April 30, 2019).

Le Coze, J.C., 2008, Disasters and organisations: From lessons learnt to theorizing, *Safety Science,* 46, 132-149. https://doi.org/10.1016/j.ssci.2006.12.001

Lewisch, S., Langensiepen, R., Lohrmann, K.D., Matschke, K.D., 2014, *Operational accident statistics. An essential element of accident prevention*, UITP (Union Internationale des Transports Publics). http://goo.gl/fB3kPX (April 30, 2019).

Lundberg, J., Rollenhagen, C., Hollnagel, E., 2009, What-You-Look-For-Is-What-You-Find – The consequences of underlying accident models in eight accident investigation manuals, *Safety Science*, 47, 1297-1311. https://doi.org/10.1016/j.ssci.2009.01.004

Ministry of Infrastructure (*Ministerio de Fomento*), 2007. *Real Decreto 810/2007, de 22 de junio, por el que se aprueba el Reglamento sobre seguridad en la circulación de la Red Ferroviaria de Interés General*, Ministerio de Fomento, Madrid. https://www.boe.es/buscar/pdf/2007/BOE-A-2007-13177-consolidado.pdf (April 30, 2019).

Ministry of Infrastructure (*Ministerio de Fomento*), 2010. *Real Decreto 918/2010, de 16 de julio, por el que se modifica el Real Decreto 810/2007, de 22 de junio, por el que se aprueba el Reglamento sobre seguridad en la circulación de la Red Ferroviaria de Interés General*, Ministerio de Fomento, Madrid. https://www.boe.es/boe/dias/2010/08/05/pdfs/BOE-A-2010-12533.pdf (April 30, 2019).

Ministry of Infrastructure (*Ministerio de Fomento),* 2011. *Real Decreto 641/2011, de 9 de mayo, por el que se modifica el Reglamento sobre seguridad en la circulación de la Red Ferroviaria de Interés General, aprobado por Real Decreto 810/2007, de 22 de junio*, Ministerio de Fomento, Madrid. https://www.boe.es/boe/dias/2011/05/10/pdfs/BOE-A-2011-8124.pdf (April 30, 2019).

Ministry of Infrastructure (*Ministerio de Fomento),* 2015. *Real Decreto 1006/2015, de 6 de noviembre, por el que se modifica el Reglamento sobre seguridad en la circulación de la Red Ferroviaria de Interés General, aprobado por Real Decreto 810/2007, de 22 de junio*, Ministerio de Fomento, Madrid. https://www.boe.es/boe/dias/2015/11/07/pdfs/BOE-A-2015-12050.pdf (April 30, 2019).

Muñoz, A., 2014, LRT in Tenerife – Spain: Integrating Successful LRT into an Automobile-Oriented City. *Transportation Research Board 93rd Annual Meeting*, invited presentation at the Workshop: "Light Rail Transit Innovations and Urban Insertion", Washington DC, January 12-16, 2014. https://drive.google.com/file/d/0BxoI3J-J1EVGTjBEemtfclFPNGs/view (April 30, 2019).

Novales, M., Bugarín, M.R, 2009, *Tranvitrén y tren-tranvía. Hacia una mejora del aprovechamiento de las infraestructuras ferroviarias*, Colegio de Ingenieros de Caminos, Canales y Puertos, Madrid (Spain). ISBN: 978-84-380-0419-7.

Novales, M., 2012, Light Rail Systems in Spain. *Transportation Research Board 91st Annual Meeting*, presentation at LRT Committee Meeting AP075, Washington DC, January 22-26, 2012. https://drive.google.com/file/d/0BxoI3J-J1EVGVzlDdDRIUTUtUzQ/view (April 30, 2019).

Novales, M., Cerezo, J.A.G., Ortega, R., 2013, Light rail in Alicante, Spain. Improving the Use of Existing Railway Lines. *Transportation Research Record*, 2353, 69-81. http://dx.doi.org/10.3141/2353-07

Novales, M., Carsi, J., Ortiz, O., Muñoz, A., 2015, Spanish LRT safety data collection and analysis. *Transportation Research Board 94th Annual Meeting*, Washington DC, January 11-15, 2015. https://trid.trb.org/View/1336839

Passelaigue, J.M., 2015, *Mode d'emploi de la base de données événements Tramway*, STRMTG (Service Technique des Remontées Mécaniques et des Transports Guidés), http://www.strmtg.developpement-durable.gouv.fr/IMG/pdf/Mode_emploi_BDD_evenement_TW_V2015.pdf (April 30, 2019).

Passelaigue, J.M., 2018, *Codification des lignes de tramway. Version du 20 décembre 2018*, STRMTG (Service Technique des Remontées Mécaniques et des Transports Guidés). http://www.strmtg.developpement-durable.gouv.fr/IMG/pdf/guide_technique_tgu_codification_lignes_tw_2018_1_1.pdf (April 30, 2019).

Rail Accident Investigation Branch, Department of Transport, 2018, *Report 18/2017, v2 – October 2018: "Overturning of a tram at Sandilands junction, Croydon, 9 November 2016"*, Derby, United Kingdom. https://assets.publishing.service.gov.uk/media/5a2a6289ed915d458e4214ba/R182017_181024_Sandilands_v2.pdf (April 30, 2019).

Railway Accident Investigation Unit, 2019, Railway Accident Investigation Unit website. https://www.raiu.ie/ (April 30, 2019).

TRB, 1978, *Glossary of Urban Public Transportation Terms*, Transportation Research Board (TRB), Washington DC.

Van der Bijl, R., Van Oort, N., Bukman, B, 2018, *Light Rail Transit Systems. 61 Lessons in Sustainable Urban Development*, Elsevier, Amsterdam (The Netherlands). ISBN: 978-0-12-814784-9.

Valencian Regional Government, 2018. Ley 7/2018, de 26 de marzo, de seguridad ferroviaria, Conmunitat Valenciana, Valencia. https://www.boe.es/buscar/pdf/2018/BOE-A-2018-5396-consolidado.pdf (March 21, 2019).

Vuchic, V.R., 2007, *Urban Transit Systems and Technology*. John Wiley & Sons Inc., New York. ISBN: 978-0-471-75823-5.

Yang, H., Chew, D.A.S., Wu, W., Zhou, Z., Li, Q., 2012, Design and implementation of an identification system in construction site safety for proactive accident prevention. *Accident Analysis and Prevention*, 48, 193– 203. https://doi.org/10.1016/j.aap.2011.06.017

Zhang, X., Deng, Y., Li, Q., Skitmore, M., Zhou, Z., 2016, An incident database for improving metro safety: The case of Shanghai. *Safety Science,* 84, 88–96. https://doi.org/10.1016/j.ssci.2015.11.023