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Tram safety management – France experience

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ABSTRACT

Since 2003 in France, the legislation about urban guided transport systems safety has required the estimation and validation of the risks and level of safety for the whole streetcar system including its infrastructure before its design phase and all along its operation. In order to have feedback experience of urban insertion configurations, the French Guided Transport Technical Office (STRMTG), which is a regulating authority, has collected national data on events involving streetcars. A first database was created, using a codification which identifies every type of section in a streetcar line and characterizes its environment, in order to have a national and anonymous view on streetcar events. This database enables the STRMTG to calculate national indicators, which permit identification and analysis specific issues and tendencies, and allows recommendations to be made about streetcars urban insertion as a result. After seven years of database use, some limitations have been detected in the codification. A huge work of re-coding has been made in 2011 and 2012, adapted to a more precise analysis of configurations, to better understand some particular problems. Each step of this process is presented in this paper.

The aim of this paper is to present how STRMTG organizes feedback experience of urban insertion configurations and employs national data to improve safety level of streetcar’s lines. These tools have been created in order to respond to the rapid development of streetcars lines in France and are adapted to the French context. With all the data collected and the first analysis made, dangerous configurations have been detected, sometimes without solutions. This paper is a way to exchange views about methodology and dangerous configurations.
1 INTRODUCTION

In France, with the rising number of guided transport systems' projects in the last decades (on March 2013, there are 56 lines in operation and 24 planned - figure 1 shows the evolution of tram lines between 2003 and 2011, ), the related legislation has been updated, first in 2002 with the "Safety of Infrastructures and Transport Systems" law, followed by the "Safety of Guided Public Transport Systems" (STPG) Decree in 2003, edited to estimate and validate the risks and the level of safety. It defines what a guided transport is: “transport system in which vehicles follow a determined path for a part or all of their journey” and specifies the safety objectives for urban guided transport systems. Streetcars, on rails or tyres, are part of the concerned systems.

Guided transport systems which operate exclusively on the national rail network and which are controlled by the French Railway Safety Authority are not concerned.

The main point of the new regulation is that the Ministry of Transportation controls the urban guided transportation systems safety before their design phase and during all the time of their operation. In order to allow a new transportation system to be operated, there is an authorization system based on four stages: three different safety files during the project and a local control for systems in operation. This last one monitors streetcar lines during their operation to maintain the safety level (modification / evolution of lines, audit of the operators, investigations after notable events...). Another main safety principle is the intervention of independent and qualified experts or agencies (also known as "OQA" and whose qualification is delivered by the Ministry of Transportation) on safety files.

FIGURE 1 French urban streetcar lines [1]
For the new systems and when existing systems are modified, the safety
demonstration principle is based on the GAME (globally at least equivalent)
principle. This principle says that “the overall safety level of the project is at least
equivalent to the overall safety level of an existing or comparable system”. It
concerns every part of a guided system, which includes:
- the infrastructure;
- the technical and safety installations;
- the rolling stocks;
- and the principles and rules for operation and maintenance.

Using the GAME principle has provided knowledge from feedback experience, to
know which installation or configuration is regarded as satisfying concerning its
safety level. Among all of its missions, the STRMTG shares information on past
experience, organizes feedback of experience at national levels, animates
reflections on events, streetcars’ interactions with other modes through national
workgroups and makes an annual analysis of reported accidents. From these
workgroups and reflections have come the need and the idea for a database and a
codification.

2 FRENCH NATIONAL DATABASE: DATA, ANALYSIS AND
RECOMMENDATIONS

With the cooperation of the streetcar operators in different cities, the STRMTG has
collected national data on events between streetcars and other road users. Accidents
on these networks are mostly coming from the interaction of road vehicles with
streetcars but they are not the only ones concerned by these accidents. Pedestrians
and bicycles can also be involved, and derailments and collisions between
streetcars, more rarely, can occur too. In order to study them and to improve the
safety level, accidents have to be considered with the type of place where they have
occurred. The analysis of these events, according to the characteristics of the places
where they occur, is one of the important objectives of the database and allows
identification of dangerous road network components.

2.1 Codification principles and database contents

To proceed to the streetcar accidents analysis at a national level, it is necessary to
have a common codifying process. So, to compare different streetcar lines and to
make them comparable, the STRMTG and the national workgroup with French
streetcar operators have decided to build a codification, "cutting" each streetcar line
in small homogeneous parts such as:
- stations;
- intersections (crossroads, roundabouts, pedestrian crossings,...);
- streetcar site (unique streetcar roads, exclusive right of way,...).

So, a codification with fourteen digits has been invented in order to identify every
type of section in a streetcar line and to characterize its environment: crossroads
qualification, what is the type of traffic lights, is there a roundabout, is there a
station, what is the speed limit for cars, for streetcars, what is the nature of the streetcar infrastructure... For example, for a section whose code is 2213001031025, the first figure means that it is in a 30 km/h zone (18.7 miles/hour zone), the second one that it is a crossroad, the third one that it is a simple crossroad, the fourth that the crossroad has traffic lights,... The signification of each figure is summarized in a table in the national guidelines [4].

Operators have codified their lines using different methods, from photos or site visits, or from to plans (like in Saint-Etienne, line 5: the third and fourth columns give the codification in the even and odd direction – figure 2).

FIGURE 2 Codification of a part of line 5, Saint-Etienne

Operators have filled in the database with events, mentioning among other things, the section number, which gives automatically the associated codification.

The STRMTG and the national workgroup with operators have defined the main information to be gathered in the database for each event, especially:

- Network identification;
- Type of event (fire, explosion, panic, electrocution, derailment, passenger accident, collision between streetcars, collision with fixed obstacle, collision with a third party, other event (vandalism...));
- Temporal situation;
- Place details using codification;
- Nature of the place;
- Railway specific aspects;
- Topography, railroad speed;
- Environment of the accident;
- Number of persons involved and how many injured or killed;
- Material consequences;
- Consequences on the operation;
- Statement of the system parameters such as speed and position;
- Circumstances.
All this information is entered on a screen from the accident database, as illustrated in Figure 3.

Every French streetcar operator uses the same database frame, but configures it for its network. Each year, they fill up their database with events and send it to the STRMTG, which compiles them in a global version. Then, the database allows review of several statistics such as:
- distribution of events by type;
- distribution of victims by type of event;
- distribution of killed people by type of event;
- distribution of victims according to the third party;
- distribution of collisions according to the third party;
- ratio number of events for 10 000 km (6212 mi);
- number of accidents by crossroads;
- number of accidents by station;
- number of collisions with cyclists.

With all this information, the STRMTG publishes these indicators in a yearly report presenting the results of the streetcar accident national database analysis and the evolution since 2003. Because of the rather small number of events, the indicators are used to detect huge problems and to show global trends, but couldn’t be used to determine the reason linked to. To know that, some specific studies have been undertaken. Thus, the aim of this database is first, to have a national view on streetcar events and second, to know which type of line configuration is related with accidents and which aggravating factors should be avoided.
2.2 Results, graphics and analysis for the years 2003 to 2011

The results concern French streetcar networks in general, no towns are identified. But it permits operators to identify if they are above the national and average indicators or not. Each operator makes its own report to the STRMTG, more detailed than the national one, with main accidents and engaged actions during the year to improve the safety level of its network. As the data come exclusively from streetcars operators, it only mention events involving streetcars, not all the collisions which appeared close to the streetcar platform.

2.2.1 General data: distribution of events, year by year and type by type

In 2011, there were 1176 collisions with third parties, which means more than 3 collisions a day, including dented bodyworks. There was one serious accident every 2 days (202 serious accidents in 2011).

![FIGURE 4 Yearly distribution of events](image)

Figure 4 shows the number of events have globally increased since 2003. However the data included only 7 towns for 2003, while 22 towns were included in 2011. The approximate doubling of crashes is reflective to the similar increase of track length, from 250km – 155 mi in 2003 to 600km – 372mi in 2011. The rise between 2010 and 2011 is probably due to the great number of new lines in new urban areas.

Collisions with third parties are the most numerous: around 70% of events every year involve third parties (the mistakes conducting to the collision mostly come from the third parties). Then, there are accidents to passengers (referring to
accidents occurring on board or at the station – fall most of the time) and collisions with fixed obstacles.

**FIGURE 5 Distribution of events by type**

2.2.2 **Indicators describing seriousness and occurrence**

In addition to general data, other indicators describe the seriousness and occurrence.

The number of events per 10,000 km (6212 mi) for all streetcar lines gathered (lines whose projects have begun before or after the STPG Decree (call STPG lines) and which have consequently begun to operate before or after 2006) and a comparison with bus systems are shown in Figure 6.

**FIGURE 6 Number of events per 10,000 km (6212 miles) driven**
According to this indicator, the steady decline observed for streetcars since 2004, gets interrupted in 2010. It probably means that French drivers and other road users are now used to this transport. And that streetcar network operators are more and more experienced. Separating pre and post-STPG lines, in order to observe its impact on safety, among many other parameters, it appears that in 2006, post-STPG lines had more accidents per 10,000km (6212 miles) than other lines but it decreased more sharply, probably because of the control on urban insertion impact on the number of accidents. The variation between 2010 and 2011 is due to the rising number of passenger accidents, while collisions are always decreasing. A key conclusion to be drawn from the data is that streetcars have around of half the number of crashes per 10,000km (6212 mi) of buses.

FIGURE 7 Percentage of collisions and distribution of victims according to the third party

According to Figure 7, the majority of collisions with streetcars involve light vehicles, the second major part is constituted by collisions with pedestrians. There is a downward trend for light vehicles but the trend is not evident for the pedestrians with an upward since 2008. There are more victims in collisions with pedestrians and with light vehicles than every other type of collision.
A pedestrian involved in a collision is generally more liable to be injured than a light vehicle driver. So, collisions with pedestrians are as numerous as with light vehicles but they are twice as serious. This can be observed in Figure 8.

Figure 9 shows the risk of collision, calculated with the number of collisions (in the whole French networks) depending on the site configuration (station, simple crossroad, roundabout,...) divided by the number of each configuration (whole French networks).

2.3 Actions following the database analysis results

Regarding all the results (all exposed in the national report [1]), the STRMTG has decided to undertake studies on specific subjects such as roundabouts, fixed obstacles,... and has produced guidelines on them, giving some possible solutions, or analysis on particular accidents, to improve the streetcar safety. Some guidelines,
edited with the cooperation of a workgroup constituted by the streetcars’ profession, have been published:

- “Fixed obstacles design” guideline (2007)

Collisions between a car and a streetcar in an intersection are numerous each year. While the consequences are often minor, this can be sharply aggravated when a fixed and stiff obstacle is directly set up after the intersection (in the direction of the streetcar): the car can be crushed between the streetcar and this obstacle; and the collision can lead to severe injuries or fatalities. This guideline defines the notion of “fixed obstacle” and rules governing the location these fixed obstacles in order to limit the consequences of such a collision. The objective is to keep a zone, free of any fixed obstacle downstream to crossroads in the direction of streetcar circulation (represented in red in figure 10). The length of the zone free of any fixed obstacle depends on the distance of the streetcar's stopping. This distance is calculated by a simple formula depending mainly on the streetcar deceleration and speed.

![Figure 10](image)

**FIGURE 10** Collision in Lyon, Paris and zone free of any fixed obstacle

- “Roundabouts design” guideline (2007) [2]

A few cities have built streetcar lines through roundabouts either to provide simpler looping operations or where existing roundabouts predate the streetcar lines. They are also naturally used when they already exist before the streetcar's project. However, experience and statistics have shown that this configuration causes a lot of accidents, mainly due to the modification of usual rules and behavior on a roundabouts when there is a streetcar in. Priority is given to cars in the roundabout, but French “Code de la Route” also indicates that streetcars have priority over other road user. It's probable that this misunderstanding in such places has caused many accidents compared to simple crossroads.
From the statistics showing the gravity and the occurrence of accidents in roundabouts, a guideline of recommendations has been edited by the STRMTG and the CERTU (French Center of studies on networks, transportation, town planning and public constructions). It specifies that it is fundamental that car drivers perceive at the right time and in a clear way the events with which they are going to be confronted. For that purpose, the layout, which has to force them to reduce their speed, must be readable and understandable, in particular by means of an adapted geometry, and give no ambiguity concerning the way of functioning. This guideline proposes geometrical conditions to cross a streetcar line in a roundabout (crossed pictures in figure 11 are avoided configurations). Some rules are given to build a “safe” roundabout, mainly concerning its size: the external radius optimal dimension has to be between 14 and 22 meters (46 and 72 feet).

“Dangerous configurations design” guideline (2012) [5]

Statistics are not the only way to identify dangerous situations. One very serious crash, a collision between two streetcars in the tunnel of the network of Rouen, has lead to global reflections.

Line-of-sight driving is the basic principle applied by the driver of a streetcar, who adapts the vehicle speed to match the available sight distance and conditions ahead. In certain particular configurations, improvement of the performance of this mode of driving exist: the implementation of a device of railway lights in a tunnel allows, for example, a speed of operation superior to the speed which would be determined by available sight distance only. However, the passing of railway lights set at danger (red) by drivers remains a possibility and can be catastrophic.

A table in the guideline recapitulates the situations and the measures to be set up. For example, in a running section, whatever the frequency is, with a speed greater than 80 km/h (50 mi/h), the risk is high because the line-of-sight driving is no longer reliable (speed identified by an operators’ workgroup). So a spacing signalization or a zone occupying signalization with an automatic system to stop the streetcar and an alarm in the traffic control office should be used.

The evolution of some indicators is difficult to understand, and need precise analysis for a correct interpretation. So, different studies have been initiated:
Study on pedestrian ways crossing streetcar lines

In the past few years, the number of collisions with pedestrians has increased and some have caused death. The aim is to give rules on the best crossing designs in different configurations.

Study on dangerous crossroads

Some crossroads have been identified by the operators and through the database, as “dangerous crossroads”, because of the huge and steady number of collisions involving a streetcar each year. A study has been done on these crossroads, using infrastructure analysis and collision scenarios, to find solutions to reduce the number of accidents. These solutions have been proposed to the local authorities and operators, and both short and long term action plans have been approved for each.

2.4 Refining the codification

After a period of seven years using the accident database, and through our studies on different subjects, some limits have been seen to the current codification and the information than can (or cannot) be obtained from it. So, in 2010, the codification was refined in order to improve the precision of the accident data and therefore their analysis, in partnership with operators, experts and local safety services.

2.4.1 Limits

For analysis and statistics on events, it turned out necessary to revise the codification to identify more suitably the configurations. Indeed, some difficulties have appeared:

- the codification is too precise on low interest points and too general on points that need more details;
- the vehicles turning-left or turning-right in a crossroad are not identified (some collisions have shown that these configurations are dangerous);
- there is no information on traffic lights in roundabouts (which have appeared to be important).

Some configurations causing events have been observed but the codification does not allow precise statistics on these subjects because they were not properly identified. This evolution is related to the increasing number of streetcar lines since the first codification. Some new configurations have appeared, which could not be precisely identified, because some characteristics had not yet raised.

2.4.2 Improvements

There will still be fourteen digits, but their coding has changed to indicate new information that have proved to be useful. The new codification presents the additional codes for:

- the intersections in which the movements of turns to the left or turns to the right are possible since there is a public road parallel to the streetcar line,
the crossing of both pedestrians and cycles,
- the type of lights for pedestrians,
- the type of road traffic lights,
- details on roundabouts.

The new codification also includes more details about ordinary site entry and residents access. Signaling is detailed for each of these configurations: static signals, light signals, upstream, dam, etc. The possible presence of visual masks and ease of identification of the streetcar platform are also new codified information.

2.4.3 Consequences on the accidents analysis

This new codification gives the possibility to identify:
- events in roundabouts;
- crossroads with “turn-left/right”;
- the type of traffic lights (French identification: R24, R11v, R11j,...) involved in the events.

As a result, new dangerous crossroads can now be detected, as in Figure 12.

![Figure 12: Number of events per intersection (2004-2011) with number of intersection (left scale)](image)

This graph puts in relation the number of events by type of intersection with the number of the intersection. That underlines the danger of roundabouts, while pedestrian/cyclist crossings appears to be less dangerous.

![Figure 13: Impact of the C20c sign (announcing the crossing to car users) for simple crossing and resident's access](image)
The two graphs in Figure 13 show the low influence of the C20c sign on the ratio for these types of intersection. This information will allow us to assess the impact of the light signaling independently of static signs.

**FIGURE 14 Number of configurations and events according to the roundabout size**

Figure 14 underlines the low number of mini roundabouts and double roundabouts crossed by a streetcar line, the analysis concern this kind of roundabouts should be interpreted with caution. We can also identify two “families” of roundabouts: small roundabouts (radius <14m - 46ft) and medium or large roundabouts (radius> 14m - 46ft).

3 CONCLUSION

The safety management in France is ruled by the estimation and validation of the risks and level of safety. But streetcars’ urban insertion is a difficult science, that is why feedback on events are essential to improve streetcars’ layouts and therefore, road users and passengers safety.

The national codification and database is a good way to get homogeneous indicators but with some years of practice, it needed to be improved. Improvements will continue during 2013 and some specific detailed analysis should be done for example, on light signals in different crossroads.

In order to know the impact of some characteristic modifications (like geometry or light signals), it is important to keep the data of historical configurations. These changes were taken into account by adding new sections which were assigned new events. Next database analysis will try to evaluate these evolutions. Specific studies will also be made in order to evaluate the impact of recommendation from guidelines, after significant time of operating.

REFERENCES


