ACCIDENTOLOGY OF TRAMWAYS

Analysis of reported events

- year 2012
- evolution 2004 – 2012
History of document versions

<table>
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<th>Version</th>
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Contents

1 - REMINDER ON THE DATABASE CONSTRUCTION .......................................................... 6
1.1 - Fields in the database ......................................................................................... 6
1.2 - Codification of tram lines .................................................................................. 6
1.3 - Events data ......................................................................................................... 6

2 - SCOPE OF STUDY ................................................................................................. 7
2.1 - Systems in operation ......................................................................................... 7
2.2 - Systems analysed .............................................................................................. 7
2.3 - Evolution of the systems analysed .................................................................... 8

3 - RESULTS ................................................................................................................ 9
3.1 - General ................................................................................................................ 9
3.1.1 - Overall data for 2012 .................................................................................. 9
3.1.2 - Remarks concerning the victims ................................................................. 9
3.1.3 - Remarks concerning the events ................................................................ 9
3.2 - Events ................................................................................................................ 11
3.2.1 - Breakdown by type – evolution 2003-2012 ............................................. 11
3.2.2 - Event monitoring indicator - comparison with bus systems ................ 12
3.3 - Events – analysis of "STPG lines" ................................................................. 13
3.3.1 - Introduction – definition of panel ............................................................. 13
3.3.2 - STPG lines – event monitoring indicator ................................................ 13
3.4 - Breakdown of victims ....................................................................................... 14
3.4.1 - Year 2012 .................................................................................................. 14
3.4.2 - 2004-2012 evolution ................................................................................. 15
3.4.3 - Monitoring of victims indicators .............................................................. 19
3.5 - Serious events ................................................................................................... 20
3.5.1 - 2004-2012 evolution ................................................................................. 20
3.5.2 - STPG lines - serious events ..................................................................... 20

4 - COLLISIONS WITH THIRD PARTIES .................................................................. 21
4.1 - Breakdown by third parties ............................................................................. 21
4.1.1 - Year 2012 .................................................................................................. 21
4.1.2 - 2004-2012 evolution ................................................................................. 21
4.2 - Causes of collisions - 2004-2012 evolution ................................................ 23
4.2.1 - Respect for traffic signals .......................................................................... 23
4.2.2 - Special circumstance - tram coming from the opposite direction while crossing a first one ................................................................. 23
4.3 - Monitoring of collisions indicators .............................................................. 24
4.4 - Consequences of collisions - 2004-2012 evolution .................................... 25
4.4.1 - Material consequences - Derailment.................................................................................................................................25
4.4.2 - Aggravating factors..................................................................................................................................................................25

5 - ANALYSIS OF CONFIGURATIONS......................................................................................................................................27
5.1 - Breakdown of collisions according to predefined configurations.................................................................27
  5.1.1 - Evolution of the breakdown of collisions for 2004-2012..................................................................................................27
  5.1.2 - Evolution of the breakdown of victims from collisions 2004-2012.................................................................27
  5.1.3 - Relative breakdown of collisions according to configuration..................................................................................28
5.2 - Overall analysis of various configurations of intersections.........................................................................................29
  5.2.1 - All intersections.................................................................................................................................................................29
  5.2.2 - Simple crossing intersection.............................................................................................................................................30
  5.2.3 - Resident's access.................................................................................................................................................................31
  5.2.4 - Simple junction with turn left/right.................................................................................................................................32
  5.2.5 - Roundabouts.................................................................................................................................................................34

6 - CONCLUSIONS......................................................................................................................................................................40
  6.1 - Constant factors.................................................................................................................................................................40
  6.2 - Reasons for satisfaction.........................................................................................................................................................40
  6.3 - New teachings or confirmations........................................................................................................................................40
  6.4 - What remains preoccupying.............................................................................................................................................40

7 - ANNEXE – MAIN ROAD SIGNALS.....................................................................................................................................41
INTRODUCTION

The purpose of this report is to present the results from the use and analysis of the tram accident database for 2012, with the evolution of accidentology since 2004. This national database is populated by accidents’ declarations provided by operators. The “tram” term covers systems on rails and rail-guided systems on tyres.

The statistical analysis is not intended to make a comparison between networks or present a classification based on safety levels. The different configurations, in terms of number of crossings, the layout of various track types and the urban structure would make such a comparison meaningless.

On the other hand, a comparative analysis of the accidentology of the various predefined and codified urban layouts, and its evolution over the period 2004-2012, is one of the main subjects of the report.

As we announced in our previous report, tram operators have begun a new codification of their lines. This codification is more accurate and better suited to a more detailed analysis of configurations, particularly for the intersections of roads with the trams. Although it is now in place on all networks, it still needs to be consolidated. The following analysis therefore operates not all potential resources of this codification. However, we are able to present a more detailed analysis of some configurations (roundabouts, “turn” movements, relations to traffic signals). The trends that emerge naturally require to be consolidated in the next years.
1 - Reminder on the database construction

More detailed information on the database is provided in the 2004 tram accidentology report and the present Report will merely reiterate the essential points.

1.1 - Fields in the database

The database fields contain the following information:
- Network identification (city)
- Type of event, based on a predefined list of undesirable events
- Temporal position (date and time)
- Geographical situation (line, tram track, location of event)
- Configuration of the site of the event, using a predefined coding system
- Environment of the event (external conditions: adherence, visibility, degraded operation, works, etc.)
- Consequences on persons, materials, operation (duration of disruption)
- Record of system parameters (according to driver's statement or data from tachymetric system, tram number)
- Police report (precision on its existence)
- Circumstances of the event (summary of event, act of suicide, aggravating fixed obstacle, third party manoeuvre, etc.) with details of the third party
- Follow-up on actions undertaken (investigation in progress, planned modification, action plan, etc.)

1.2 - Codification of tram lines

The codification consists of describing the various tram line configurations through 14 codified digits in order to create a descriptive database common to all the lines. It makes possible the analysis of events on all networks according to the characteristics of the sites where they occur, to make comparisons between configurations and to identify the most accident-prone.

The main changes introduced by the new codification concern intersections. Seven types of intersection were selected:
- simple junction
- turn-left or right
- roundabout with or without traffic lights
- pedestrian / cycle crossing
- resident's access
- mixed-zone entry
- other intersection

Signalling is detailed for each of these configurations: static signals, light signals, on close position of the tracks, long before the conflict zone, etc.. The possible presence of visual masks and ease of identification of the tram track are also new codified information.

Detailed principles of the new codification can be found in the guide « Codification des lignes de tram, nouvelle édition 2010 » on the STRMTG website.

1.3 - Events data

The information comes from operators’ declarations.
The great efforts by operators to complete the database and codify their lines has to be underlined.

However, declarations are not quite identical from one network to another: some declare all significant events, while others declare only events which are likely to result in a claim against their insurers.

As in previous years, we observe again significant differences between networks, which lead us to remain prudent in considering the raw annual results and to give priority to analysing their evolution.
2 - Scope of study

2.1 - Systems in operation

Operated tram networks were present in 25 urban areas in 2012, representing 58 tram lines – 54 tram on rails and 4 tram on tyres.

2.2 - Systems analysed

The analysis of accidentology was led for the network lines which declare their production in km or journeys. Thus, some lines which were commercially operated for only a very short period in the year and for which no production declaration was made, are excluded from analysis for the year concerned. This is the case in 2012 for the network of Le Havre, the T5 line in Lyon and the T3b line in Paris.

The analysed networks are summarised in the following table:

<table>
<thead>
<tr>
<th>Urban area</th>
<th>Type</th>
<th>Number of lines</th>
<th>Mkm</th>
<th>Mjourneys</th>
<th>Opening</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angers</td>
<td>tram on rails</td>
<td>1</td>
<td>0.93</td>
<td>8.05</td>
<td>25/06/2011</td>
<td></td>
</tr>
<tr>
<td>Bordeaux</td>
<td>tram on rails</td>
<td>3</td>
<td>4.74</td>
<td>73.67</td>
<td>20/12/2003</td>
<td></td>
</tr>
<tr>
<td>Brest</td>
<td>tram on rails</td>
<td>1</td>
<td>0.6</td>
<td>4.76</td>
<td>23/06/2012</td>
<td></td>
</tr>
<tr>
<td>Caen</td>
<td>tram on tyres</td>
<td>2</td>
<td>1.27</td>
<td>8.62</td>
<td>18/11/2002</td>
<td></td>
</tr>
<tr>
<td>Clermont-Ferrand</td>
<td>tram on tyres</td>
<td>1</td>
<td>1.12</td>
<td>14.59</td>
<td>13/11/2006</td>
<td></td>
</tr>
<tr>
<td>Dijon</td>
<td>tram on rails</td>
<td>2</td>
<td>0.42</td>
<td>4.28</td>
<td>02/09/2012</td>
<td></td>
</tr>
<tr>
<td>Grenoble</td>
<td>tram on rails</td>
<td>4</td>
<td>3.92</td>
<td>44.74</td>
<td>05/09/1987</td>
<td>C line: May 2006 D line: October 2007</td>
</tr>
<tr>
<td>Le Havre</td>
<td>tram on rails</td>
<td>2</td>
<td>1.37</td>
<td>13.73</td>
<td>14/11/2007</td>
<td></td>
</tr>
<tr>
<td>Lille</td>
<td>tram on rails</td>
<td>3</td>
<td>1.51</td>
<td>9.4</td>
<td>04/12/1909</td>
<td></td>
</tr>
<tr>
<td>Lyon</td>
<td>tram on rails</td>
<td>6</td>
<td>5.39</td>
<td>65.82</td>
<td>18/12/2000</td>
<td>T4 line: April 2009 RhônExpress line: August 2010</td>
</tr>
<tr>
<td>Marseille</td>
<td>tram on rails</td>
<td>2</td>
<td>1.23</td>
<td>16.71</td>
<td>26/06/2007</td>
<td></td>
</tr>
<tr>
<td>Montpellier</td>
<td>tram on rails</td>
<td>4</td>
<td>4.87</td>
<td>51.65</td>
<td>01/07/2000</td>
<td>L2 line: December 2006 L3, L4 lines: April 2012</td>
</tr>
<tr>
<td>Mulhouse</td>
<td>tram on rails</td>
<td>3</td>
<td>1.28</td>
<td>13.49</td>
<td>12/05/2006</td>
<td></td>
</tr>
<tr>
<td>Nancy</td>
<td>tram on tyres</td>
<td>1</td>
<td>1.04</td>
<td>9.96</td>
<td>28/01/2001</td>
<td></td>
</tr>
<tr>
<td>Nantes</td>
<td>tram on rails</td>
<td>3</td>
<td>4.77</td>
<td>69.29</td>
<td>07/01/1985</td>
<td></td>
</tr>
<tr>
<td>Nice</td>
<td>tram on rails</td>
<td>1</td>
<td>1.26</td>
<td>28.9</td>
<td>26/11/2007</td>
<td></td>
</tr>
<tr>
<td>Orléans</td>
<td>tram on rails</td>
<td>2</td>
<td>2.06</td>
<td>14.99</td>
<td>24/11/2000</td>
<td>B line: June 2012</td>
</tr>
<tr>
<td>Paris Île-de-France</td>
<td>tram on rails</td>
<td>3</td>
<td>3.86</td>
<td>106.62</td>
<td>06/07/1992</td>
<td>T3b line: December 2012</td>
</tr>
<tr>
<td>Reims</td>
<td>tram on rails</td>
<td>2</td>
<td>1.01</td>
<td>13</td>
<td>16/04/2011</td>
<td></td>
</tr>
<tr>
<td>Rouen</td>
<td>tram on rails</td>
<td>1</td>
<td>1.46</td>
<td>15.11</td>
<td>16/12/1994</td>
<td></td>
</tr>
<tr>
<td>Saint-Etienne</td>
<td>tram on rails</td>
<td>3</td>
<td>1.71</td>
<td>22.27</td>
<td>01/01/1881</td>
<td></td>
</tr>
<tr>
<td>Strasbourg</td>
<td>tram on rails</td>
<td>6</td>
<td>5.72</td>
<td>68.71</td>
<td>26/11/1994</td>
<td></td>
</tr>
<tr>
<td>Toulouse</td>
<td>tram on rails</td>
<td>1</td>
<td>0.86</td>
<td>5.4</td>
<td>11/12/2010</td>
<td></td>
</tr>
<tr>
<td>Valenciennes</td>
<td>tram on rails</td>
<td>1</td>
<td>1.17</td>
<td>6.41</td>
<td>03/07/2006</td>
<td></td>
</tr>
<tr>
<td><strong>25 urban areas</strong></td>
<td><strong>58</strong></td>
<td><strong>53.56</strong></td>
<td><strong>690.19</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 00

- network, new line or line extension not taken into account in the 2012 results considering their opening date
- network, new line or extension line opened in 2012 and included in the results
2.3 - Evolution of the systems analysed

The evolution of the urban guided systems observed here is represented by the graphs below: through the number of urban areas and lines, then through the production in km travelled and journeys.
3 - Results

3.1 - General

3.1.1 - Overall data for 2012

The number of declarations processed is 1832, distributed in accordance with the established list of undesirable events:

<table>
<thead>
<tr>
<th>Events</th>
<th>No</th>
<th>Total</th>
<th></th>
<th>Victims</th>
<th></th>
<th></th>
<th>Passengers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Slightly</td>
<td></td>
<td>Seriously</td>
<td></td>
<td>Fatal</td>
<td>Slightly</td>
</tr>
<tr>
<td></td>
<td></td>
<td>injured</td>
<td></td>
<td>injured</td>
<td></td>
<td></td>
<td>injured</td>
</tr>
<tr>
<td>Fire, explosion</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td>5</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Panic</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electrocution</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Derailment</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Passenger accidents</td>
<td>563</td>
<td>532</td>
<td>32</td>
<td>5</td>
<td>1</td>
<td></td>
<td>532</td>
</tr>
<tr>
<td>Collision between trams</td>
<td>2</td>
<td>9</td>
<td></td>
<td>9</td>
<td></td>
<td></td>
<td>9</td>
</tr>
<tr>
<td>Collision with obstacle on track</td>
<td>24</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Collision with third parties</td>
<td>1207</td>
<td>335</td>
<td>307</td>
<td>26</td>
<td>2</td>
<td>233</td>
<td>26</td>
</tr>
<tr>
<td>Other events</td>
<td>30</td>
<td>14</td>
<td>14</td>
<td>9</td>
<td>5</td>
<td></td>
<td>621</td>
</tr>
<tr>
<td>Totals:</td>
<td>1832</td>
<td>897</td>
<td>862</td>
<td>31</td>
<td>3</td>
<td>242</td>
<td>26</td>
</tr>
</tbody>
</table>

Table 03

Two categories of event represent a large majority of declarations: collisions with third parties and passenger accidents.

3.1.2 - Remarks concerning the victims

It is important to define what is meant by a “victim” in this report.

Are designated as victims and declared as such by the operators the persons who do not get through unharmed from an event. This concept in no way prejudges the seriousness of personal injuries.

The definitions of serious injuries and fatalities are however those accepted and used within the European Union.

Seriously injured = duration of hospitalisation more than 24 hours.

Fatal = death within the 30 days following the event.

These statistical elements on the nature of the victims clearly depend on the information available and the extent of the operator's knowledge.

3.1.3 - Remarks concerning the events

3.1.3.a - Fire - explosion

Two events occurred in 2012 with no victim:

- Beginning of fire in an electrical cable of a civil engineering structure’s vault.
- Start of a fire involving defective cables at the power junction box of a traction engine.
3.1.3.b - Derailment
Four derailments were reported in 2012:

- 2 derailments on line: derailment at a station exit due to the presence of rubblestone that resulted in the lifting of the rolling stock and caused the derailment; derailment of a tramway during its reversal manoeuvre on a manual mode communication due to incorrect needle position caused by ice and grease stuck in the needle.

- 2 events in terminus: derailment during a reversal in terminus following a switch pull rod breakage; derailment in a reversal drawer after an incorrect needle position because of debris stuck due to bad weather conditions.

3.1.3.c - Passenger accident
This event category is the subject of a detailed analysis later in the report, chapter 3.4.
We report here the circumstances of one fatal event that took place in 2012: an elderly person fell off in a tramway after a driver vigilance type of emergency braking.

3.1.3.d - Collision between trams
Two events in 2012:

- A driver went the wrong route and hits at low speed another tramway that also runs at low speed in the opposite direction, resulting in two slightly injured persons.
- A driver collided with a stopped tramway at a station which was waiting for injection, making 7 slightly injured persons.

3.1.3.e - Collision with obstacle on track
24 collisions with obstacles on track of different types: garbage cans, bicycles, pallets, barriers (construction site or not), metal or concrete studs, caddies, cobblestones, iron bars...

3.1.3.f - Collision with third parties
A detailed analysis of this category can be found in Chapters 4 and 5 of this Report. We here relate the circumstances of 2 fatal pedestrian events:

- At a tram station, poor understanding between a tram driver and a pedestrian who first stopped before crossing the tracks and then started again while at the same time the tram driver attention is captured by works at the station platform.
- Unexpected crossing of a drunk person at a tram station, with a tram coming from the other side, while trams were passing each other.

3.1.3.g - Other events
30 other events: vandalism, catenary hanging, collisions of third party with tram system infrastructure, etc...
Three track end stops overruns were observed (2 can be attributed to the reduced attention of the tram drivers).
3.2 - Events

3.2.1 - Breakdown by type – evolution 2003-2012

3.2.1.a - All events - raw data

The increase in the number of events reported in 2012 is to correlate with the increase of the production in millions of km.

3.2.1.b - All events - relative distribution

The overall distribution per type of events remains the same over the period 2004-2012. However, we see an increase in the proportion of passenger accidents and a slight decrease in the proportion of a collision with a third party. This trend has to be followed in the next years. It also should be noted that the increase in the proportion of passenger accidents can also be linked with the reporting of operators who have evolved on this point.
3.2.2 - Event monitoring indicator - comparison with bus systems

The number of events per 10,000 km is a same routine indicator for some tram and bus networks. We obtained bus accident data for 8 tram networks, for which the events taken into account for buses are almost the same as those for trams: essentially collisions with third parties and passenger accidents.

Applying this to all the networks which declared their production, we obtain the following graph:

According to this indicator, the steady decline observed for trams since 2004, stabilizes over the years 2010-2012.

The comparison with buses gives advantage to the tram system.
3.3 - Events – analysis of "STPG lines"

3.3.1 - Introduction – definition of panel

STPG is for the “Sécurité des Transports Publics Guidés” - safety of guided public transport. We use the term "STPG lines" by contrast with “conventional lines”. This a linguistic device to allow easy identification of tram lines built in accordance with the STPG Decree of 2003.

This means that STPG lines are those which entered commercial operation from the year 2006.

These lines represent over the years 2006-2012 the following production elements:

<table>
<thead>
<tr>
<th>Year</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
</tr>
</thead>
<tbody>
<tr>
<td>Km</td>
<td>5 %</td>
<td>22 %</td>
<td>27 %</td>
<td>28 %</td>
<td>29 %</td>
<td>33 %</td>
<td>38 %</td>
</tr>
<tr>
<td>Journeys</td>
<td>4 %</td>
<td>20 %</td>
<td>27 %</td>
<td>28 %</td>
<td>29 %</td>
<td>31 %</td>
<td>34 %</td>
</tr>
</tbody>
</table>

Table 07

3.3.2 - STPG lines – event monitoring indicator

The general trend is decreasing, less marked over the last 3 years; notice the best “performance” of STPG lines in recent years especially in 2012 (the lowest ratio obtained since 2006).
3.4 - Breakdown of victims

3.4.1 - Year 2012

3.4.1.a - All victims

The number of victims resulting from events in 2012 reaches **897**. Types of victims break down as below according to the nature of the events and the victims:

<table>
<thead>
<tr>
<th>Victims</th>
<th>Third party victims</th>
<th>Passenger victims</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total</td>
<td>%</td>
</tr>
<tr>
<td>Fire, explosion</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Panic</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electrocution</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Derailment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Passenger accidents</td>
<td>538</td>
<td>60 %</td>
</tr>
<tr>
<td>Collision between trams</td>
<td>9</td>
<td>1 %</td>
</tr>
<tr>
<td>Collision with fixed obstacles</td>
<td>1</td>
<td>0,1 %</td>
</tr>
<tr>
<td>Collision with third parties</td>
<td>335</td>
<td>37,3 %</td>
</tr>
<tr>
<td>Other events</td>
<td>14</td>
<td>1,6 %</td>
</tr>
<tr>
<td><strong>Totals:</strong></td>
<td><strong>897</strong></td>
<td><strong>100 %</strong></td>
</tr>
</tbody>
</table>

Table 09

The two main events which give a rise to victims are passenger accidents and collisions with third parties. The majority of victims observed are passengers. **Collisions with third parties are however more serious and represent the 28 serious injuries observed (2 fatalities).**

3.4.1.b - Passenger victims of passenger accidents

- Falls in the tram: 465 (86,4 %)
  - Including 275 (59,14 % after emergency braking)
- Falls from the tram at the station: 22 (4,1 %)
- Falls from the platform: 16 (3 %)
- Trapping in the tram: 30 (5,6 %)
- Fall into gap: 1 (0,2 %)
- Dragged by the tram: 4 (0,7 %)

Passenger victims in passenger accidents are essentially concerned by falls in the train.
3.4.2 - 2004-2012 evolution

3.4.2.a - All victims

- Raw data

Passenger victims have the largest share of victims.

- Annual breakdown of victims by event

Passenger accidents and collisions with third parties continue to be the predominant events resulting in victims.
No significant change is observed over the period 2004-2012.
3.4.2.b - « Severe » victims

Severe victim correspond to a deceased person within 30 days or a person who was hospitalised for more than 24 hours.

- Annual breakdown of the proportion of severe victims according to events

Severe victims - relative distribution

The share of severe victims remains low overall. Collisions with third parties remain the type of event generating the most severe victims.

- Annual evolution of the proportion of severe victims, distinguishing between seriously injured persons and fatalities

Severe victims - evolution of seriously injured & deaths

We underline again the low proportion of severe victims: less than 6% of all victims in 2012.

It should be remembered that the statistical elements about the nature of the victims remain dependent on the information available and brought to the knowledge of the tram operator.

Furthermore, the essential part of the annual change concerns the variation in the number of severe victims, although it is not possible to discern a trend over these six years.
3.4.2.c - *Passenger victims*

The graph below shows the annual change over the period 2004-2012 of passenger victims, distinguishing those generated by an emergency braking from those with other causes.

An important part of the passenger victims is generated by emergency braking. And we do not see significant changes in the proportion.

3.4.2.d - *Passenger victims of emergency braking*

It seems interesting to analyse in deeper detail the cause of the emergency brakings, while this analysis is dependent on the accuracy provided by operators in their declared events.

The graph below shows the distribution of passengers victims of emergency brakings according to the different causes of these brakings and their evolution over the period 2004-2012.
We identified in the declarations of events six cases of emergency braking causing passenger victims:

- "Dead man device" category is for the emergency braking resulting from the absence of activation of the dead man's switch by the driver.
- "Technical" category means technical malfunctions during testing periods. The event declarations of operators do not allow to identify the nature.
- "Doors" category is the emergency braking caused by opening doors, either because of travellers (forcing) or due to maladjustment of doors' system.
- "Alarm Handle" category is for the device available to passengers when tram is leaving the station.
- "Automatic braking device" or Automatic Train Protection: some networks with specific configurations have trams equipped with automatic braking systems, for example in tunnels or on single track or whose with operating speed exceeding 80 km/h. Networks (or parts of these networks) equipped with this device have been in commercial operation since 2008. The largest number of emergency braking occur during the testing period, some were caused by driving error.
- Finally, the "Controller handle action" category includes all emergency braking caused by traffic in urban areas and concerns all the actions made actively by tram drivers and designed to avoid a collision with third parties.

**Driver actions are by far the leading cause of emergency braking at a rate still above 75%.**

The chart below shows the breakdown of passenger victims of emergency braking by the five first causes identified above (i.e. excluding drivers' actions).

The share of various technical reasons, such as doors or automatic breaking system varies from one year to another depending on the occurrence of problems and / or resolution (and as mentioned above, the accuracy of the event declarations from operators).

Nevertheless, the dead man's switch is an identified cause by operators for all years since 2005 and has for the past six years a significant cause of passenger victims of emergency braking. It should be noted that the origin of the lack of activation of the dead man device remains unclear. They may be related to the improper handling of the tram driver, his drowsiness or his cognitive overload.

Moreover, the proportion of serious victims among passenger victims emergency of emergency braking is very low, between 0.3% and 2.6% over the period 2004-2012.
3.4.3 - Monitoring of victims indicators

3.4.3.a - Overall results

No significant change for passenger victims and third party victims indicators over the period 2004-2012. A slight decrease seems to start especially for third-party victims. It will be necessary to confirm this trend in the coming years.

The fatalities’ indicator fell sharply in 2012, but since it’s based on small numbers, it is more sensitive.

3.4.3.b - Results for severe victims

Previous indicators but now calculated for the seriously injured victims remain in the same proportions relative to all victims (1 to 100 passengers and 1 to 10 for the third parties).

The indicator of severe victims does not follow the evolution of the indicator of all victims, but we do not see any distinctive evolution during the period.
3.5 - Serious events

For the purposes of a statistical analysis of the database, we have, with the profession’s agreement, defined serious events by the following criteria:

- Serious bodily injury: fatality or serious injury or more than 5 victims,
- Significant physical damage (including for the third party) or derailment of the tram,
- Derailment during commercial operation in a zone shared with third parties.

3.5.1 - 2004-2012 evolution

Serious events represent only a small proportion of all declared events, but a larger proportion of victims.

We should state here again that not all victims were seriously injured.
If we disregard the peculiarity in the year 2006 concerning the victims of serious events, a point underlined in § 4.1.2.b, we can see the confirmation of a growing trend on the part of serious events as well as the victims of serious events.

3.5.2 - STPG lines - serious events

These lines entered into service in 2006 (cf. § 3.3.1). The following graph shows the evolution of the share of serious events and victims of serious events for these lines.

There is no distinctive trend over the period.
However note that the proportion of serious events for the STPG lines shows a significant increase in 2011.
4 - Collisions with third parties

4.1 - Breakdown by third parties

4.1.1 - Year 2012

With 1207 collisions in 2012, collisions with third parties represent 66% of all reported events and 38% of victims.

The graph below shows the distribution of collisions and casualties according to the type of third party.

Collisions with private cars represent the great majority of cases. Collisions with pedestrians are much less numerous but create an equivalent proportion of victims.

4.1.2 - 2004-2012 evolution

4.1.2.a - Collisions - Overall results

The global variation of the breakdown of collisions according to the third party is small for the period analysed.
4.1.2.b - **Victims of collisions - Overall results**

The breakdown of victims is different: we see more marked/clearer variations for pedestrians and private cars, with for the latter an growing/increasing trend since 2007.

It should be noted a particularity in 2006 in the “public transport or lorries” category: three collisions in this category have resulted in a total of 29 victims.

4.1.2.c - **Severe victims of collisions**

The proportion of serious victims in collisions remains low (less than 7% of total pedestrian victims). We observe an increase for the "pedestrian" category, the most represented one, especially in 2012.
4.2 - Causes of collisions - 2004-2012 evolution

4.2.1 - Respect for traffic signals

No significant trend is seen in the evolution of the proportion of disrespect according to the type of signals. Non-compliance with R17 signals (a few cases per year) by tram drivers still occurred in 2012, even though the offence represents a very low proportion of causes of collision in the last 5 years.

4.2.2 - Special circumstance - tram coming from the opposite direction while crossing a first one

The graph below shows the proportion of collisions with third parties whose circumstances appear to involve a tram coming from the opposite direction while crossing a first tram.

This circumstance remains low for all collisions with third parties with less than 4% of cases. The upward trend that we observed since 2007 isn't confirmed in 2012.

We also note a significant proportion regarding pedestrian/cycle category.
4.3 - Monitoring of collisions indicators

We presented in § 3.3.2 an indicator for monitoring events calculated to 10 000 km. We also know that not all networks adopt the same procedure when declaring some events such as passenger accidents.

However, we are reasonably confident in the consistency of statements collision with third parties, in their continuity over time and between networks. A monitoring indicator consisting in collisions reported to kilometres therefore seems more relevant than the one which was presented in 3.3.2.

The graph below shows the evolution of the number of collisions at 10.000 km, as well as evolution of STPG lines as defined in § 3.3.

The general trend is a reduction, less marked over the last 3 years. It should be noted the best "performance" of STPG lines in recent years and especially in 2012 (the lowest ratio obtained since 2006).
4.4 - Consequences of collisions - 2004-2012 evolution

4.4.1 - Material consequences - Derailment

We have seen the bodily consequences of collisions with third parties in the preceding paragraphs. The graph below illustrates the material consequences of collisions: the important consequences for third parties as to/for the system, and the tram derailment.

![Collisions with third parties - consequences graph](image)

The proportion of important physical impact remains below 15%, it tends to grow over the period 2004-2012. And the proportion of derailments is very low, less than 1%, and does not change significantly over the analysed period.

4.4.2 - Aggravating factors

The graph below shows the repartition of aggravating factors involved in collisions with third parties.

![Collisions with third parties – aggravating factors graph](image)

Collisions with third parties for which an aggravating factor has been identified is a very small proportion of all collisions; the maximum is reached in 2010 with 1% of the total number of collisions.
Four aggravating factors are identified in the declarations of operators and categorised as following:

- «fixed obstacle» is an obstacle close to the cinetic envelope that aggravates the consequences of a collision, third party vehicles being caught between the fixed obstacle (not moving away) and the tram.
- «third party speed» as an aggravating factor is appreciated by the operator according to the statement of the tram driver.
- «tram speed» is considered excessive when it greatly exceeds the speed limit of the area or of the operational instruction to follow considering the accident scenario.
- «braking pad abuse» means the practice of using the magnetic brake pads instead of an emergency braking. This practice extends time and braking distances, thus leading to higher speed of tram when striking third parties.

The fixed obstacle is the aggravating factor present throughout the whole period, without being dominant each year.
5 - Analysis of configurations

The codification of lines allows an analysis of the breakdown of events according to the various configurations of lines, and thus allows identification of the most accident prone zones, in particular for junctions.

As we announced in our previous report, tram operators have started a new codification of their lines. This codification is more accurate and better suited to a more detailed analysis of configurations, particularly for intersections.

Although it is now in place on all networks, it still needs to be improved. Therefore the present analysis uses not all potential resources of this codification.

However, we can present more detailed analysis of some configurations (roundabouts, turns left/right with related signalling). The trends that emerge will require to be fortified in the coming years.

Events considered in this chapter are collisions with a third party.

5.1 - Breakdown of collisions according to predefined configurations

5.1.1 - Evolution of the breakdown of collisions for 2004-2012

The graphic below shows the breakdown of collisions according to eleven types of configurations: stations – without distinguishing types, seven types of junctions and three types of running sections.

Collisions with third parties occur in majority in turn left/right junctions, in the roundabouts and then in simple junctions and segregated tracks.

Globally, we don’t see any noticeable trend in this breakdown’s evolution during the period, at one exception related to pedestrian/cycle crossings.
5.1.2 - Evolution of the breakdown of victims from collisions 2004-2012

The breakdown of victims is slightly different from the one of collisions, with a greater proportion of stations. We also don’t observe significant trend in the evolution of the breakdown of victims over the period. However, attention should be paid to pedestrian/cyclist crossings for which victims proportion is clearly increasing for 2012.

5.1.3 - Relative breakdown of collisions according to configuration

The graph below shows the 2004-2012 evolution of the relative proportion of collisions according to configurations.

We observe that the proportion of roundabouts/giratories is predominant in the collision risk over the entire period.
5.2 - Overall analysis of various configurations of intersections

The construction of a new codification must be accompanied by the conservation of historical configurations. Indeed, during the life of a tram system, the urban environment evolves, in particular we have intersections whose characteristics have been modified: geometry, traffic signals or other components.

In the previous codification, these changes were taken into account by adding new sections to which were assigned new events.

Checks and corrections mentioned above concerns the history of sections as well as the proper allocation of events and environment as it was when this event occurred.

In 2012, a major effort was made by the operators to make more reliable the configurations’ history. We are now able to analyse a little more finely some configurations (in terms of geometry and signalling) over the period 2004-2012 in that the sample of configuration was sufficient for carrying out a proper analysis with respect to their accident rates.

The set of graphs that will be presented in the following paragraphs include two scales: one for the number of intersections (left scale), represented by bars, and one for the number of events per intersection (right scale) over the period 2004-2012, represented by a curve.

Nota: for signs meanings (C20c, R11v, R11j, R14,...) see the annex.

5.2.1 - All intersections

This graph complements the previous graphic by illustrating the difference between the number of different types of intersection (left scale). The blue curve (right scale) represent for each type of intersection, the number of events per intersection for the entire period 2004-2012.
5.2.2 - Simple crossing intersection

5.2.2.a - Impact of C20c sign

C20c sign is a position sign for a tram line crossing. The codification identifies this sign for some "simple" intersections.

There is a better ratio for simple crossings with C20c (1.61) rather than without C20c (2.02).

5.2.2.b - Impact of traffic signs type

The following graphs include two scales: one for the number of configurations (left scale), represented by bars, and one for the number of events per configuration (right scale) over the period 2004-2012, represented by a curve.

On this graph, only the results of configurations with “Stop” signal (AB4) “R11v” traffic lights and “R24” red flashing traffic lights or no signalling’s types are based on exploitable samples.

R11v signal (used on the largest number of these configurations) has a slightly better ratio (1.86) than the two other signals (in particular Stop (2.69) or R24 (1.87)).

However, it should be noted the rather favourable ratio of 1.66 related to “R11j” traffic lights (with flashing yellow replacing the green) but based on a small sample (21 configurations).
5.2.3 - Resident’s access

5.2.3.a - Impact of C20c sign

We observe the same trend as for simple crossings, namely a better ratio for resident’s access with C20c (0.48) than without C20c (0.98).

5.2.3.b - Impact of traffic signs

On this graph, resident’s access configurations most represented relate to those without signalling, with a STOP (AB4) and to a smaller extent with R24. R11v and R24 signals have a similar ratio (0.41 and 0.46 respectively). STOP (AB4) presents the “worst” ratio (1.12) into usable data.
5.2.4 - Simple junction with turn left/right

5.2.4.a - Impact of the track layout in turn configuration

The graph below illustrates the impact on the event ratio of the tram track's position regarding the adjacent roads, at intersections of the "turn" type.

For “turn” type intersections, the events ratio remains almost identical (between 1.91 and 2.05 events per configuration) regardless of the position of the tram track: axial, lateral or if changing in the intersection.

Data on the bilateral site and on the general traffic entry layouts should be taken with caution because of the low size sample.

5.2.4.b - Impact of traffic signs type

It has been shown previously that the tram track’s position related to the adjacent roads had little impact on the ratio of events.

Therefore, this characteristic has not been taken into account in the following analysis.

It seems interesting to look at the influence of the type of signalling in the « turn » type intersections and its position: « upstream » or « crossing ».

The diagram below shows what “upstream” and “crossing” positions means for traffic signs.
The following table below summarizes the overall results of the set of possible "turn" configurations type.
For each of them, we remind the number of configurations, and the "number of accidents per configuration" ratio.

<table>
<thead>
<tr>
<th>Upstream sign</th>
<th>Nothing</th>
<th>C20c</th>
<th>AB3a</th>
<th>AB4</th>
<th>R24</th>
<th>R11v</th>
<th>IB</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nothing</td>
<td>45</td>
<td>1,93</td>
<td>23</td>
<td>3,48</td>
<td>3</td>
<td>9,33</td>
<td>12</td>
<td>7,00</td>
</tr>
<tr>
<td>AB3a</td>
<td>3</td>
<td>2,33</td>
<td>2</td>
<td>0,50</td>
<td>2</td>
<td>11,50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AB4</td>
<td>2</td>
<td>3,50</td>
<td>2</td>
<td>1,50</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R14</td>
<td>75</td>
<td>3,49</td>
<td>27</td>
<td>1,33</td>
<td>4</td>
<td>1,50</td>
<td>2</td>
<td>6,00</td>
</tr>
<tr>
<td>R11v</td>
<td>466</td>
<td>2,56</td>
<td>243</td>
<td>1,59</td>
<td>2</td>
<td>4,00</td>
<td>36</td>
<td>2,97</td>
</tr>
<tr>
<td>R11v+R16</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td>1,00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>3</td>
<td>2,00</td>
<td>4</td>
<td>2,25</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The boxes filled in red correspond to configurations for which the samples appear to be sufficient enough to be able to make relevant analyses.

Overall, we see the following items:

- paradoxically, the ratio obtained in configurations without upstream and crossing signalling is quite low. This deserves to be deepened based on the environment of these junctions (layout, traffic, ...) for a better understanding of this ratio.

- other ratios are quite similar (around 3) for a certain number of configurations, with the exception of the following configurations :
  - « C20c crossing, R11v upstream» for which the ratio is better (1,59),
  - « R24 crossing, nothing upstream» for which the ratio is not good (4,02).

- we also note that configurations with R14 upstream does not give a very good ratio (for those usable) and confirm the comments of the National technical instruction for road safety, on the difficulty of good perception for the user.

The graphs below represent the most significant configurations based on the crossing signs.

**No crossing sign – Ratio of events according to upstream sign**

![Graph 45a](image)

In this configuration without crossing sign, the best ratio is obtained "paradoxically" in case of no upstream sign (1.93).

The best ratio is then achieved with R11v upstream (2.56) and then with the R14 (3.49).
**C20c crossing - Ratio of events according to upstream sign**

In this configuration with C20c crossing, the best ratios are obtained with the R14 (1.33) and the R11v (1.59) upstream. However, given the samples, we need to be careful on the analysis.

**R11v crossing - Ratio of events according to upstream sign**

In this configuration with R11v crossing, we observe higher ratios than previous configurations. Furthermore, the samples are small. However, we can see for the two ratios which are the less weak that the ratio related to R11v crossing and R11v upstream is equivalent to that of a R11v upstream without crossing (respectively 3.10 to 3.33).

**R24 crossing - Ratio of events according to upstream sign**

In the case of configuration with R24 crossing, for the largest samples, there is a better ratio for the configuration "R24 crossing and R11v upstream" (2.97) than for the configuration "R24 crossing and nothing upstream" (4.02).
5.2.5 - Roundabouts

5.2.5.a - Impact of geometrical characteristics

Size of roundabouts
Roundabouts or gyratories are codified into five main categories according to their size.

On the graph below the curve of the number of events per roundabouts allows us to identify three “families” according to their size: small (radius <14m), medium (14m< radius <22m) and large (radius >22m) roundabouts.

This graph also highlights the low number of mini roundabouts and double roundabouts, for those any statistical analysis should be interpreted with caution.

However, even comparing some combinations (e.g. roundabouts with radius less than 14m) according to this only variable remains irrelevant due to the impact of other factors (e.g. entrance signs).

Considering the small number of configurations for mini roundabouts and double roundabouts, these have not been studied in more detail.

In the following, we will study the three following configurations:

- small roundabouts (radius <14m)
- medium roundabouts (14m < radius <22m)
- large roundabouts (radius > 22m)
**Size of the roundabout's ring**

The graph below shows, for each family of roundabout, the number of configurations and accidents per configuration according to the size of the ring.

For roundabouts with radius smaller than 22m, the best ratios are found with roundabouts for which the size of ring is below 6m.

The impact of the size of the ring in large roundabouts is not demonstrated.

It is also observed that small roundabouts have the best ratios.

**Number of entrance lanes**

The chart below distinguishes, for each family of roundabout, the number of configurations and accidents per configuration according to the number of entrance lanes in the roundabout.

Whatever the size of the roundabout, the best ratios are found in roundabouts with a single entrance lane.

It is also observed, as before, that small roundabouts have the best ratios.
5.2.5.b - Impact of traffic lights

In the following, the concept of “reinforced signalling” means more than 2 signals per crossing.

Small roundabouts (radius <14m)

The sample of small roundabouts equipped with an entrance signal is too low to allow meaningful analysis (R24: 4, R11v: 9, R11j: 7).

We will then study the impact of the crossing signal for small roundabouts with no entrance signal.

For these roundabouts, where the reinforced R24 is the most encountered crossing signs (more than 2 signals), we find that the ratio (1.59) is in favour of this type of signal.

The number of other configurations is low and lead us to be cautious on their analysis. However, it seems that for a given signal, the fact of reinforcing improves the number of accidents per configuration ratios.

Medium roundabouts (14m < radius <22m)

As for small roundabouts, given the low number of roundabouts equipped with an entrance signal (see graph below), we will only study the impact of the crossing signal for medium roundabouts with no entrance signal.

It should be noted that for roundabouts fitted into R11j entrance (numbering 39), 28 are equipped with R24 crossing for which the ratio is 5.35.

The configuration with R24 reinforced crossing is the largest of these mean roundabouts. The ratio is much better with reinforced R24 (2.9) rather than with R11v (5.4) or R24 (7.1).
Large roundabouts (radius > 22m)

Considering samples for large roundabouts equipped with an entrance signal, we will study the impact of the crossing signalling:

- for large roundabouts with no entrance signal (47)
- for those equipped with R11V entrance (27).

The configuration with R24 crossing is the greatest of these large roundabouts. The best ratio is obtained for the configuration with reinforced R24 (2.25).

The ratios associated with R11V and R24 crossing are of the same magnitude (4.8 and 4.92 respectively).

The graph above shows the case of gyratories. We see that the ratio of R11v is worse than for roundabouts without crossing signal. However, it should be noted that the samples are small.
Summary of "Roundabouts" configuration

<table>
<thead>
<tr>
<th></th>
<th>Small roundabouts (radius &lt;14m)</th>
<th>Medium roundabouts (14m &lt; radius &lt;22m)</th>
<th>Large roundabouts (radius &gt; 22m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ratio of events</td>
<td>3.35</td>
<td>7.41</td>
<td>9.73</td>
</tr>
<tr>
<td>Ratio of events according to the size of ring (ratio &lt;6m versus &gt;6m)</td>
<td>2.68</td>
<td>6.11</td>
<td>10.47</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>8.2</td>
<td>9.42</td>
</tr>
<tr>
<td>Ratio of events according to the number of entrance lanes (ratio 1 lane versus 2 lanes et plus)</td>
<td>3.22</td>
<td>4.88</td>
<td>6.7</td>
</tr>
<tr>
<td></td>
<td>4.43</td>
<td>11.03</td>
<td>11.68</td>
</tr>
<tr>
<td>Ratio of events depending on the impact of crossing signal with no entrance signal</td>
<td>R24 r =&gt; 1,59</td>
<td>R24r =&gt; 2,93</td>
<td>R24r =&gt; 2,25</td>
</tr>
<tr>
<td></td>
<td>R24 =&gt; 4.4</td>
<td>R11v =&gt; 5.4</td>
<td>R24 =&gt; 4.8</td>
</tr>
<tr>
<td></td>
<td>R11v =&gt; 5.5</td>
<td>R24 =&gt; 7.1</td>
<td>R11v =&gt; 4.9</td>
</tr>
</tbody>
</table>

Given the results shown in the table above, it appears that small roundabouts have a better ratio. This ratio is even better than the ring’s width is small or the number of entrance channels is reduced. This seems logical because such a geometry limits the speed near the tram track. It should also be clarified that we were unable to correlate these results with the traffic data.

Regarding signalling, whatever is the size of the roundabout, for those with no entrance signal, the reinforced R24 appears to be the type of signal having the best ratio.

R11v has either a close ratio to R24 or a better ratio in the case of the medium roundabouts.

These results remain to be confirmed over time in connection with the reliability of codification which is to date not fully completed.
6 - Conclusions

6.1 - Constant factors
- The breakdown of events according to their type (passenger accident, collision with third party, etc.)
- The position of roundabouts/gyratories and « turn » intersections in hazardous configurations

6.2 - Reasons for satisfaction
- The low proportion of serious victims: fewer than 4% of all victims since 2007, and stability of the indicators for these victims, passengers and third parties
- The decreasing trend for number of events and number of collisions at 10,000 km for all lines
- Favourable comparison of this indicator with some bus networks
- The low proportion of aggravating factors, including fixed obstacles in collisions with third parties which remains less than 1% of the total.

6.3 - New teachings or confirmations
- The proportion of the "opposite direction tram" is low in the whole accidents, about 3% of collisions.
- The proportion of the passenger victims caused by an emergency braking related to the dead man's switch remains below 10%
- The proportion of severe passenger victims caused by an emergency braking is less than 3%
- The increase of proportion of events in the pedestrian / cycle intersection configuration.
- There are three "families" for roundabouts in tram accidentology and related to their size: small (radius <14m), medium (14m< radius <22m) and large (radius >22m) roundabouts.

Regardless of the studied criteria (related to geometry or signalling), the ratios of events are better for small roundabouts even if they couldn't be correlated with the level of traffic.
- « Turn » configurations are very multiple in terms of signalling and therefore each of them could not be subject to any detailed analysis. The key points to remember are:
  - The ratio of events obtained in configurations without upstream and crossing signalling is quite low. This deserves to be deepened based on the environment of these junctions (layout, traffic, ...).
  - The C20c crossing, R11v upstream configuration has a favourable ratio of events
  - The R24 crossing, nothing upstream configuration has an unfavourable ratio of events
  - We also note that configurations with R14 upstream does not give a very good ratio and seems to confirm the comments of the National technical instruction for road safety, on the difficulty of good perception for the user.

6.4 - What remains preoccupying
- The increasing trend on the proportion of severe events and of the victims of these events over the period 2004-2012.
- The progress of the proportion of collisions with important material consequences over this period.
- The progression of severe pedestrian victims.
7 - Annex – Main road signals
<table>
<thead>
<tr>
<th>Type of signal</th>
<th>Name of signal</th>
<th>Number</th>
<th>Representation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Give way (position sign)</td>
<td>AB3a</td>
<td></td>
</tr>
<tr>
<td>Priority signs</td>
<td>Stop sign (position sign)</td>
<td>AB4</td>
<td></td>
</tr>
<tr>
<td>Mandatory signs</td>
<td>Trams only</td>
<td>B27b</td>
<td></td>
</tr>
<tr>
<td>Information signs</td>
<td>Trams crossing (position sign)</td>
<td>C20c</td>
<td></td>
</tr>
<tr>
<td>Warning signs</td>
<td>Trams crossing ahead</td>
<td>A9</td>
<td></td>
</tr>
<tr>
<td>Intersection traffic light signals</td>
<td>Intersection signals</td>
<td>R11v: red, yellow, green</td>
<td>R11v, R11j: red, yellow, flashing yellow</td>
</tr>
<tr>
<td>Type of signal</td>
<td>Name of signal</td>
<td>Number</td>
<td>Representation</td>
</tr>
<tr>
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</tr>
<tr>
<td>Intersection traffic light signals</td>
<td>Intersection pedestrian signals</td>
<td>R12</td>
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<td>Bus intersection signals</td>
<td>R13b</td>
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<td>Cycle intersection signals</td>
<td>R13c</td>
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<tr>
<td>Directional signals</td>
<td>R14tg : turn left</td>
<td></td>
<td><img src="image" alt="Image" /></td>
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<tr>
<td></td>
<td>R14dtg : go straight and turn left</td>
<td></td>
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<td>R14d : go straight</td>
<td></td>
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<td></td>
<td>R14dtd : go straight and turn right</td>
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<tr>
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<td>R14td : turn right</td>
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<tr>
<td>Anticipation signals with flashing arrows</td>
<td>R16dtg : go straight and turn left</td>
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<td>R16d : go straight</td>
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<td>R16dtd : go straight and turn right</td>
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<td>R16td : turn right</td>
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<td>Number</td>
<td>Representation</td>
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<td>Public transport signals</td>
<td>R17</td>
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<td>Public transport directional signals</td>
<td>R18g: left  R18d: right</td>
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<td>Flow control signals</td>
<td>R22j: red, yellow, flashing yellow</td>
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<td>Stop signal for all road users</td>
<td>R24 flashing red</td>
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<td>Warning signal for all road users</td>
<td>R1 flashing yellow</td>
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<td>Public transport line crossing - pedestrian/cyclist signals</td>
<td>R25</td>
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<td>Intersections with barriers</td>
<td>IB</td>
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