



EUROPEAN COOPERATION IN SCIENCE AND TECHNOLOGY



OPERATION AND SAFETY OF TRAMWAYS IN INTERACTION WITH PUBLIC SPACE

*A report on **COST ACTION TU1103** for the Nordic Light Rail Association, 2 November 2022*

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www.cerema.fr - *search for TU1103*

There are trams all over Europe...



Lisbon, Portugal
Photo: Wikipedia



Helsinki, Finland
Photo: Krisse Walmsley



Seville, Spain
Photo: D A Walmsley



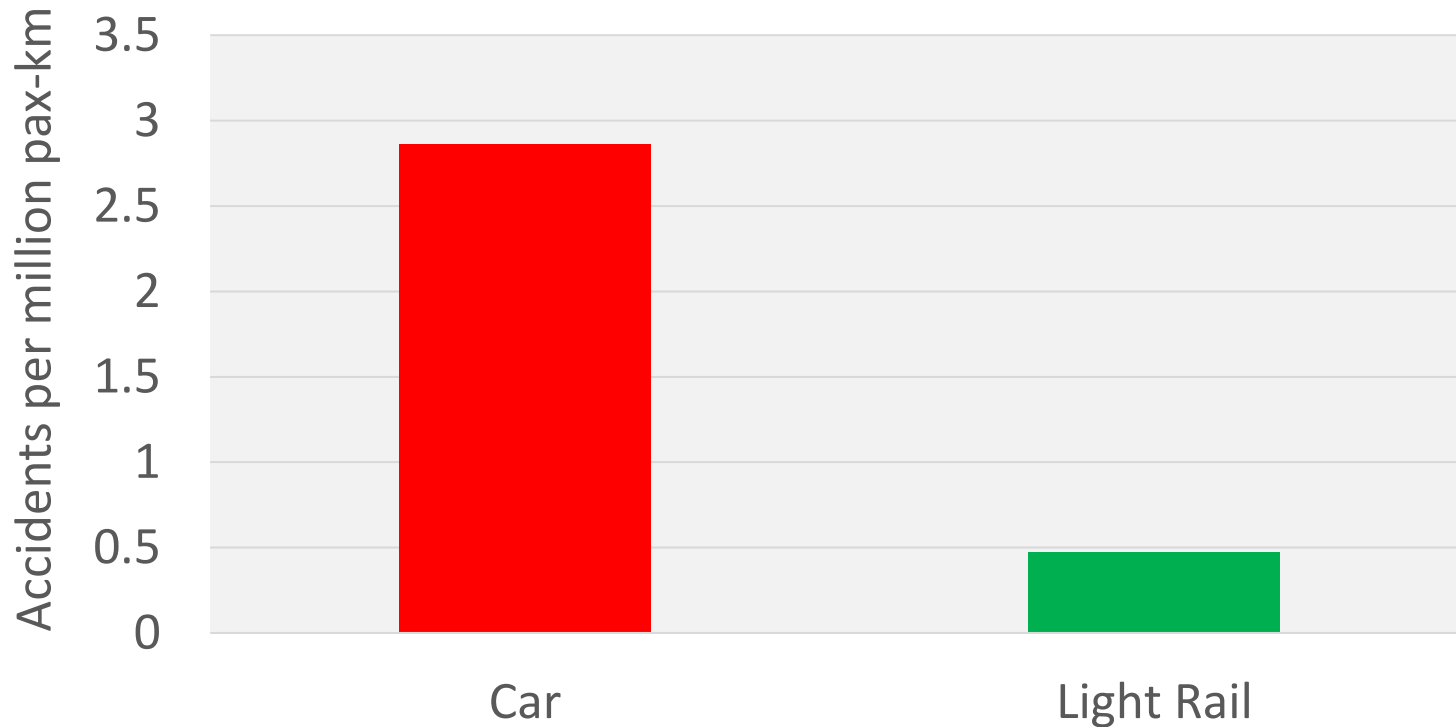
Prague, Czech Republic
Photo: Wikipedia

What are the advantages of Trams?

- **Trams can –**
 - carry a large number of people,
 - get people out of cars,
 - are accessible for people with reduced mobility,
 - are good for the environment – no pollution at point of use
 - have positive economic benefits, help city regeneration, good for city image
- **Trams are safe - as safe as buses, and safer than cars**

Trams have 6 times fewer accidents than cars

Accident rates - Car and LRT compared
Average of 15 sampled cities



*Source: UITP 2021 – “Knowledge brief:
LRT: A safe means of transport”*

Tram accidents do happen ...



Dublin O'Connell Street 2009
Tram jumped the red light and hit bus
24 injured, 3 seriously, including the tram driver and a pedestrian

Lyon Part Dieu 2017
Car jumped the red light and derailed the tram
16 injured, including the tram and car drivers



London (Croydon) 2016
Photo: Rail Accident Investigation Branch
Tram driver lost awareness and took the corner too fast
7 killed, 19 seriously injured, most other passengers had injuries

Trams are safe - but accidents do happen ...

- *Any accident has a big impact*
 - *Tram accidents are sometimes serious, sometimes spectacular*
 - *Press and TV reports*
 - *Journeys delayed*
 - *City-wide disruption*
 - *Impact on reliability and productivity*
- **THERE IS ALWAYS ROOM FOR IMPROVEMENT**

Objectives of Action TU1103 (2011 – 2015)

“Operation and safety of tramways in interaction with public space”

- **The primary cause of tram accidents is conflict with other road users**
 - Most tram accidents are caused by third parties – misbehaviour by drivers or pedestrians
 - Accidents can be reduced by *designing* to minimise conflicts
- *Objectives of the Action:*
 - To develop better understanding of tram safety issues
 - To share potential solutions across European cities
 - To improve safety overall



Benefits of improving safety

- Reduce accidents and improve safety for all users of public space
- Improve efficiency and reliability
- Decrease the maintenance and operating cost
- Optimise the investment in the tramway system
- Ultimately, to help moderate the impact of the car in cities

Participants in the Action

- Austria
- Belgium
- Czech Republic
- France
- Germany
- Hungary
- Ireland
- Israel
- Italy
- Netherlands
- Poland
- Portugal
- Spain
- Switzerland
- United Kingdom
- *But unfortunately no Nordic countries*

Analysis of Hotspots

- Identifying the **Hotspots** is the first step for analysis
- From a small survey of operators across Europe:
 - A specific location where most accidents occur
 - Identifies where to put most effort to reduce risks
- The survey identified the main **Interaction Points** – the locations where accidents most frequently occur

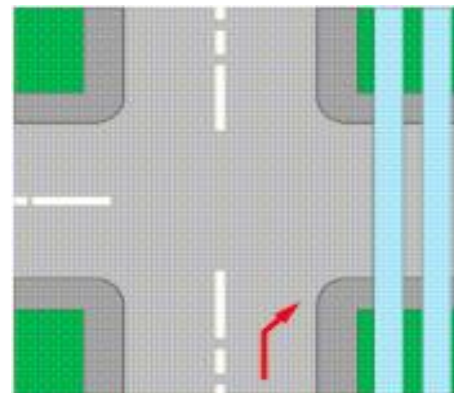
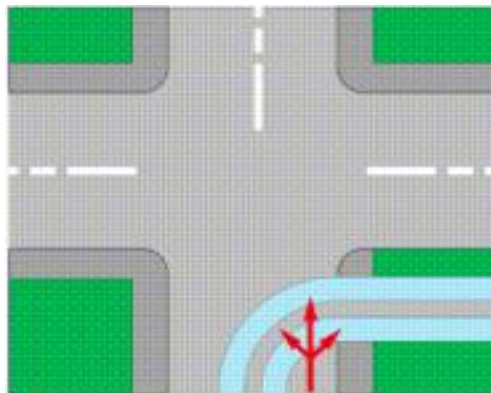
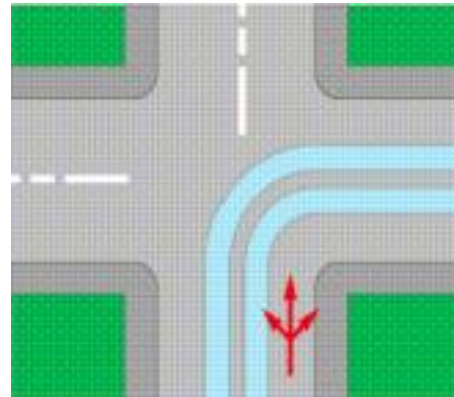
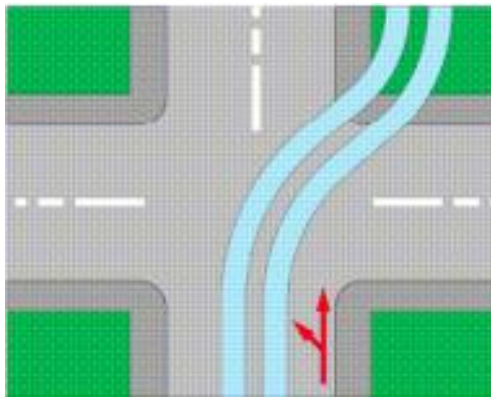
Identification of Interaction Points

Twelve Interaction Points identified, grouped into 5 categories for analysis:

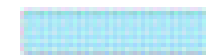
<ul style="list-style-type: none">• Tram stops and access to them• Interchange areas	■ Stops and stations
<ul style="list-style-type: none">• Road crosses tramway• Left turn across tramway• Traffic (road and pedestrian) signals	■ Road junctions
<ul style="list-style-type: none">• Roundabouts (traffic circle, rotary, gyratory)	■ Roundabouts
<ul style="list-style-type: none">• Tramway in pedestrian area• Cyclists in segregated areas• Pedestrian crossing across tramway	■ Pedestrian areas and crossings
<ul style="list-style-type: none">• Tramway segregated in street• Tramway in mixed street• Signs and signals for tram drivers	■ Running (link) sections

Identifying the configurations - example

Road junctions with tramway changing direction



Legend:

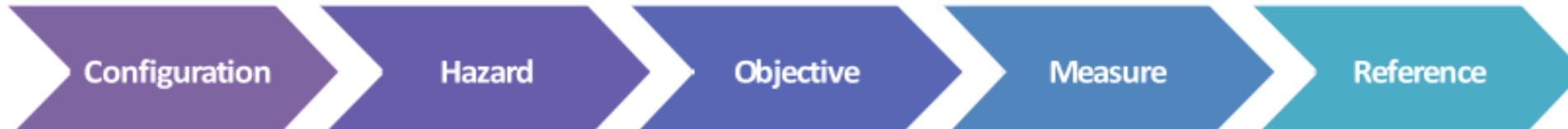


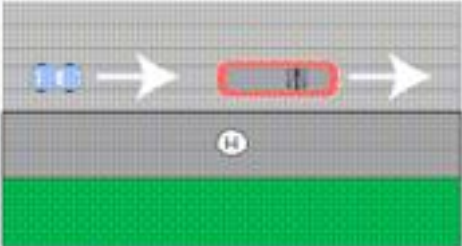


Tramway



Traffic movements that need
a special attention and control

Methodology: for each interaction point:



Configuration	Hazard	Objective	Measure	Reference
<p>1.1 Tracks are located in lateral position. There is no dedicated platform. Tram shares the traffic lanes with road traffic.</p> <p>1.1.1 Configuration with one lane in each direction shared by vehicles and tram</p>  <p>1.1.1 no dedicated platform - mixed</p>	<p>When there are staggered platforms (not face to face), pedestrians might cross anywhere and in particular behind a tram when a second tram approaches from the other direction.</p>	<p>To channel pedestrians onto a designated crossing</p>	<p>A pedestrian crossing is drawn between the two platforms. Between the two tracks, there is a physical separator except at the crossing.</p>	<p>FR2_1 (Stations)</p> 
	<p>Road vehicles that overtake a tram when it is at the station surprise another tram or a vehicle arriving from the other direction</p>	<p>To avoid vehicles overtaking the tram when the tram stops in station</p>	<p>To implement a physical barrier between the two tracks.</p> <p>Other types of separator, such as a kerb, white line or rumble strip, can be used; they are less intrusive but may not be so effective.</p> <p>To ensure vehicles stop behind the tram, using Stop-lines etc</p>	<p>FR2_1 (Stations)</p> 

Example

Stops and stations

- A fixed location where passengers may board or alight from a tram
- The first contact between the users and the system
- Area where pedestrians, road traffic and passengers mix



Stops and stations

1st category: People waiting at a stop or station

- Hazard: Pedestrians waiting on track when the platform is crowded or too narrow
- Objective: To make the track uncomfortable for pedestrians and the platform comfortable
- Measure:
 - To use awkward materials between the rails and
 - To widen the platform



Porto: wider platform, textured surface between rails

Stops and stations

2nd category: Passengers crossing the track to board the tram or after alighting

- Hazard: Crossing between platforms, sometimes behind a tram when another tram is approaching
- Objective: To prevent pedestrians crossing the track in the station
- Measure:
 - **Passive**: To signal danger for pedestrians between platforms
 - **Prescriptive**: To use textured or ballasted track
 - **Forcing**: To install barriers in the middle of the track



Porto: platform edge signs

Lyon: barriers

Stops and stations

2nd category: Passengers crossing a traffic lane to board or after alighting

- Hazard: Crossing the traffic lane in front of the stop and getting hit by a road vehicle
- Objective: To avoid passengers being left in the driving lane and hit by car
- Measure:
 - **Prescriptive**: To raise the roadway level with the sidewalk - improves access for the passengers, makes a speed hump for cars
 - **Forcing**: To create a staggered crossing with barriers and textured surface



Vienna stop: central track, raised road surface



Sheffield: staggered crossings, harsh surface

Stops and stations

3rd category: Vehicles passing a tram in mixed traffic

- Hazard: Road vehicles overtaking a tram at a station and getting hit by another tram or another vehicle
- Objective: To prevent road vehicles overtaking the tram when the tram stops at a station
- Measure: Prevent incorrect vehicle movements by:
 - **Passive** To implement roadway marking and signage,
 - **Forcing** To install physical barriers



Sheffield: cars overtaking tram at a tram stop



Wien: platform cape prevents overtaking

Road Junctions



Manchester, Holt Town

Road Junctions – Improving visibility

- Maximize visibility for
 - tram drivers to see the junction clearly
 - road users to see approaching trams clearly
- Alert road users to approaching tram
- Road equipment and street furniture must not impair visibility
- Prevent or discourage illegal movements with kerbs, pillars, fences, etc.



Road Junctions – Improving visibility: Manchester

Road junction – without traffic signals

Problem: Poor sightlines at junction of cars with tramway

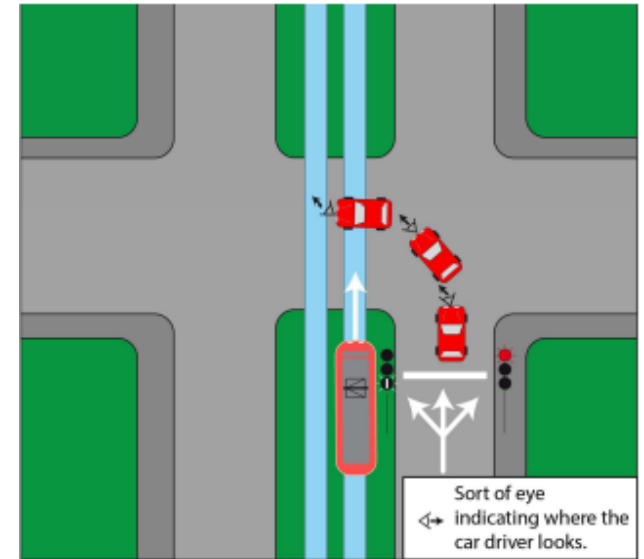
Solution: Larger signs erected with yellow background and active warning



Manchester: Mosley Street / Booth Street junction

Road Junctions – Left turn at junction (Right turn in UK and Ireland)

- Problem: Left turn across tramway: Car driver unaware of a tram approaching from behind
- Each traffic movement should have a specific lane, clear signs and markings
- If city structure allows, traffic should be re-routed
- Traffic signals may be a better solution with:
 - Green phase extended for tram
 - Separate phase for tram



Road Junctions – Signalised junctions (with traffic lights)

- Usual solution for managing conflicts at junctions with tramway
- Often used to increase reliability with tram priority
- Sensors control traffic light cycle to:
 - add a special phase for the tram,
 - switch to or extend a compatible phase with the movement of the tram,



Roundabouts

Car drivers watch their exit, not the tram, so traffic lights needed to give the tram priority

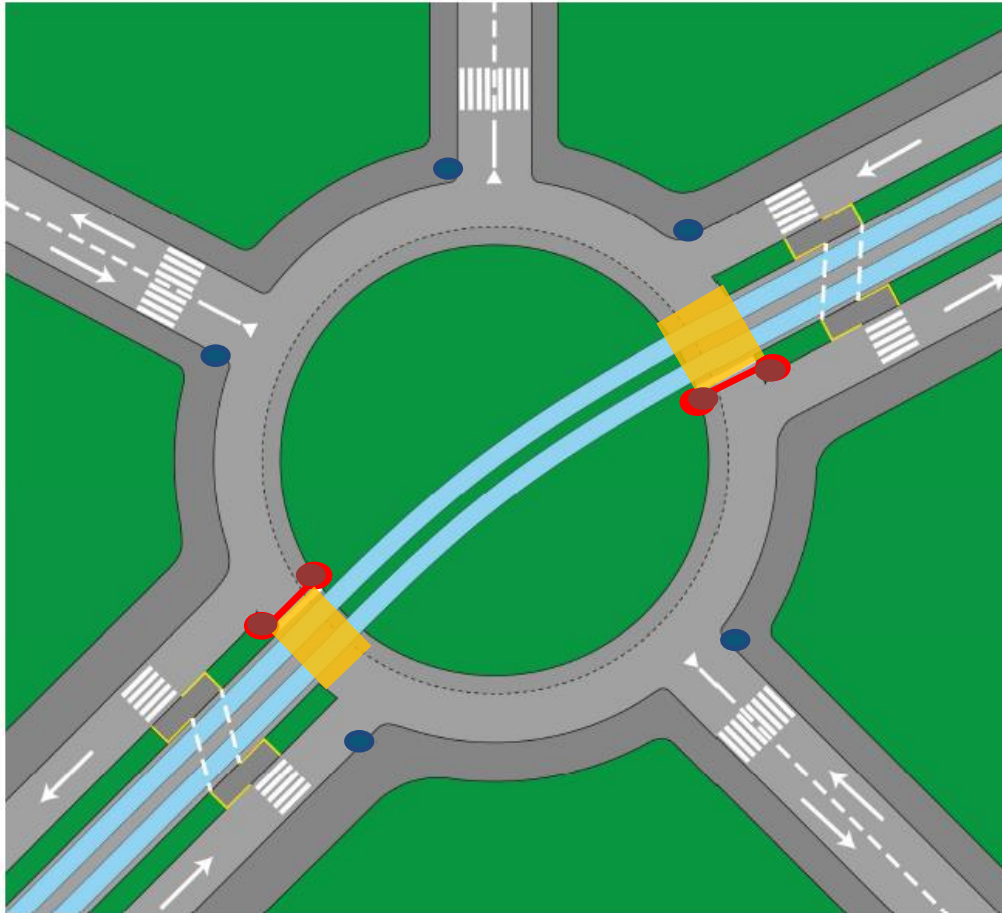


Bordeaux

Roundabouts – Analysis

- HAZARD:
 - Car drivers' attention is diverted in two directions in roundabout
 - Unintentional traffic light infringement by car driver
- OBJECTIVE:
 - Reduce complexity of roundabout situation for driver
 - Reinforce traffic light information
 - Simplify traffic light regime
- MEASURES:
 - **Passive** Signs and markings at the entrances to the roundabout and at the tramway crossing
 - **Prescriptive** Traffic lights at the entrances to the roundabout and at the tramway crossing
 - **Prescriptive** Add “repeater” lights on traffic light poles
 - **Forcing** Use “**All red**” phase when the tram is approaching
 - Avoid layouts where the tramway crossing is immediately after the roundabout entrance

Roundabouts – How to protect the tramway



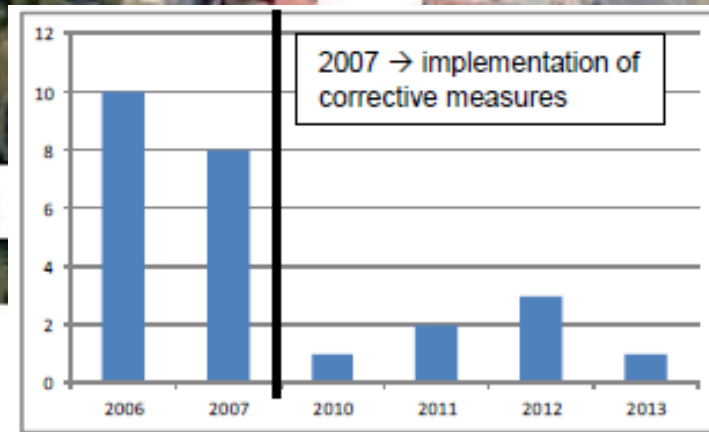
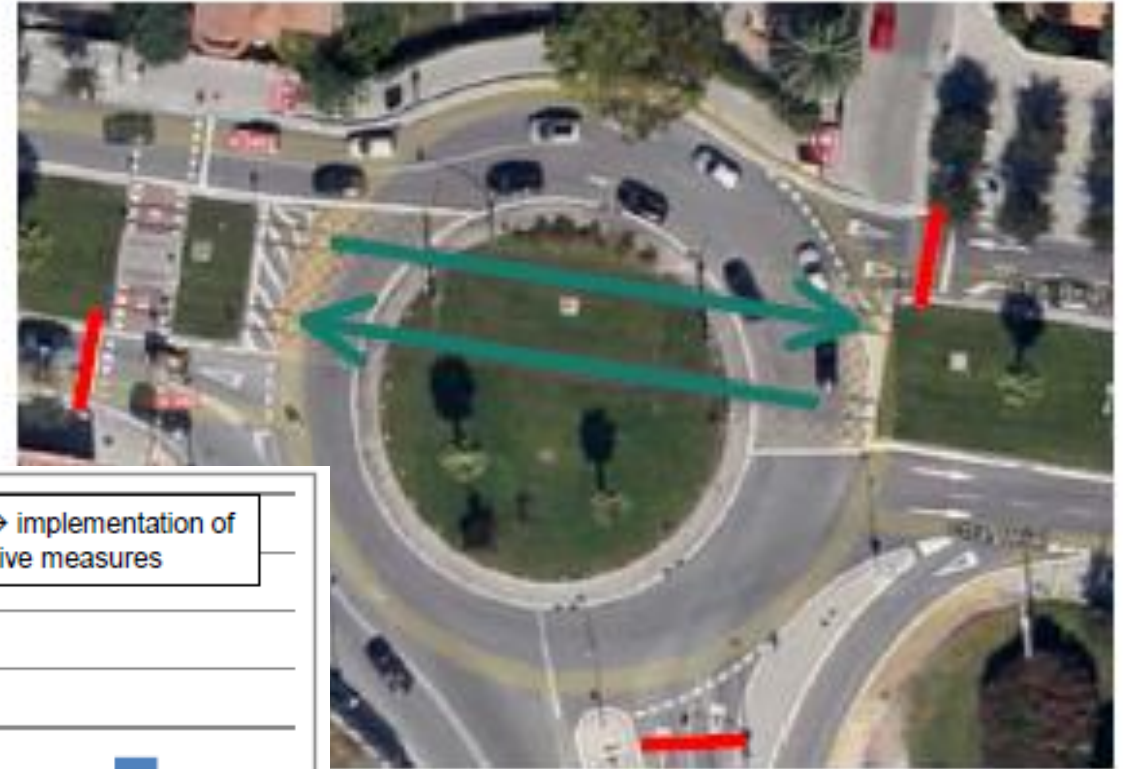
1. Differentiation of the road colour
2. Traffic lights before the tramway crossing
3. Stop line away from the swept path (around 1.5 m)
4. Vertical signs for improving awareness
 - Before the entrance of the roundabout
 - Before the tramway crossing (on the pole of the traffic light)



Roundabouts – Example: Barcelona

Problem: Collisions between trams and traffic entering the roundabout

Solution: Close entry to the roundabout for traffic during the tramway green phase



Roundabouts – Example: Montpellier

- HAZARD: All the hazards at roundabouts
- OBJECTIVE: Change to other configuration to avoid the hazards
- MEASURE: Transforming the roundabout into another solution



Roundabout: France | Montpellier | Rond Point Ernest Granier

Roundabouts – When to use them

Main recommendation:

- **Do not use roundabouts as a general solution**
- Use roundabouts only when there are strong reasons to prefer them to a conventional signal-controlled junction

It is crucial that the road vehicle drivers perceive at the right time:

what kind of situation they are facing

is a tram **approaching?**

do they have **priority or not?**

Pedestrians

- Pedestrians are vulnerable road users but also difficult to constrain
- Pedestrian behaviour may be unpredictable
- Pedestrians prefer to cross by the shortest route
- Pedestrians and trams also interact with other modes



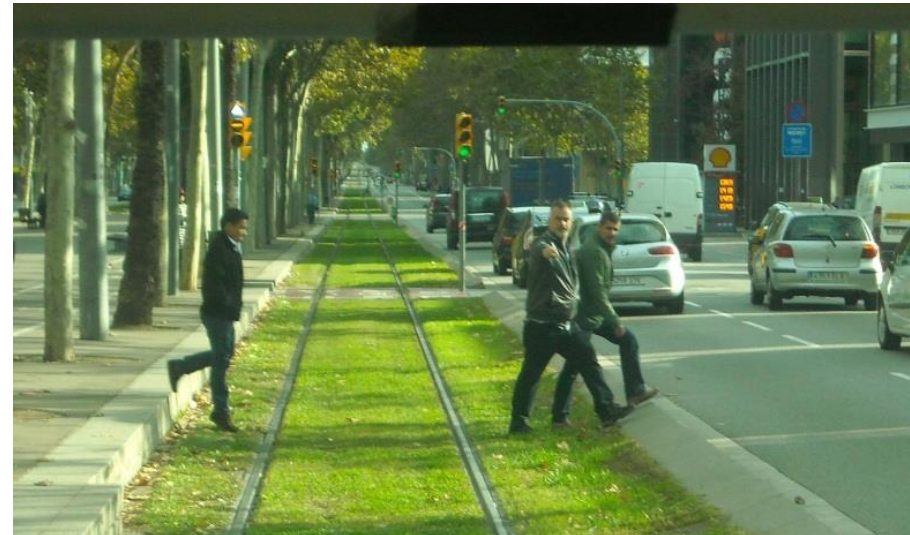
Lack of awareness

Headphones, mobile phones, and a general distracted behaviour cause many accidents



Violating rules

People take a voluntary decision to violate a traffic rule. Crossing anywhere or violating red light signals are causes of many accidents.



Hazard: Pedestrians not aware of tramway presence

warning passive measures

Vertical signs



Pavement texture



Pavement colours and markings



Tactile Paving



Pavement markings



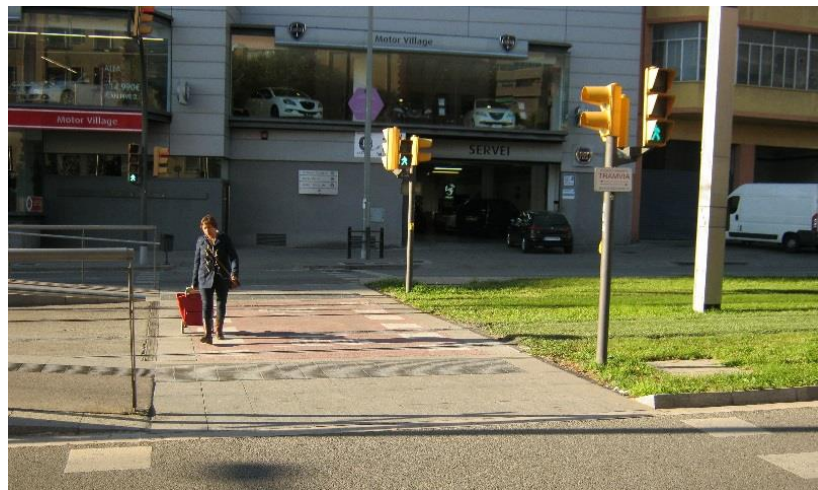
Pavement colours and signs



Hazard: Pedestrians not aware of tram approaching

Measures

- Use of active warning measures
 - Flashing lights or signs
 - Acoustic signals.
 - LED pavement lights.



Use of controlled pedestrian crossing and deterrent paving

Hazard: Pedestrians not aware of tram approaching

Forcing measures

Measures

- Use of:
 - Channelling barriers
 - Z-Crossings



Blackpool: Fence prevents access to track



Stuttgart: Z-crossing forces pedestrians to look towards oncoming trams

Running (link) sections

The parts of a tramway between stations, apart from junctions, roundabouts or pedestrian crossings

On a running section, trams and road users *should not* come into conflict

The designer's job is to ensure they *do not* come into conflict



Running (link) sections – avoiding conflicts

- **Passive measures**

 - Remove or re-locate obstacles

 - Mark the swept path, different colours, textures and markings, tactile paving

- **Prescriptive measures**

 - Direct drivers the right way

 - Separate tramway from traffic

 - Signs, signals, lane markings

 - Prevent illegal parking

- **Forcing measures**

 - Prevent drivers going the wrong way

 - Lane separators, kerbs, barriers, bollards

 - Allow left turn only at selected junctions

Problem:
Unawareness
Solution:
Safety campaigns



Basel



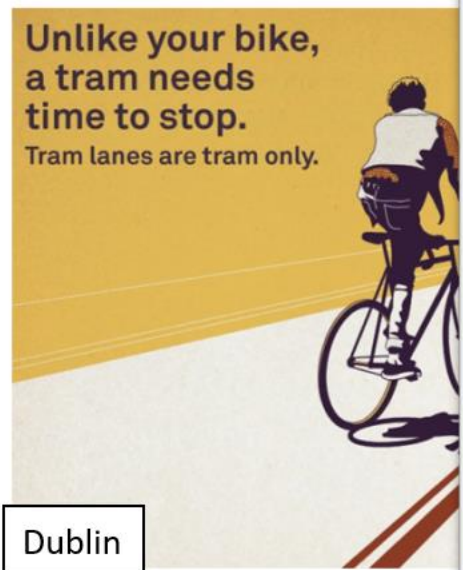
Barcelona



Warsaw



Stuttgart



Dublin



Safety campaign – Warsaw



*Tram safety demonstration
Warsaw, 2013*

Photo: D Walmsley

Bądźmy Razem Bezpieczni
Let's stay safe together

- ***Demo***
- ***Leaflets / posters***
- ***Press / TV / radio***
- ***Safety Conference***

Conclusion – we looked at ...



...and we arrived at three main causes of accidents:

“I did not **see** him!”



Angle of sight

Intervention on geometry of the sight is very important in order to achieve the best angle when road users interact between them.

Objective – 90° Perpendicular.

Obstacles

Clean sight from any obstacles (trees, urban furniture, pools, cabinets,...)

Contrast

Enhance the presence of the vehicle using bright colours and circulate with the lights On



I did not **understand!**



Intervention on the tramway system infrastructure through:

Tramway

Highlighting the presence of the tramway bed and swept path, using **different materials, textures, colours and/or other elements like fences, bushes etc.**

But!

Do not forget to guarantee the visibility between road users.



I did not **know** !



Use **understandable** and **sufficient** information to make clear the presence of a tramway system and to regulate the movements of road users, through:

signage;
traffic signs;
traffic lights;

...

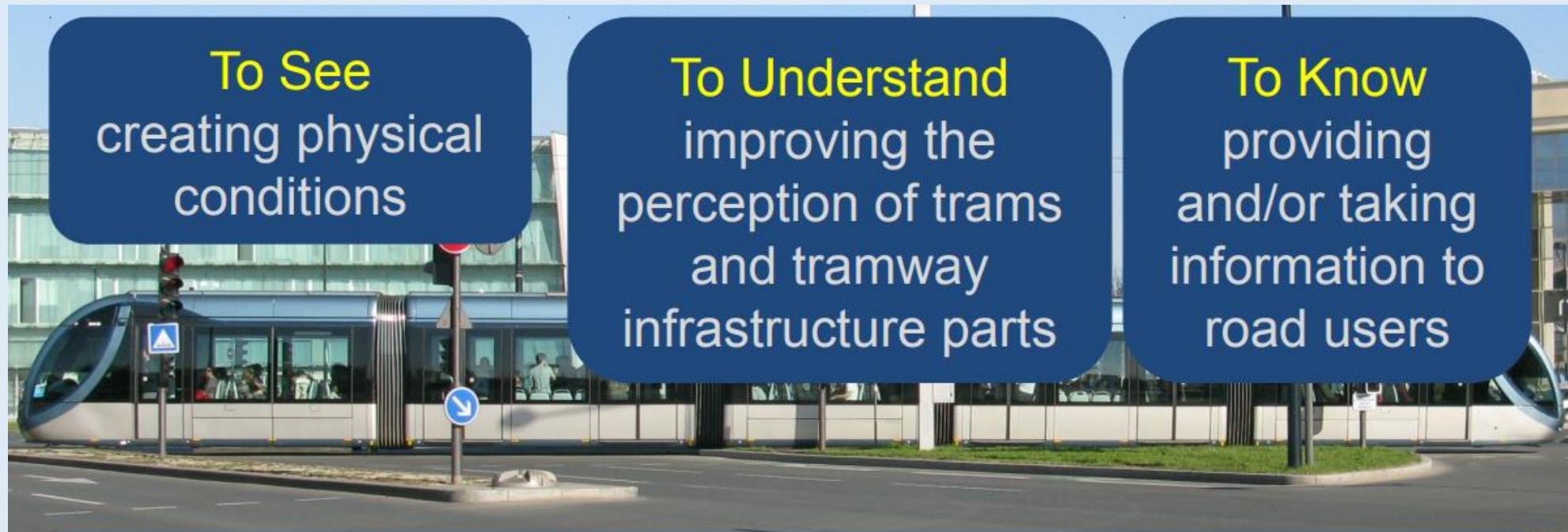
And other type of information to “shape” the behaviour of road users for a safe circulation in a Tram zone:

flyers;
outdoors;
Social networks campaigns

...

Tramways operate in the cityscape and interact with other traffic

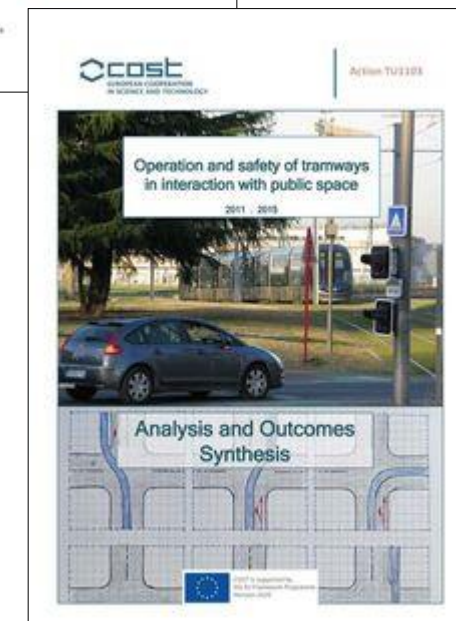
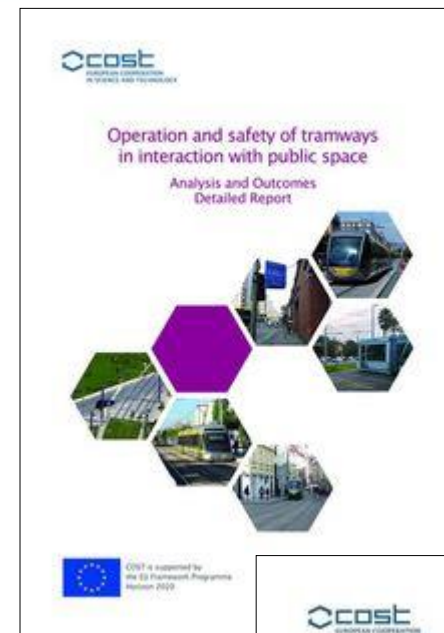
So their design must allow people ...



...in order to guarantee safe and trouble-free use of public space for all

Final Report and summary Brochure

- are available on the TU1103 pages of the CEREMA website www.cerema.fr
 - https://www.cerema.fr/system/files/documents/2019/04/tu1103_brochure_0.pdf
 - https://www.cerema.fr/system/files/documents/2019/04/tu1103_report_red.pdf
 - Or go to www.cerema.fr and search for **TU1103**
-
- The Action Team continues to meet annually as the **Urban Tram Forum**, now with participants from Copenhagen (DK), Los Angeles (USA), Adelaide (South Australia) and Hong Kong (China)



Thank you for listening!