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EUROPEAN COOPERATION
IN SCIENCE AND TECHNOLOGY

Action TU1103

Operation and safety of tramways in interaction with public space

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Analysis and Outcomes Synthesis

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EUROPEAN COOPERATION
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Operation and safety of tramways in interaction with public space

Analysis and Outcomes
Synthesis

Colophon

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This synthesis is based on the full report, which was written with contributions of all participants of this COST Action (see complete list at www.tram-urban-safety.eu and at the end of this brochure).

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COST is a unique means for European researchers, engineers and scholars to jointly develop their own ideas and new initiatives across all fields of science and technology through trans-European networking of nationally funded research activities. COST is the oldest and widest European intergovernmental network for cooperation in research.
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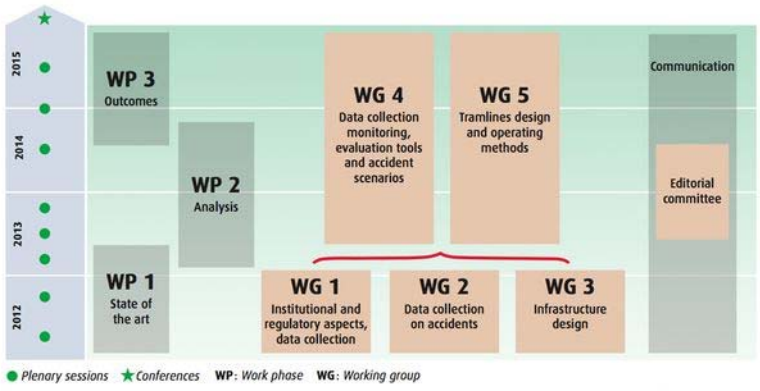
What is Action TU1103 about?

COST Action TU1103 "Operation and safety of tramways in interaction with public space" deals with the improvement of tramway and Light Rail Transit (LRT) safety through a better management of their insertion into urban spaces, and therefore with the minimization of accidents and their impacts on both the transport system and society.
The Action enables a better understanding of tramway safety issues in urban areas, and the sharing of potential solutions across European cities.

How has the Action been built?

The first Work Phase (WP1) report dealt with what exists in Europe (regulations, indicators, and layouts). The following Work Phases 2 and 3 of this Action dealt with best practices and their analysis. There are no "a priori" good/safe or bad/dangerous solutions when we talk about tramways.



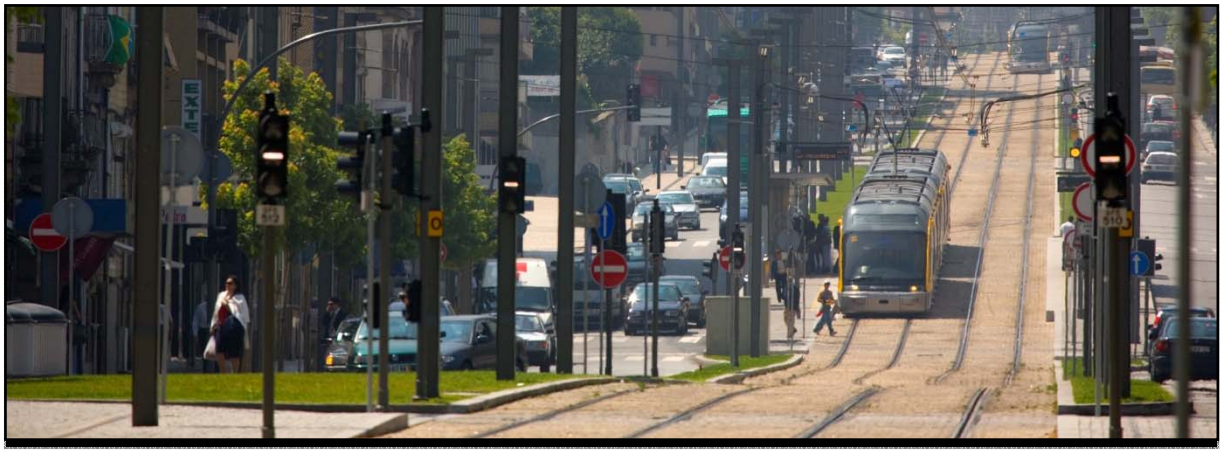
Each case is unique and it should be designed or adapted according to its urban environment and traffic conditions. We want to keep tramways integrated with the urban environment, not separated by fences or placed underground.

The Tramway and the City

Today, tramway systems follow a new philosophy for a public transit mode, where several advantages are combined such as operating in a specific public space corridor, having priority over all modes of traffic, and having the physical and psychological comfort of travelling at ground level, enjoying the urban landscape in all its fullness.

We must be conscious that tramway systems do not interact only with the cityscape. Once a tramway starts to operate, it will interact with and change the daily habits of the citizens, with the biggest impact on the street users. Knowing this, an accurate and well-balanced integration of trams in the city will influence positively the performance, comfort and safety conditions of the system. On the other hand, tramway systems that put the focus only on the transport system or on urban design will suffer traffic stress, boosting the number of dangerous events involving cars, motorbikes, pedestrians and cyclists.

So, to merge tramway performance and urban space, interactions have to be dealt with properly.



Who should be concerned with improving urban tram safety?

The primary cause of tram accidents is the conflict with other users of public space, in relation to their behaviour and their perception of risk.

This report has two main target groups, designers (for projects) and operators (for running). It also addresses all decision makers and actors who may be concerned by interaction between tramway and urban space, at all stages of desing and operation .

What are the benefits ?

Keep in mind that improving tramway safety will play a part in improving road safety in general and for vulnerable road users in particular. It will also decrease operation and maintenance costs, contribute to rationalising and optimising the investment in the tramway system, improve its insertion, its safety and its efficiency and reliability, and indirectly will go in the direction of moderating the place of the car in town.

First tool: accident report in the field

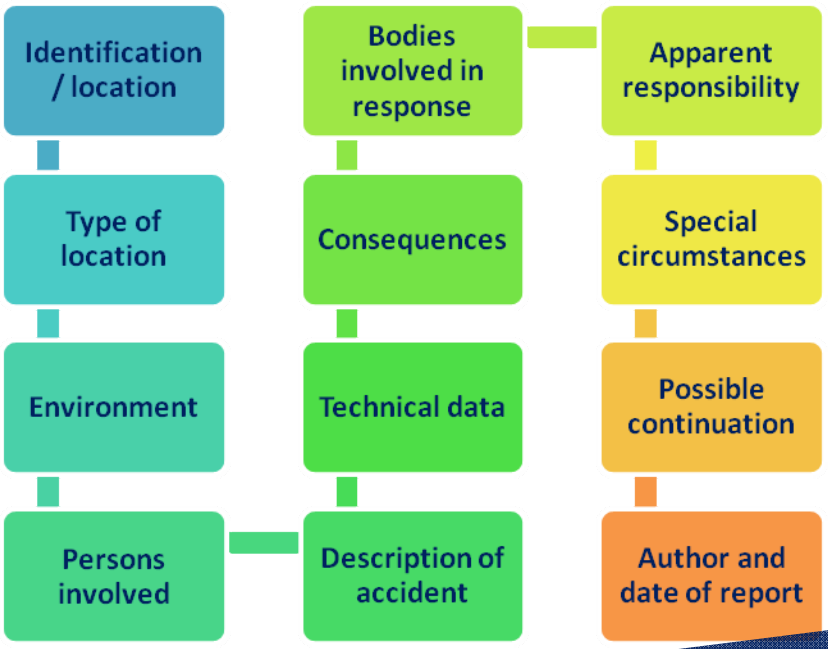
A homogeneous design of these documents within the operating company can assure consistent data acquisition and evaluation.

The Ideal Accident Report (IAR) model/template is a suggestion, adaptable for each operator's needs, internal and external data. It is a detailed list of pertinent data which is strongly suggested tramway operators should collect in order to:

· Allow post-analysis and best understanding by operators but also researchers,

· Use data for evaluation for accident prevention.

For many operators the use of template checklists and accident report forms has been proven successful.



Do not forget!
Every detail can be of crucial importance for subsequent investigations.

Ideal Accident Report (IAR)

The main task promoted by the **IAR** is to summarize the essential information for all important actors, from operators and infrastructure managers through transport authorities and research bodies to health and safety departments.

Other tools to collect data

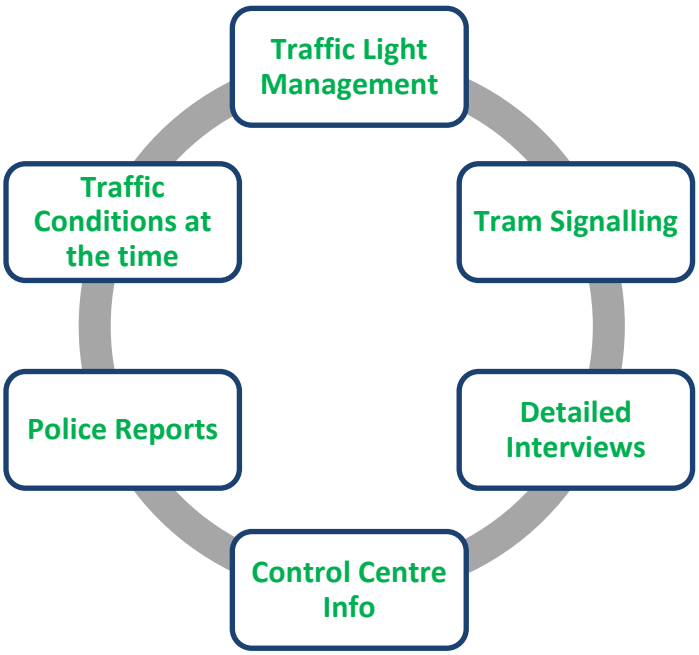
Besides the *tram accident report*, there are other tools to collect data that can be split in "*more objective tools*" - video images; pictures; automatic recording (*black box*); voice recording and tracks and traces in the incident area – and "*more subjective tools*" – personal information from drivers, passengers and/or witnesses; occurrence books and newspapers and other news channels.

Those tools are also very important for analysing the performance of the alignment on urban insertion.

Other useful sources

City planners and managers may have relevant information about vehicle and pedestrian traffic at the time of an accident, traffic lights status, road characteristics, mutual visibility of tram and other road users and environmental conditions, which gives a more comprehensive picture of the analysed situation.

In addition, in every application of these tools there are still some entities that can be working in other framework programmes like in the safety modes comparison or in any typology accident.



The aim of the Action was not to build a European database, nor to compare tramway safety in various countries. However we proposed an analysis of the advantages and difficulties of doing so.

Database at a Local, National or European level. Is it important?

Indicators may be useful to assess evolution of safety level on a network or a line, but not to compare results of networks between them. They may help to identify some risky situations (e.g. roundabouts or "turn on" junctions) on a local basis, but are not relevant to explain why accidents occur.

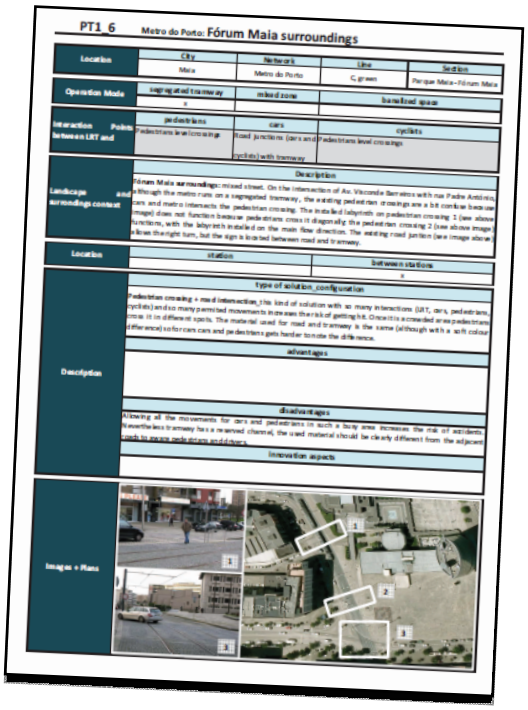
Is it possible?

The core problems are the sensitive issue of sharing figures about safety between operators and others, and some possible quick but misleading comparisons. There are advantages and difficulties to implement a database at a European, national or even local level. However there are some lessons to be learnt which could help to reduce risks on new systems.

Post-analysis through integration of all data

The post-analysis phase starts some time after accident resolution or closure, looking at it with a fresh mind, new angles and a global view, with accident reports and other sources. The post-analysis based model of accidents aims at understanding what happened in one single particular accident or a group of accidents and how to avoid such accidents.
The objectives are to :

- Propose measures of safety planning / management
- Improve the organizational / operational system
- Improve the environmental system
- Make economical evaluations
- Analyse the human behaviour
- Complement driver training
- Evaluate and minimize risk
- Improve the rolling stock
- Improve the infrastructure
- Check the rules and procedures


PT1_6 Metro do Porto: Fórum Maia surroundings

Hotspots on a tramway: What are they, and why is it important to identify them?

A Hotspot is a specific location on the tram network defined as a place in the urban area where the most accidents or collisions occur in a fixed period of time. The consequences of this identification are to know where to put most effort, to count the number of accidents per location all along the line (for the last year or for the last x years) and to focus on the locations with the highest numbers. Concerning the (reactive) post-analysis of accident data, it is worthwhile to generate accident statistics periodically (monthly, quarterly or annually).

Be PRO-ACTIVE!

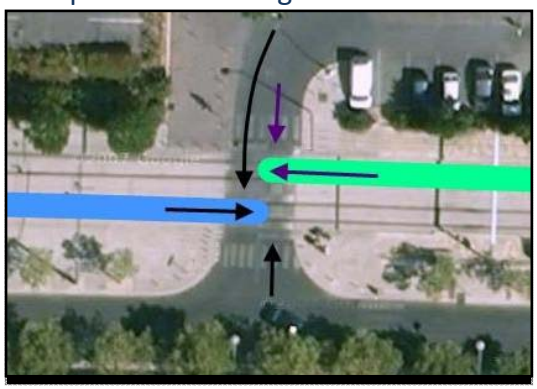
In the identification of "hotspots" do NOT just be reactive where accidents have happened. It is essential also to be PRO-ACTIVE in hotspot detection, because people on the spot can often identify where potential accidents could occur before they happen.

Main observed tram hotspots

From a small survey of 89 hotspots identified by operators, the majority of them were located at intersections (76). A smaller proportion took place on running sections – in this case including pedestrian crossings or at stations.

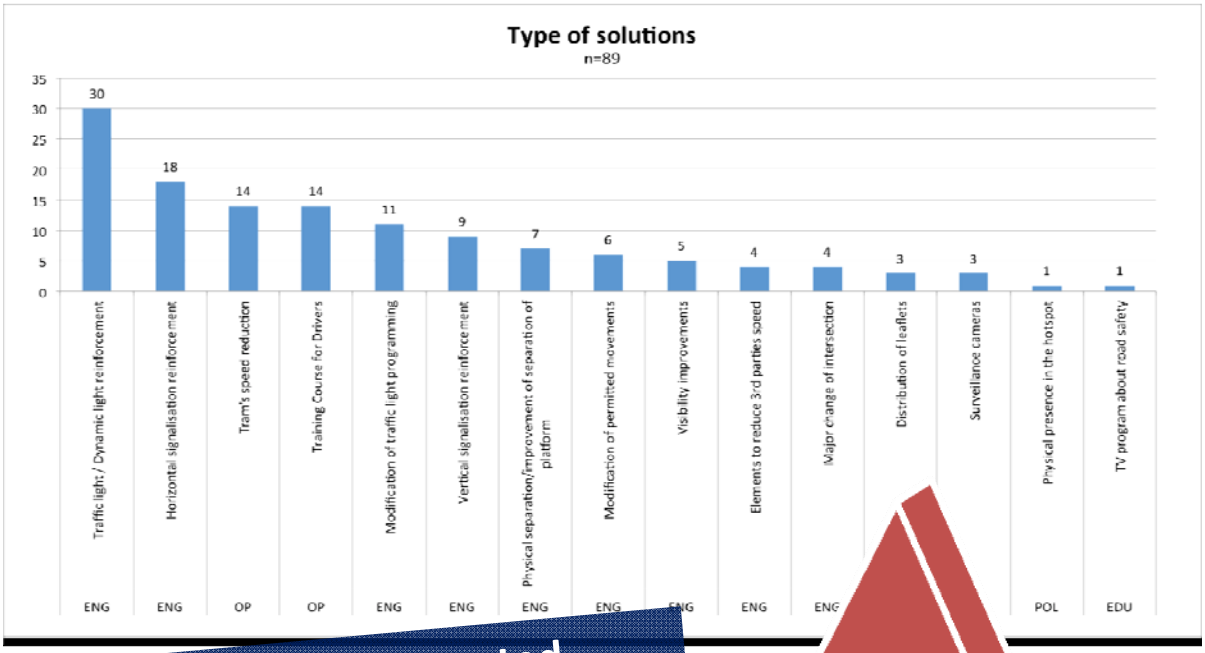
The intersections for their part are divided into junctions and roundabouts. 64 of all intersection hotspots are located at junctions, the rest on roundabouts.

In 88% of the cases, a road vehicle is involved in the accident. Another 10% of accidents involve pedestrians and only 2% motorcycles.



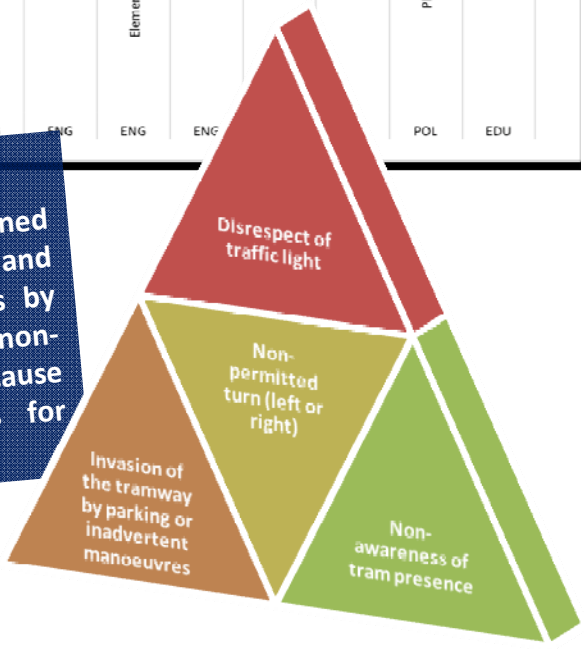
What solutions are applied by tram operators?

In order to address the major cause of accidents at hotspots, a third of all operators involved in the questionnaire advocate improving traffic light design and efficiency for a better priority for trams, and stricter enforcement. Other favoured engineering solutions include carriageway markings and modifications of traffic light programming. 16% of operators mention also operational solutions like tram speed reductions or training.



Main causes detected

In the hotspots observed, the most mentioned cause of accident is linked to third parties and results from a disrespect of traffic lights by vehicle drivers. Furthermore, the non-awareness of tram presence is a relevant cause of collisions, for vehicles as well as for pedestrians.



Indicators

Regarding tram safety, indicators are a useful tool to show the trends in terms of safety. In this perspective, we distinguish three categories of indicators for tramway safety related to interaction with public space: “global”, “geographical” and “typological”.

	2005	2006	2007	2008	2009	2010	2011	2012	2013
SERVICE LEVEL									
Tram million kms	2.47	2.67	2.74	2.73	2.64	3	3.86	3.99	3.88
% change		+8%	+2.6%	-1.0%	-3.3%	+13.6%	+28.7%	+3.3%	-2.7%
INCIDENTS/ACCIDENTS									
Road traffic collisions (RTC) road vehicle/tram	36	24	28	32	23	30	30	24	38
Contact of person with tram	8	21	18	20	18	22	13	7	8
Collision between two trams	1	0	0	0	0	0	0	0	0
Derailment in depot	4	0	3	1	0	0	0	0	0
Derailment in service	1	1	0	0	1	2	0	0	0
SPADs	-	-	-	-	-	-	-	30	24
Emergency brake applications	940	747	540	435	350	374	478	414	446
Fire	0	0	0	0	0	0	0	0	3
Failure of a part of a Tram	0	0	0	0	0	0	0	0	2
Failure of OCS Support	0	0	0	0	0	0	0	0	1
Road vehicle striking an OCS support Pole	0	0	0	0	0	0	0	0	1
Emergency handle applications (incidents)	14	6	4	3	13	3	10	3	3
***Total Incidents/ Accidents**	**1004**	799	593	491	405	431	531	478	526
Incidents/Accidents per million km	406.5	299.3	216.4	179.9	153.4	143.7	137.6	119.8	135.6
CONSEQUENT INJURIES									
Fatality	0	0	0	1	0	0	1	1	0
First Aid	5	1	3	1	5	2	1	0	1
Medical Attention	10	9	11	4	20	15	9	7	12
Hospital Care	2	2	2	1	4	3	1	0	0
Total Injuries	**17**	**12**	**16**	**7**	**29**	**20**	**12**	**8**	**13**
Injuries per million km	6.9	4.5	5.8	2.6	11.0	6.7	3.1	2.0	3.4

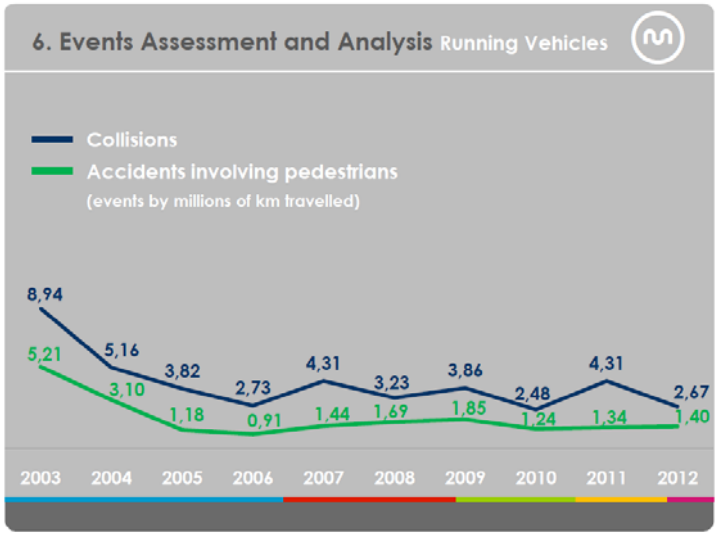
Table 2 *Summary of all accidents and incidents by category*

Source : Railway Procurement Agency

Global Indicators are related to the line or networks as a whole (without any reference to the location of accidents), the whole period of operation (without any reference to date nor time) and all types of events (derailments, collisions, etc.), and severity (casualties, injuries).

Geographical Indicators are calculated and used in locations of accidents, and are used to compare figures regarding: different parts of networks, various types of alignment (junctions, stops, etc.) and the spatial location of accidents.

Typological Indicators are related to the circumstances of accidents and parties involved, such as: categories of persons involved; periods of time when accidents occur; causes of accidents and other contextual items (e.g.: the use of figures about the severity of accidents to determine whether pedestrian or cyclists are the most vulnerable ones.)



Source : Metro do Porto

Besides these indicators dedicated to safety, we can identify some other indicators, regarding economic aspects or quality of service aspects which are related to impacts of accidents (e.g.: operational disruption, through its duration or corresponding loss of income, infrastructure and rolling stock repair costs, and social costs).

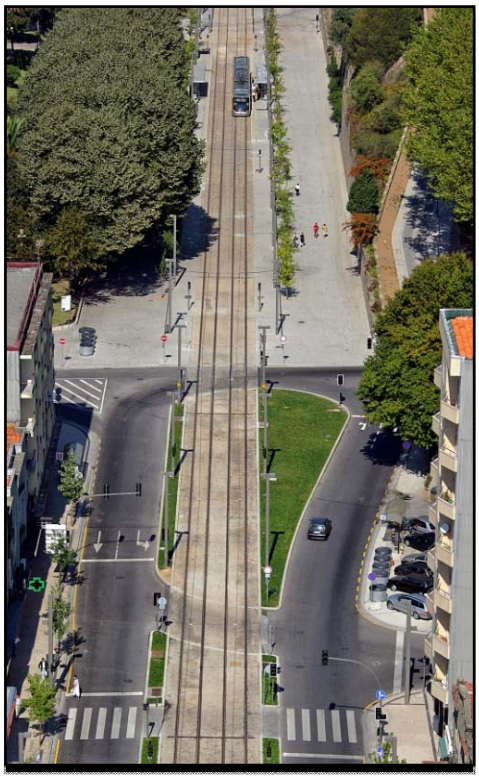
Cooperation between transport companies and municipalities

Trams serve and operate in an urban environment. They interact with street traffic, leading to a need for some coordination between tram companies and municipalities. Some companies have had a close cooperation with the municipality for many years. The key issue is to best adjust the tram service to the requirements of the citizens. In such cases the authorities responsible for town planning, highways and traffic management and tramway promotion, infrastructure and operation usually meet regularly to monitor tramway performance and safety issues.

Outlines for a cooperation

To identify optimum solutions there must be a cooperative activity between all these agencies and in many situations implementing solutions must also be a joint activity.

Urban insertion - tram infrastructure



The main achievement in this Action is the compilation and analysis of good and bad practices in relation to safety when trams interact with other street users (pedestrians, cyclists and road vehicle users).

The objective is to agree on some measures that will protect each type of Interaction Point in as natural a way as possible. From existing examples and experience, an analysis has been made of the features of the best and lest successful layouts.

It was observed that operators from different networks share common experiences on accident occurrences, but that the collection of data varies.

Interaction Point identification

Interaction Points are the main location and aspects of the tramway infrastructure whose design has to be properly studied in order to optimise the safety of the system in its interaction with public space. Through our work, we have identified the following Interaction Points and for each of them, the main actors in the public space:

Interaction point ID	selection		
	pedestrians	cars	cyclists
Road junctions (cars and cyclists) with tramway		x	x
Road junctions (cars and cyclists) with a left turn		x	x
Roundabouts		x	x
Tramway segregation along the street (lanes and sidewalks)	x	x	x
Tramway perception on mixed streets (cars and cyclists)		x	x
Tramway perception on pedestrian areas	x		
Pedestrian level crossings	x		x
Cyclists in segregated areas			x
Stops and accesses to them	x	x	x
Interchange areas	x	x	x
Traffic (road & pedestrian) signals	x	x	x
Line signs and signals (for tram drivers)	x	x	x

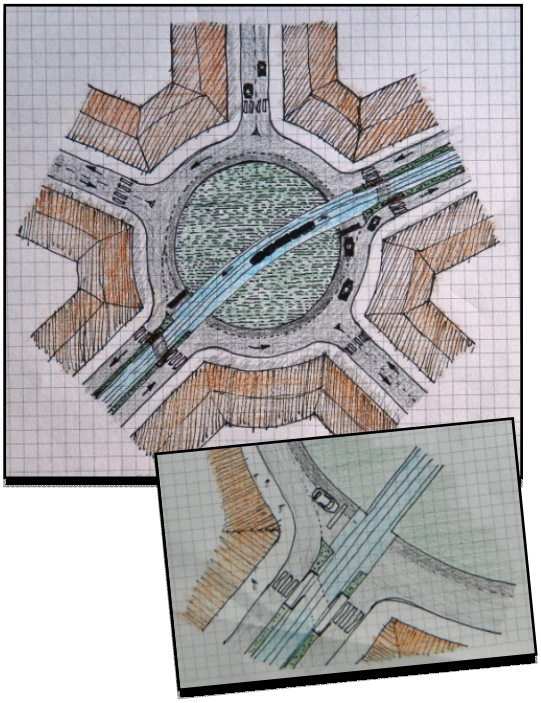
Methodology

Road junctions and roundabouts with tramway

The insertion of a tramway into a city requires careful consideration. Junctions and roundabouts are locations of higher accident frequency and have been identified as a major Hotspot on tram networks. A junction or roundabout that has a tramway traversing it should be readily recognized as such by other road users. To prevent uncertainty, junctions crossed by a tramway, should be constructed and signed/signalled to make obvious what sort of behaviour is expected from the road users.

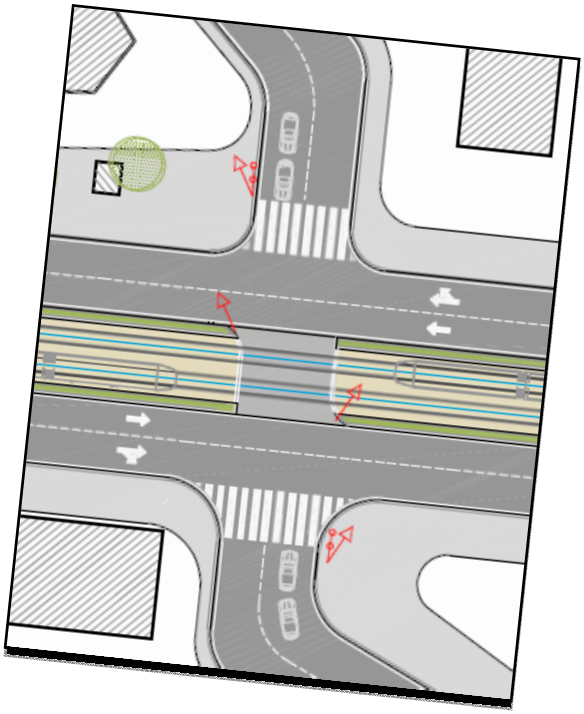
Roundabouts

When a tram crosses a roundabout, traffic operation changes. So, in relation to roundabouts, do not use this configuration with trams, unless there are strong reasons that make it more advisable than a conventional signal controlled junction. In that case, a correct design is crucial for the safety of this type of Interaction Point.



Road junctions

If the city structure allows, the routeing of traffic should be reorganized to avoid left turns across the tramway path, where possible. This leads to resolutely prohibiting this dangerous turning movement. Where re-routeing is not possible and warning signs are not effective, using dedicated traffic lights and physical separation between lines at the junction may be a better solution.



Pedestrian crossings

Even though the number of accidents involving pedestrians is not high compared to accidents with cars, they tend to produce more severe consequences.

As a general consideration, it was found that pedestrians' desire lines has to be closely addressed; however, safety is increased by design, signage and marking of crossings which guide pedestrians and alert them about tram presence. Refuge areas if multiple car and tram lanes have to be crossed, and a good visibility throughout also are essential.

Stops and stations

Stops and stations can be considered as the access point to tramway and LRT systems, being the first contact between the user and the system. All areas should be dimensioned according to the intensity of the expected flow. It is important for the passengers to have direct and fast accessibility to the stop and a good connectivity with the pedestrian area in the urban environment.

Not all pedestrians are tram users, there are people who only want to use the pedestrian crossing, but even so they need to be aware the presence of the moving tram. Also tram users might adopt dangerous behaviour in order to board the vehicles as fast as they can. The accumulation of users during the rush hour in the limited space of the platform and the possible presence of stopped vehicles which restricts the visibility of other approaching trams can generate further safety hazards.

So, stops and stations have specific hazards to be covered when (re)building a layout including, by type of movements and usage of the area: people waiting at a stop or station, pedestrians crossing, vehicles circulating.

Success stories

Hotspot surveys were returned from 26 cities in 14 countries. The data obtained from the answers to the hotspot survey has been analysed to identify problems, solutions and lessons learnt.

Here are some examples of success stories:

Porto - Portugal

Hotspot	Problem	Solution	Result
Intersection Left turn	Tramway is on reserved track in central reservation. Left turning vehicles were at risk of collision with trams.	Left turning traffic movements prohibited and controlled by traffic signals and road signs. When the tram signal shows "proceed" all road traffic movements are stopped	Fewer collisions

Lessons learnt

An effective method of eliminating hazard of collisions is to prohibit the left turn traffic movement.

Tenerife - Spain

Hotspot	Problem	Solution	Result
Roundabout	Drivers miss the red light in this huge roundabout and collisions occurred. One of them led to a derailment.	Duplicate traffic lights between road lane and the tramway, plus a new traffic light in the nearest entrance to the roundabout, so drivers can only proceed when a tram is not crossing.	No more accidents since 2012

Lessons learnt

Traffic lights installation or duplication at a roundabout entrance close to the tram tracks were effective in reducing accidents.

Dublin - Ireland

Hotspot	Problem	Solution	Result
Intersection Junction	Car drivers were not able to see the approaching tram because of solid timber hoarding, so they passed red traffic signals.	In cooperation with the land owners, a section of the solid timber hoarding was replaced with a mesh type fencing which has improved the line of sight for both tram and road vehicle drivers.	A reduction in incidents and accidents has been observed at this location.

Lessons learnt

An example of simple 'common sense' solution to basic sight lines problem, which required negotiations with several parties.

Milano - Italy

Hotspot	Problem	Solution	Result
Pedestrian crossing	Crossed the intersection on the crosswalk without looking at the tram on these important arterial roads to the city centre from the north.	Creating paths with fences that force pedestrians to see if the tram is coming.	No more problems with pedestrians crossing the tramway.

Lessons learnt

By directing pedestrians to see the oncoming tram, safety was improved without the use of traffic lights.

Geneva - Switzerland			
Hotspot	**Problem**	**Solution**	**Result**
Running sections	Frequent encroachments of road traffic on tram tracks. No accidents but risky situation.	Red and white small collapsible posts installed to complement the marks on the ground and physically separate the lanes.	Fewer intrusions
			
Lessons learnt Additionally to white painted lines, physical objects help street users to respect swept path and lanes.			

Conclusions from success stories

- Wide variety of measures that were locally implemented.
- Many of these measures are low cost and relatively quick to implement, e.g.:
  - Changing or adjusting traffic signal timings or phases;
  - Introducing or improving tram detection and priority signals (signals activated by trams);
  - Introducing separate signals or filters for turning traffic;
  - Changing lane markings and providing physical separators;
  - Improved traffic signing.
- Common cause of accidents is where left turning vehicles (right turning in left-drive countries) cross a tram track to their left and do not see an approaching tram. Many examples show that the conflict could be removed by :
  - Signalling the left turn separately;
  - Re-routeing left turn movements;
  - Providing clearer traffic signs or signals.
- Major reconstruction works, for example for a new tramway station or a new intersection, also bring the opportunity to re-design the tramway tracks to reduce or eliminate conflict points between trams and other street users.
- Special attention is needed to reduce conflicts with pedestrians and cyclists by improving sight lines, modifying guardrails, introducing chicanes and improved signing and lighting.
- Roundabouts with tramways can be problematic.
- Speed limit of trams was reduced in specific situations, especially in pedestrian zones.
- Targeted training courses for tram drivers and driver awareness campaigns can result in improved safety .

Many of the features described here can be incorporated in new tram systems or extensions to existing ones during project steps, to avoid the occurrence of accidents once the system opens.

What are the main conclusions?

The TU1103 Cost Action report is the result of sharing European experiences in order to better understand the link between tramway safety and public space layout, and to improve this safety as much as possible, through a better management of the insertion of trams in urban areas.
The Action might then help to improve the safety of European tramway networks, leading to a better knowledge and understanding of the causes of accidents.

In Chapter 2, we discussed data collection. It was observed that only a few countries have a mandatory, centralised scheme for recording accidents and recording them in a database. An Ideal Accident Report (IAR) was devised as a suggested template to collect all necessary data in order to reach a comprehensive analysis and assessment.

In Chapter 3, we analysed tram infrastructure layouts and five main interaction points between trams and other road users were identified: road junctions, roundabouts, pedestrian crossings, stops and stations, and running sections (that is, the stretches of track without pedestrian crossings, junctions or stops). The main types of hazards associated with each type of interaction point were identified, key objectives to be achieved defined and possible measures suggested for avoiding them, illustrated by examples when available.

In Chapter 4, some examples of success stories from several tramway systems were addressed.

The Action was a source of rich and fruitful exchanges between its members who shared their tools, experiences, success stories and methods. The same was true for safety authorities and monitoring organisations at different levels, other transport agencies and tramway operators, road network managers, other designers, architects, engineering consulting firms, and research bodies. We shared strategies and ideas, which had been implemented in one country that could have the potential to be transferred and implemented in another, enabling all to learn from others' experiences and economizing on resources.

So, after four years of sharing experiences from all over Europe, discovering other methods, gathering knowledge, recognizing similarities, learning from our differences… between tram operators, safety authorities, researchers, designers, about safety management, data collection and/or layout solutions, COST Action TU1103 has successfully presented in the report the essential results produced by this collaborative effort.

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