COST TU1103

Operation and safety of tramways in interaction with public space

Public Report

Work Phase 1

Operation and safety of tramways in interaction with public space

Public report Work Phase I

www.tram-urban-safety.eu

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1 COST Foreword

This publication is supported by COST.

COST- the acronym for European COoperation in Science and Technology- is the oldest and widest European intergovernmental network for cooperation in research. Established by the Ministerial Conference in November 1971, COST is presently used by the scientific communities of 35 European countries to cooperate in common research projects supported by national funds. The funds provided by COST - less than 1% of the total value of the projects - support the COST cooperation networks (COST Actions) through which, with EUR 30 million per year, more than 30 000 European scientists are involved in research having a total value which exceeds EUR 2 billion per year. This is the financial worth of the European added value, which COST achieves. A "bottom up approach" (the initiative of launching a COST Action comes from the European scientists themselves), "à la carte participation" (only countries interested in the Action participate), "equality of access" (participation is open also to the scientific communities of countries not belonging to the European Union) and "flexible structure" (easy implementation and light management of the research initiatives) are the main characteristics of COST. As precursor of advanced multidisciplinary research COST has a very important role for the realisation of the European Research Area (ERA) anticipating and complementing the activities of the Framework Programmes, constituting a "bridge" towards the scientific communities of emerging countries, increasing the mobility of researchers across Europe and fostering the establishment of "Networks of Excellence" in many key scientific domains such as: Biomedicine and Molecular Biosciences; Food and Agriculture; Forests, their Products and Services; Materials, Physical and Nanosciences; Chemistry and Molecular Sciences and Technologies; Earth System Science and Environmental Management; Information and Communication Technologies; Transport and Urban Development; Individuals, Societies, Cultures and Health. It covers basic and more applied research and also addresses issues of pre-normative nature or of societal importance. For further information, http://www.cost.esf.org

Credit Photo:

TU1103 COST Action’s participants.

2 Chair's foreword on TU1103 – Operation and safety of tramways in interaction with public space

Tramway and Light Rail Transit systems were reduced in the 1950s, but since the 1980s , they have been reintroduced or extended in many cities all over Europe. This expansion in numbers and length of lines has multiplied the interaction of tramways with other users of urban space.

But still, trams are involved in fewer accidents than other road users - car colliding with another car, a bicycle or a pedestrian. However common problems are encountered all over Europe. All networks are facing difficulties or having bad experiences. Their experience could be useful for others and would enable them to avoid some mistakes, thanks to access to the knowledge and experience.

The sharing of information, feedback, and experience is one of the best ways to improve tram safety in urban spaces. Urban insertion of LRTs is not an exact science, butthe sharing of ideas and practical solutions is a good way to help designers of a tram network to find the best layouts for an existing dangerous crossroad or a new one.

The aim of the final report of the Action will be recommendations on safe tram urban insertions.

Laetitia FONTAINE,
Chair of the COST Action TU1103
Service Technique des Remontées Mécaniques et des Transports Guidés (STRMTG – France)

3 Availability of deliverables of the Action

This Report is the deliverable for Working Phase 1 of the Action. It is a Public Report, and is available on the public part of the Action`s website. The Report includes summaries of working group outcomes and general information about the progress and outcomes of the Action.

Detailed information about each topic and the entities involved in the Action will be covered in the Working group reports (for each Working phase). These will be restricted to the members` part of the Action webiste, but specified parts of this detailed information can be made available on demand, which will be expressed by request to the Action webmaster Mr. Dominique Bertrand (webmaster@tram-urban-safety.eu).

4 Executive Summary of Working Phase 1 outcomes

The outcomes of the Work phase 1 (WP1) can be summarized in **3 sections, which correspond with 3 Working groups (WG)** present in the WP1.

The main objective of **Working group 1** during the investigation of the state of the art was to compile an overview on national key points for each country, to identify regulations concerning trams and to establish a common vocabulary.

First of all, exploration has been concerned with setting out a global view for each country participating to the Action. New tramway systems and lines are spreading all over Europe. After a period of gradual closure of this technology on their urban PT networks, LRT systems are now growing with new vehicles and technology and existing ones are being extended in most medium and big cities of the EU. Germany has the greatest number with 58 operators and more than 20 extensions in progress, and Ireland the least with two tram lines in Dublin. France has known the highest expansion of new lines during the last decade. A wide variety of the main tram regulations across the countries is observed also, while the need for a deeper understanding of tramway safety issues is emerging, as urban mobility and transport safety are relevant topics of European transport policy. Safety management is mostly based on a reactive approach to reduce the frequency of undesired recurring events in black spots of the networks. The operator collects accident data but there is no established practice to manage and analyse them in a national database according to common safety indicators, except in one country. Generally there are no national databases for accidents' the collection and analysis of accident data (except in the case of France) and some countries require the introduction of a Safety Management System (e.g. UK + IRL) to proactively reduce the risk of accidents, while others rely on a reactive approach based on the investigation of individual accidents to develop a corrective action plan. There are a lot of types of accidents; the big variety is linked to the different locations where tramway and traffic interact, to the degree of track segregation (fully segregated, partially segregated or in mixed traffic), and to the speed of operation. There is no typical accident though the majority of them are obviously connected to intersections.The most typical places of conflicts is a turn-left movement with tram in the back, which is separately identified. Cars are the vehicles most implicated in collisions with trams. Pedestrian crossings are also an issue. Other problems are encountered: lack of attention from other street users, speed, restricted sightline/visibility, traffic jams. Accidents tend to happen because road vehicle drivers are not aware of the presence of a tram or do not treat it with sufficient respect recognising its longer stopping distance or different path. Whatever the regulation, whatever different solutions, all countries face these problems.

Secondly, exploration has concerned the legal and the technical frameworks of LRT systems, and a complete list of regulations concerning tramway systems has been collected for EU level and for each country. There is a wide variety of regulations across the countries. Regarding tramway systems, in the majority of the cases, there is no single code which collects all the laws concerning the tramway sector, but there are rather interpretations of the laws regarding railway and road sectors. The system components, on the other hand, often have norms based on national technical standards, sometimes from European norms, which apply to LRT. Some of them are related to railway statistics and safety management, but most of them concern technical aspects (rolling stock, power supply, track).

Last objective, a common glossary has been established to check if there was any language issue and to avoid potential misunderstandings or mistranslations. This glossary (not a dictionary) is on the main terms in the

original language and their descriptions in English (tramway, LRT, mixed zones, segregated lines...), illustrated. A global table with all translations in each language represented and comments has also been made. Globally, no complicated issue occurred but terms such as “Metrobus” or “local authority” have appeared to mean slightly different ideas.

Working group 2 had to deal with accident data and other indicators, which are related to accident occurrence (e.g. emergency braking). Regarding safety matters, the final objectives of WG2 work were described as:

- harmonisation of data collection on accidents and operations and analysis tools (indicators), keeping in mind to avoid too many complications in their implementation,
- common knowledge on safety issues (problems, levels, impacts, indicators, causes of accidents and incidents).

Among the operational objectives, the following items have been identified:

- to produce an overview of organisational options in terms of gathering and using data on safety and operation;
- to establish a shared methodology and analysis criteria for accident data;
- to produce the corresponding safety assessments.

To reach these ultimate goals at the end of our work, it has been decided that the first important task to be coordinated by the Action was to make an inventory of the current situation of all participants, by identifying the data, information and analysis methods available while highlighting the most useful ones. More precisely, WG2’ topics were intended to be data collection on accidents, both at national and local level:

- tools and mechanisms for data collection and processing,
- criteria of analysis,
- indicators,
- results.

From the exposed methodology from each country (with sometimes differences within operators in a same country), we have identified the most common collected data:

- number of events (total);
- number of events (by types of events);
- number of fatalities;
- number of seriously injured people;
- number of slightly injured people;
- number of victims (passengers and third parties);

Globally, a majority of the countries uses the number of events as an indicator at a national or individual level.

No major difference appeared between the national level and the individual operators. Indicators were classified in 4 types: global indicators, geographical indicators, typological indicators and economic indicators.

Extensive reports on the state of the art in recording and analysis of accident data and indicators in different countries were delivered. But not all WG2's goals were reached: the great variety of data and means of data recording and analysing in different countries showed difficulties in reaching a common approach. Some definitions can also be different. Finally, there is a difference between data (which people collect and use) and indicators (which people use to assess tram safety).

Concerning the need for the analysis of safety indicators (data collection and analysis) to be harmonised at European levels, the group has answered two questions:

- should a country have a means to harmonise its tram safety indicators? How to do it?
- should it be done on a European level? If so, how?

A comparison to what already exists has been made in terms of harmonisation:

- railways: trams are not railways. Trams are different since they operate in a street environment where the risks come from external actors (car drivers, pedestrians, highway authorities) over which the tramway operator has little or no control. The only possible approach for LRT systems is make sure that drivers and controllers are prepared for the risks and take action to reduce them.
- road: another comparison has been proposed since tramway companies are generally public transport companies and they have also public transport systems like buses. But trams are specific, with long braking distances, a constrained trajectory and various systems of priority.

But none of them are satisfactory to LRT systems. The core problem is to share the figures of the indicators between operators and outside - sensitive questions, possible quick comparisons... And the benefits of European wide harmonisation are difficult to determine and would probably be very difficult to achieve. There may however be some lessons to be learnt which could reduce risks on new systems.

The main work developed by **Working Group 3 – Infrastructure design** was the identification and gathering of information about common "Interaction points" in the LRT lines/networks from the different participating countries. Interaction points are the main points of the LRT's infrastructure whose design has to be properly studied in order to guarantee the safety of the system in its interaction with public space. It should be pointed out that the meaning of "interaction point" in this case is wide, including interaction locations but other interaction elements as well, such as signalling and signage.

In relation to the Interaction Points identification, the first main conclusion is the need to study separately the stations/stops and the rest of the infrastructure (called "between stations"). This distinction is made due to the important differences between those two kinds of zones, both in relation to the operation of the system (low vehicles speed when approaching on line of sight) and to the users'/pedestrians' behaviour whose awareness of the approaching vehicles as they want to board them could be balanced by the need to hurry, the tendency to cross as directly as possible, and visibility restricted by another LRT.

On the other hand, the other street users in "between stations" zones can be less aware of the existence of the LRT system, or, more commonly, of the approaching of a LRT vehicle. This fact can lead to additional different risks in these zones.

Once this distinction between different zones was made, the WG members considered which main users of the streets would conflict with the system. This was a pretty simple question, as obviously every one of the other users of the street - road vehicles, pedestrians and cyclists - is a candidate to conflict with the system. . Finally, a brainstorming was made by the WG3 members in order to identify the interaction points.

Once the interaction points were identified, the next step was the gathering of information about good and bad design examples for these interaction points in the different countries participating in the Action. For this purpose, a template sheet was prepared in such a way that the Working Group members from each country could fill it in with their examples of "stations" or "between stations", in order to have a standardised source of information for the next phases of the Action. This document had to be filled in with indications on the location of the layout in question, the operation mode, the kind of interaction point shown and what other users of the streets are involved in addition to LRT, the urban context and the description of the issue, highlighting the advantages, disadvantages and innovation aspects of the solution, with finally images and plans to illustrate.

In total, 27 examples have been provided for stations and 84 for between stations.

After the compilation of all the examples gathered by the Working Group members, first conclusions have been achieved in relation to good and bad practices for LRT design in interaction with public space. These conclusions are related to the following subjects:

- Stations:
  - Pedestrian pathways at stations.
  - Platform design and stop/station location.
- Between stations:
  - Pavement treatment: on shared channels and on segregated channels.
  - LRT separators on segregated channels: green separators and other kinds of separators.
  - Intersections: left-turn intersections; roundabouts; intersections of general streets with shared channels; pedestrian and cyclists crossings; and specific LRT signalling at intersections.
  - LRT channel differentiation and protection by means of pavement, marks, fences and barriers.
  - OCS (overhead contact system) location of poles.

5 Acknowledgements

5.1 Countries involved

During this COST Action, 34 entities from 15 countries have been involved (new entities were continuously accepted during the whole of Work Phase 1):

- Austria
- Belgium
- Czech Republic
- France
- Germany
- Hungary
- Ireland
- Israel
- Italy
- The Netherlands
- Poland
- Portugal
- Spain
- Switzerland
- United Kingdom
- UITP was also represented

5.2 List of the Action TU1103 participants

COUNTRY	**ENTITY**	**Status**	**Number on the map**
AUSTRIA (Graz)	City of Graz	Local authority	30
BELGIUM (Hasselt)	Hasselt University (IMOB)	Public research institution	1
BELGIUM (Brussels)	Société des Transports Intercommunaux de Bruxelles (STIB)	Tram network operator	28
CZECH REPUBLIC (Prague)	Transport Research Centre (CDV)	Public research institution	2
CZECH REPUBLIC (Olomouc)	Palacky University n Olomouc	Public research institution	3
FRANCE (Lyon)	CERTU	State technical agency	4
FRANCE (Grenoble)	STRMTG	State technical agency	5
FRANCE (Paris)	TRANSAMO	Engineering & transport service operation group	6
FRANCE (Aix en	Cete Méditerranée	Public engineering centre	7

COUNTRY	ENTITY	Status	Number on the map
Provence)			
GERMANY (Stuttgart)	Regierungspräsidium Stuttgart Oberbaurat		8
GERMANY (Stuttgart)	Stuttgarter Strassenbahnen AG	Tram network operator	9
GERMANY (Cologne)	VDV: Verband Deutscher Verkehrsunternehmen	Association of German operators	10
GERMANY (Berlin)	Gesamtverband der Deutschen Versicherungswirtschaft	German Insurance Association	11
HUNGARY (Budapest)	Szent Istvan University	Public research institution	12
IRELAND (Dublin)	Railway Procurement Agency	State agency	13
ISRAEL (Haifa)	4sight, Ergonomics & Safety Ltd	Engineering and design office	34
ITALY (Catania)	University of Catania	Public research institution	14
ITALY (Reggio di Calabria)	Mediterranea University	Public research institution	15
NETHERLANDS (Amersfoot)	ARCADIS	Engineering and design office	16
POLAND (Warsaw)	Road and Bridge Research Institute	Public research institution	17
POLAND (Warsaw)	Warsaw University of Technology	Public research institution	32
POLAND (Warsaw)	Warsaw trams	Public Transport Company	33
PORTUGAL (Lisbon)	CARRIS	Public Transport Company	18
PORTUGAL (Porto)	Metro do Porto SA.	Public Transport Company	19
PORTUGAL (Lisbon)	IMT	State agency	20
SPAIN (Madrid)	Consorcio Regional de	Public Transport Regional	21

COUNTRY	ENTITY	Status	Number on the map
	Transportes de Madrid	Authority	
SPAIN (Barcelona)	Tramvia Metroploia SA	Concessionaire company	22
SPAIN (A Coruna)	University of A Coruña	Public research institution	23
SPAIN (Tenerife)	Metropolitano de Tenerife	Transport service operator	29
SWITZERLAND (Zurich)	ETH Zurich	Public research institution	24
SWITZERLAND (Zurich)	VBZ	Transport service operator	25
UNITED KINDOM (London)	UKTram	pan-industry body for the tramway industry in the UK	26
UNITED KINGDOM (Manchester)	TYC	Consultant	27
(Brussels)	UITP	International Association of Public Transport	31

Table 1 - Members involved in the Action

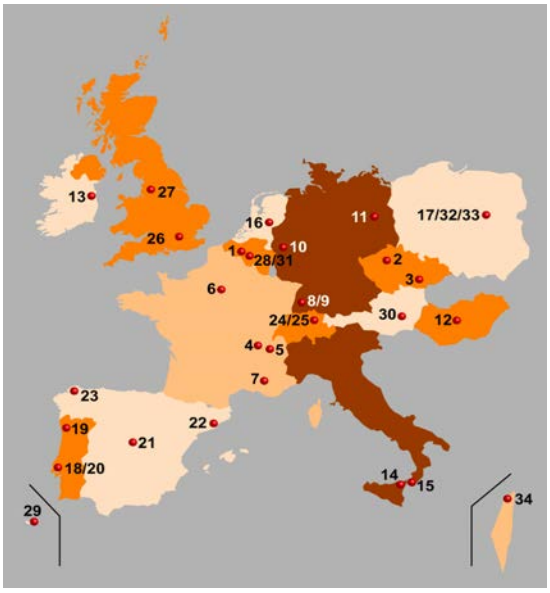


Figure 2 - Countries involved in the Action

6 General background

With networks in more than 150 towns all over Europe, Light Rail Transit (LRT), including trams, is a major tool for managing travel in both large and medium-sized conurbations. LRT sometimes represents a significant market share of Public Transport use,, or an opportunity for increasing the Public Transport share of modal shift, in a context of increasing concern about the use of urban public space.

Over recent years, important developments in LRT systems have taken place throughout Europe, integrated with the strategic sustainability of cities and regions, both by renovating historical networks and creating new lines. This trend continues; rolling stock manufacturers are expecting a growth of about 3.7% for this market during the next few years.

Depending on the history and context of different European countries, there is a high disparity between historical networks (Germany, Switzerland, Poland and some other Eastern countries...) and more recent ones (France, Spain, Portugal...), in terms of institutional context (involved actors, regulations, culture…), organisation of safety and operational monitoring, and technical choices (rolling stock, running conditions, infrastructure...).

Even though Public Transport remains the safest mode, everywhere safety is a hot issue for LRT systems. Accidents are sometimes serious, often spectacular and overexposed in the media. Beyond the direct consequences for victims, safety also has a big impact on the productivity and reliability of transport systems and urban functioning, because when the operation of one part of the LRT is disturbed, the effects are often felt across the whole public transport network. The primary cause of LRT accidents is the conflicts between LRT and other users of public space, in relation with their behaviours and their perception of the risk.

Thus, urban insertion of LRT through infrastructure design and traffic handling is a crucial challenge for both transport authorities and operators.

Moreover, the internationalisation of stakeholders such as transport system operators, rolling stock and equipment manufacturers, engineering consulting firms and enterprises, in a context of a harmonisation of European legislation, is also an important background to the field with which this Action is concerned. It demands a homogeneous approach on behalf of the national or regional institutions, which are the interlocutors of these actors.

This Action has a bottom-up character. Indeed, it consists in exchanging available data and results as well as information on practices and operating methods.. The Action deals with practical aspects of LRT accidents and running conditions, corresponding more to applied research rather than launching a pure research project.

6.1 Scope of the action

As an introduction to our Action’s progress and in order to reach the necessary consensus about our field of discussions, we launched during 1st meeting a debate about the definition of safety and the distinction between safety and security, and identified what we are going to consider as being “Light Rail Transit”, as far as urban insertion is concerned. Here are the conclusions.

What do we understand by safety?

In this Action, we are not talking about security (counter terrorism, vandalism, etc), neither about health hazards due to pollution and similar. Safety deals with the risk related to accidents and injuries, and the precautions taken to reduce this risk.

Tram Vs LRT

In the title of the Action, we use the term "trams" but in the content, we write LRT. So, the main question is, what are we going to consider here as being "Light Rail Transit", in relation with our Action and urban insertion?

The Management Committee has decided that:

1. Our Action will look at urban fully guided public systems running predominantly above the ground;

2. The Action is concerned with all LRT systems - but not with heavy rail or trolleybuses - and with their operation and design insertion within urban, suburban, and mixed zones;

3. More precisely, our scope concerns all fully guided systems, which share public space with road/bike/pedestrian traffic; so we won't deal with metro systems (subways), which are not running on public space neither in crossing roads;

4. The whole tram system, included the infrastructure, is important.

In conclusion, all good ideas or bad experiences should be shared in this Action within these limits.

Collisions, rail/rail accidents & derailments

We have found a consensus to focus on tram interaction with other road users (pedestrians, car drivers, cyclists...) in urban spaces, as planned by our proposal and confirmed in the MoU (Memorandum of understanding).

So we will look at accidents and near-misses when they are recorded, between LRT vehicles and other users of public space.

During the debates, the question arose whether we would include collisions between rail vehicles or with trackside equipment, and derailments… However, for many reasons, we decided not to include these types of incident because:

1. This subject does not only concern LRT; it is wider than trams and LRT, and also concerns heavy rail, subways and metros;

2. We would need to verify if this subject is or has already been treated by other groups (not only from COST);

3. We cannot study collisions between rolling stock and derailments without looking at rail points and the signalling system;

4. Also this item concerns track design or wheel/rail interface;

5. European standards on collision and crash resistance already exist (EN 15 227);

6. Last but not least, main reason is that our Action has been validated by COST Office without this subject; then, we can't change it.

6.2 Objectives

The main objective of the Action is to improve tram and LRT safety, through a better management of their insertion in urban spaces, and therefore to minimize accidents and their impacts on both the transport system and on society.

The Action enables at a European scale a better understanding of problems, solutions, and a shared feedback about:

- LRT safety assessment, through a harmonised approach in order to facilitate comparisons,

- LRT running in various infrastructure configurations, through a shared analysis of advantages, drawbacks and impacts on transport system functioning.

The goal is also to measure the impact of accidents on the system's productivity and to verify if a more expensive investment would allow economies to be made on the future operation. In order to do so, it is also necessary to assess this productivity (the effect on journey times, regularity, time loss due to operation's disruptions, repairing costs and other financial consequences of accidents).

The Action's approach is to gather specialists who represent their profession and country in order to share feedback and to find a harmonised approach to LRT safety in public space. This Action will set up a network of various stakeholders and specialists striving to achieve the following practical outcomes:

- panorama of the institutional organisations,
- harmonisation of data collection on accidents and operations and analysis tools (indicators), keeping in mind to avoid too many complications in their implementation,
- common knowledge on safety issues (problems, levels, impacts, indicators, causes of accidents and incidents),
- assessment of various tools' efficiency (e.g. signage, street furniture), road design and traffic handling methods, regarding safety and operation,
- identification of good practices and innovative configurations for the insertion of LRT into public space, and disseminate these to the whole profession.

The operational objectives of the project are multiple:

- to produce an overview of institutional contexts and regulations about the construction and operation of LRT lines,
- to produce an overview of organisational options in terms of gathering and using data on safety and operation, and to capitalise on feedback from LRT systems,
- to determine a common vocabulary in the field of LRT,

- to create a database of existing reference documents (official texts, technical reference materials, research reports...) in the field of urban insertion of LRT in Europe,
- to establish a shared methodology and analysis criteria for accident data,
- to produce the corresponding safety assessments,
- to highlight the advantages and drawbacks of various configurations and traffic handling methods concerning LRTs,
- to favour the technical exchanges between partners.

The ultimate objective is to make this information available to every authority, operator, road network manager and firm concerned with LRT and its interaction with public space. It will also be very fruitful for research bodies dealing with these topics.

An international network is one of the best ways to get out of a "national" point of view, to open minds to ways of doing/sharing experiences and good practices. The multidisciplinary approach of the project will avoid looking at different situations and issues from only individual perspectives.

Moreover, the Action will enable the integration of stakeholders with different skills and sources of professional enrichment, favouring a global "system" approach in a "bottom-up" way.

Functioning in an organised network favours much more productive exchanges than independent and occasional bilateral contacts. Furthermore, it will allow a saving of time and improvement in efficiency by sharing contacts already established by participants. The objective is to be as exhaustive as possible and to cover all networks in the countries involved in the project. All participants will have useful contributions to make to the project based on their existing knowledge or contacts in other non-participating countries. And a network approach allows us to get more persons and countries associated, while debates concern a common problematic in many countries.

The idea is also to maintain the exchanges after the Action comes to an end, hence the importance of building up a network.

Applications from the Action will be guidelines with good practices, recommendations, leaflets, a website and a forum to expose problems and ask for solutions or ideas, and a database to collect European reference documents.

6.3 Benefits of the Action

The broad benefits will be improvements in LRT safety and reductions in the number and the gravity of accidents between LRT and public space users (pedestrians, car drivers, cyclists...). It will thus take part in improving road safety in general and for vulnerable users in particular.

The Action will more precisely contribute to:

- improve the safety of European LRT networks, through knowing better the causes of accidents,
- bring to light and qualify the link between safety and productivity,

- address the question of “increase in safety vs. increase in costs”,
- decrease the cost of accidents (maintenance / operating),
- contribute to rationalising and optimising the investment of LRT, improving its insertion, its safety and its efficiency and reliability,
- and indirectly to go in the direction of moderating the place of the car in town.

Besides, it will contribute to strengthen European skills and know-how in LRT safety and urban insertion, thus increasing their influence at an international scale in a profitable market.

6.4 The research organisation of the Action

6.4.1 Approach: three main topics

The first important task to be coordinated by the Action is to make an inventory of the current situation of all participants, by identifying the data, information and analysis methods available while highlighting the most useful ones. The knowledge of the state of the art is imperative. It is often attractive to transpose configurations and modes of operation, but before every layout’s modification, it is necessary to be able to estimate them and compare them, hence the interest in common indicators and in methods and tools of follow-up being harmonised (without being necessarily standardised). The comparison of data and results requires premises in terms of definitions, modes of data collection, and treatment processes.

This state of the art has been bound by the common definition of LRT and safety.

The second important task is to analyse all the data provided in the first phase, by highlighting weaknesses and strengths, and by emphasizing the interface between LRT accidents and the use of urban space. It consists in defining comparable or common descriptive criteria and typologies, for safety assessment and for the analysis of track layout configurations. Then, the analysis of collected information and data will be carried out according to the operational objectives detailed earlier.

A third task to note is that a set of recommendations for data collection, analysis methods, regulation evolution, design specifications, and research fields would be very useful. It will be an extension of the previous task, by producing practical results (conclusions on analysis, highlighting of good practices, recommendations…).

These three topics will correspond to the first three Work Phases (WP) of the work plan while a fourth Work Phase deals with the dissemination aspects:

- WP1: state of the art and context exploration;
- WP2: comparison / analysis / best practices;
- WP3: proposals and recommendations;
- WP4: dissemination aspects

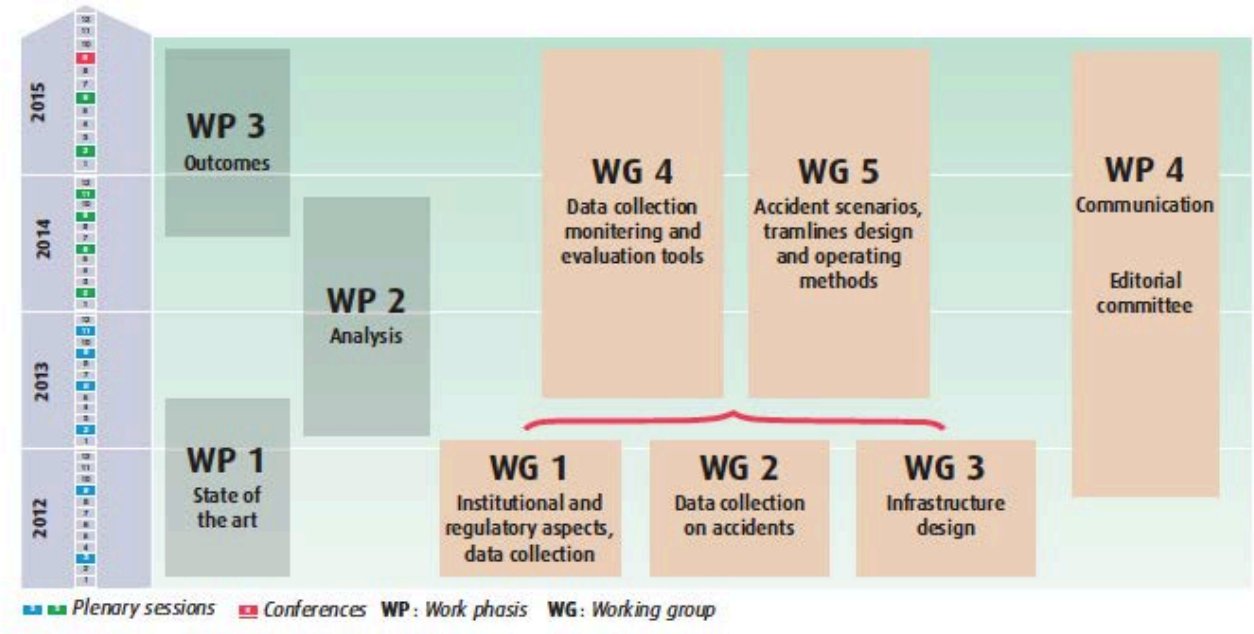


Figure 2 – TU1103 four years organisation

The first three work phases should follow on consecutively, while the last one will occur throughout the duration of the whole Action.

6.4.2 WP1: state of the art and context exploration

Gathering together many countries has made it possible to establish a large inventory and to integrate many different points of view in a future objective of harmonisation. At this stage, the work has been based on information made available by members, existing research and studies (among them those from research organisations and accident survey agencies). The Action has had to respect confidential questions and intellectual property rights; however the basis of this WP1 is the sharing of enough pertinent information.

A methodology has been set up and improved according to each member's context in order to produce an effective inventory about:

- existing rules about LRT's running and integration into public space, and how these are applied in practice (organisational and legal aspects, standard practices, etc.),
- ways, methodologies and difficulties for data collection,
- assessment tools,
- analysis of accidents and analysis of LRT's running conditions, used to assess the impacts of accidents on operation and productivity,
- infrastructure design and operating methods,

- results in terms of safety and its impact on level of service (commercial speed, regularity, operating loss, number of users concerned...).

To do this, working groups were constituted about the following topics, gathering the different points mentioned above:

- Institutional and regulatory aspects and data collection (at the state level): a framework has been built up, to harmonise the presentation of the state of the art in various countries and to facilitate the compilation of information. Each country gave its own information but the working group did the work of collating and synthesis.. The information covered the legal basis and the technical requirements for LRT systems, operational, control and supervision practices, as well as operational measures aimed at increasing safety and users' awareness, social and cultural issues.

- Data collection on accidents (at the national and local level): tools and mechanisms for data collection and processing, criteria of analysis, indicators, results. Beyond the data themselves, there has been a focus on the monitoring tools, to identify their limitations and possible future avenues for improving feedback; this is related to organisation and the key players involved as well as to the type and form of the data and information to be collected.

- Infrastructure design: just as for accidents, the Action has focused both on practical aspects (existing configurations, running handling, signage and operational performance) on the basis of examples, and on the tools (guidelines, regulation...). The working group has particularly highlighted the innovative aspects of this field.

At the end of this Phase, this first deliverable has been produced to capitalise the state of the art, according to the objectives:

- The overview of organisational context, stakeholders and tools dealing with LRT's safety,

- The information database.

6.4.3 WP2: comparison / analysis / best practices

In this Phase, a particular attention will be paid to the causes of accidents and efforts will be made to identify the configurations that:

- Pose recurrent problems in terms of operation or safety, on intermediate sections as well as at intersections and stations,

- Correspond to sections of line that perform well and/or have no accidents,

- Are innovative in terms of design.

To achieve this second work phase, it will be appropriate to reconstruct the working groups in a way in line with the objectives. So, during the WP2, there will be two Working Groups dealing with:

- Data collection, monitoring and evaluation tools,

- Accident scenarios, track layout design and operating methods.

This work phase will not result in publishable deliverables; they will rather be integrated in working documents useful for the following phase.

6.4.4 WP3: prospects and recommendations

The detailed content of the WP3 depends on the WP2's work and reflections. So the Management Committee will have to set it up at the right moment, but results, good practices and best examples should be gathered in deliverables. Some recommendations should be formulated, so that they can be adapted for use by each of the interested countries. These will relate both to safety and operational monitoring systems and to good practices for infrastructure design and LRT running.

In addition the Action will attempt to see the recommendations input into guidance and regulations, hence alleviating the number of accidents in the urban environment.

This third work phase will be a continuation of the second one, the same working groups will be continued to achieve these tasks on the two topics identified for WP2.

7 Working phase 1 outcomes - Institutional and regulatory aspects, data collection (Working Group 1)

The main objective of WG1 during the investigation of the state of the art was to form an overview on national key points for each country, to identify the regulations concerning trams and to establish a common vocabulary.

7.1 Introduction of the working group's results

This working group has focused on four main questions:

- How to give a quick global overview for each country in a few pages? Can we then have a European overview?
- What are the regulations in each country related to trams?
- Is the same thing meant by the different terms in different countries, the same idea beyond an English word, since it is the native language for only two of the 14 countries?
- What are the existing studies on trams, especially related to their urban insertion?

7.2 The data collection method

Since the amount of information to gather is important, Working Group 1 has:

- Implemented a frame for the regulations at: national, regional and operational level
- Defined four groups of questions for the global view: networks in the country, main regulation and its philosophy, the different actors and the main issues concerning tram and its urban insertion.

The methodology for both points has consisted of: proposing a frame, giving examples and using them as tests, making improvements based on these first tests, discussing results and improving the frame, validating the frame, then validating the final contents and having them checked by all, and finally, analysing the contents to identify obvious general issues and conclusions.

The bibliography and synthesis are principally a gathering of information as a list of documents or answers. The synthesis is completed by an analysis.

7.3 Overview of organisational context, stakeholders and tools dealing with LRT's safety

7.3.1 Objectives

The aim of WG1 was that "*A framework will be built up, to harmonise the presentation of the state of the art of various countries and facilitate the compilation of information.* Each country should give its own information but the working group will do the work of collating and synthesis.*These will concern the legal*

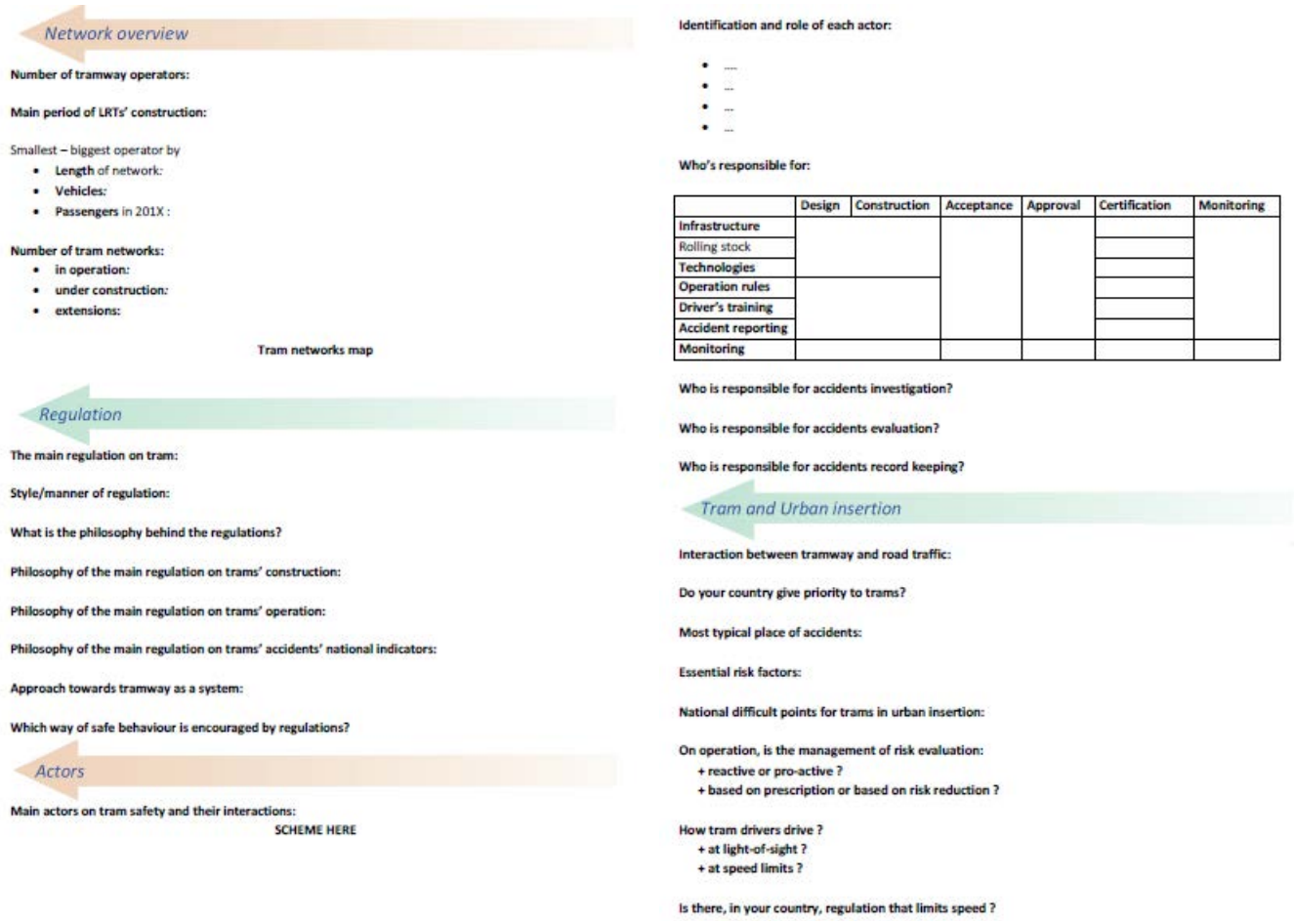
basis and the technical requirements for LRT systems, operational, control and supervision practices, as well as operational measures aimed at increasing safety and users' awareness, social and cultural issues." [MoU]

So, first of all, exploration has been concerned with setting out a global view for each country participating to the Action. For this purpose, a template sheet was prepared in such a way that the Working Group members from each country could fill it in with core and summary information on its tram systems and their urban insertion, in order to get a quick and global overview per country.

This has been achieved by each representative answering few questions, on:

- Networks
- Main tram regulation
- Actors
- Tram and urban insertion

Then, to analyse all these data, all answers for each question have been collected and compared, trying to identify if there are common points or not on these general topics. Global views are available on request to our webmaster.



Network overview

Number of tramway operators:

Main period of LRTs' construction:

Smallest – biggest operator by
- **Length** of network:
- **Vehicles:**
- **Passengers** in 201X :

Number of tram networks:
- **in operation:**
- **under construction:**
- **extensions:**

Tram networks map

Regulation

The main regulation on tram:

Style/manner of regulation:

What is the philosophy behind the regulations?

Philosophy of the main regulation on trams' construction:

Philosophy of the main regulation on trams' operation:

Philosophy of the main regulation on trams' accidents' national indicators:

Approach towards tramway as a system:

Which way of safe behaviour is encouraged by regulations?

Actors

Main actors on tram safety and their interactions:

SCHEME HERE

Identification and role of each actor:
- ---
- ---
- ---
- ---

Who's responsible for:

	Design	Construction	Acceptance	Approval	Certification	Monitoring
Infrastructure						
Rolling stock						
Technologies						
Operation rules						
Driver's training						
Accident reporting						
Monitoring						

Who is responsible for accidents investigation?

Who is responsible for accidents evaluation?

Who is responsible for accidents record keeping?

Tram and Urban insertion

Interaction between tramway and road traffic:

Do your country give priority to trams?

Most typical place of accidents:

Essential risk factors:

National difficult points for trams in urban insertion:

On operation, is the management of risk evaluation:
+ reactive or pro-active ?
+ based on prescription or based on risk reduction ?

How tram drivers drive ?
+ at light-of-sight ?
+ at speed limits ?

Is there, in your country, regulation that limits speed ?

Figure 3 - Global view frame

7.3.2 Synthesis and analysis

From all the global views and data collected, we assemble here n overall view of the context of European tram and urban insertion safety. Among these numerous presentations on tram overviews, some similarities and differences have been observed.

It is important to note that this analysis was done with only partial data on four countries: Austria, Belgium, Hungary and Israel. In fact, these four countries joined the project later. They have provided information during the synthesis and analysis phases, and when this is complete it will be integrated into a later version of this document. Nevertheless, the quality of the results is not decreased due to this reason, since substantial information on eleven countries was available for making the study.

General figures

New tramway systems and lines are spreading all over Europe. After a period of gradual closure of this technology on their urban PT networks, LRT systems are now growing with new vehicles and technology and existing ones are being extended in most medium and big cities of the EU. Germany has the greatest number with 58 operators and more than 20 extensions in progress, and Ireland the least with two tram lines in Dublin. France has known the highest expansion of new lines during the last decade. This diversity can be explained by national technological traditions, local and national politics, the roles of various players, the image of tram systems and policies towards sustainable mobility.

- **Main period of construction of LRT systems**

5 countries have LRT built at the beginning of the twentieth century, with new lines being added in two of them during the last decades. Nine countries have built LRTs during the last 30 years but most countries have re-discovered this mode of public transport.

- **Number of tramway operators**

There are 144 operators in the 11 participating countries. A high disparity in the number of tram networks in each country can be observed (Germany has the greatest number with 58 operators, and Ireland one in Dublin). The highest progression during the last decade has been in France.

- **Number of tram networks in operation**

In total, 141 networks are in operation in the studied countries, with the following distribution:

- Germany (58)
- France (21)
- Poland (14)
- …
- versus Ireland (1)

The following figures illustrate these data (excluding some countries for which data were not available, and incuding
some countries not particpating in the Action):

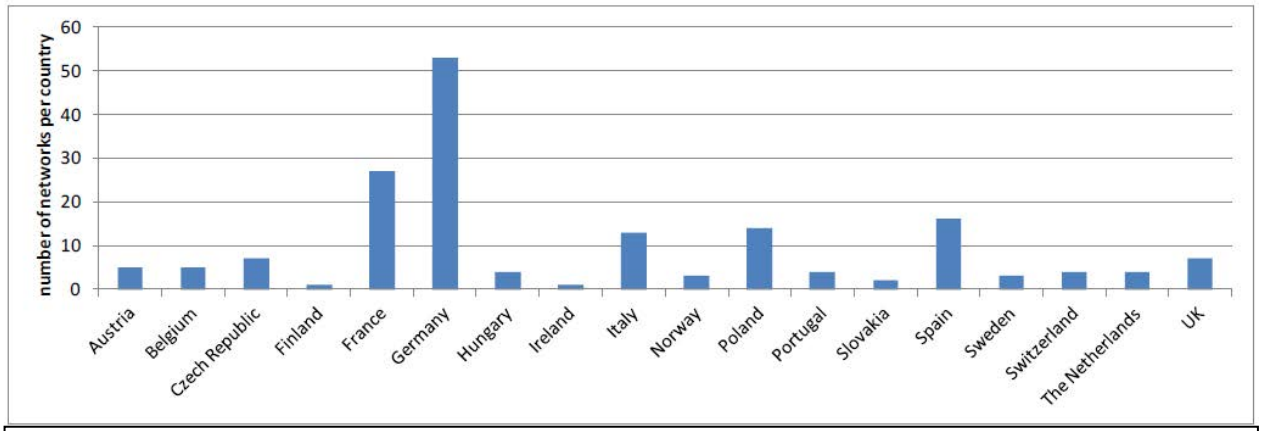


Figure 4 - Number of networks in 18 European countries

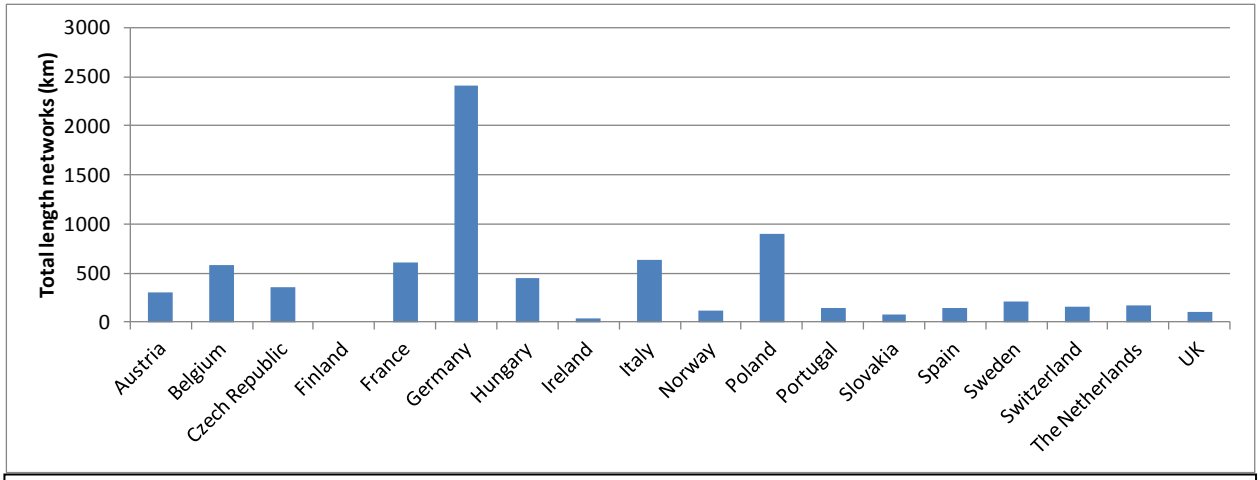


Figure 5 –Total length of the networks in 15 European countries

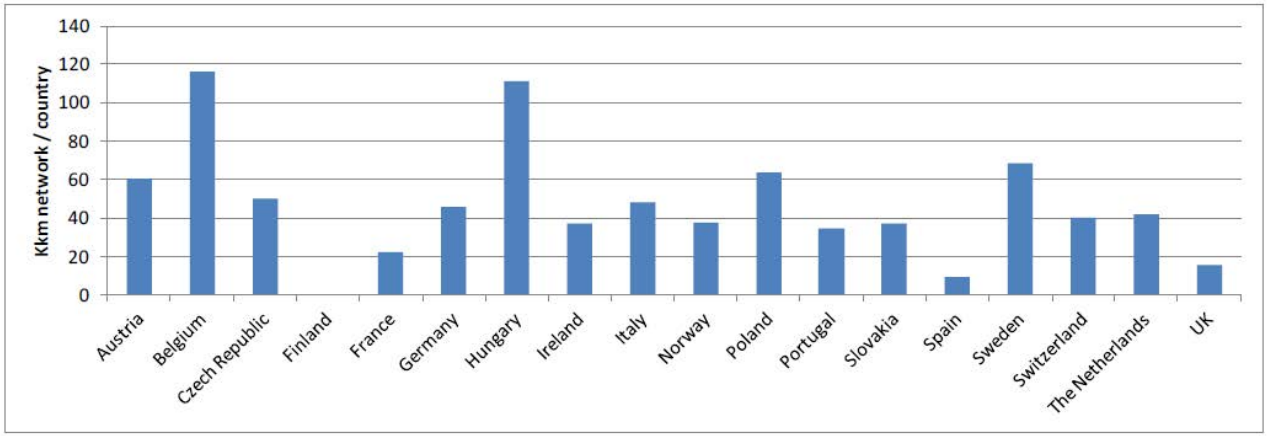


Figure 6 – Average length of the network in 15 European countries

A look at the graphs reveals that Germany and France - the biggest countries in Europe - have the highest number of networks, but the networks are relatively small, on average between 20 and 30 kilometres.

Belgium and Hungary on the other hand only have respectively 5 and 4 networks, but each network has a lot of kilometres: Belgium has on average 116 kilometres per network and Hungary 111.

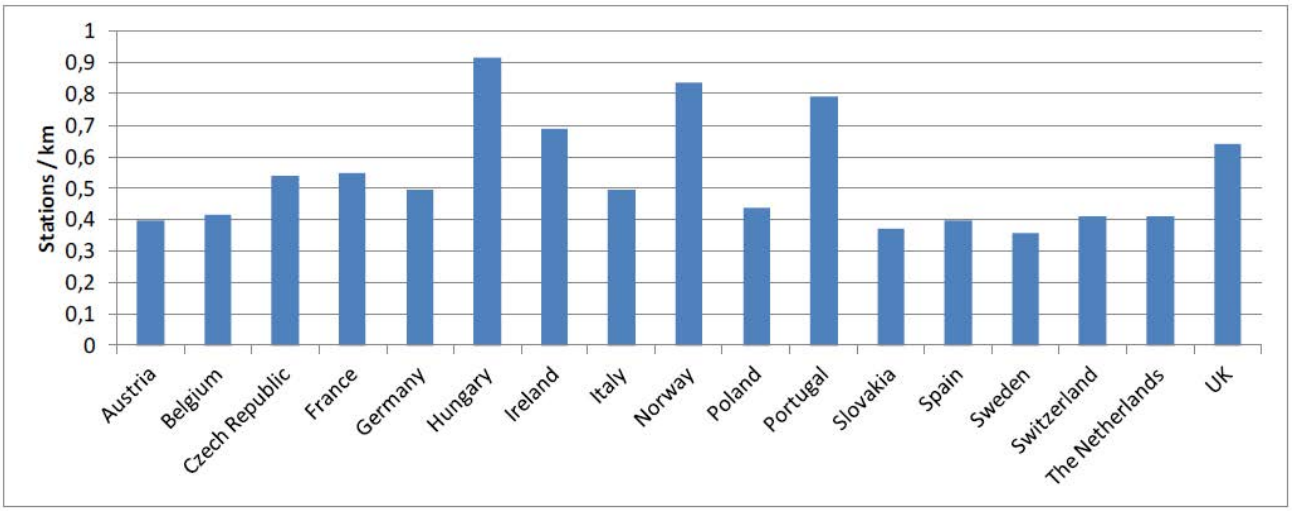


Figure 7 -Number of stations per km network in 15 European countries

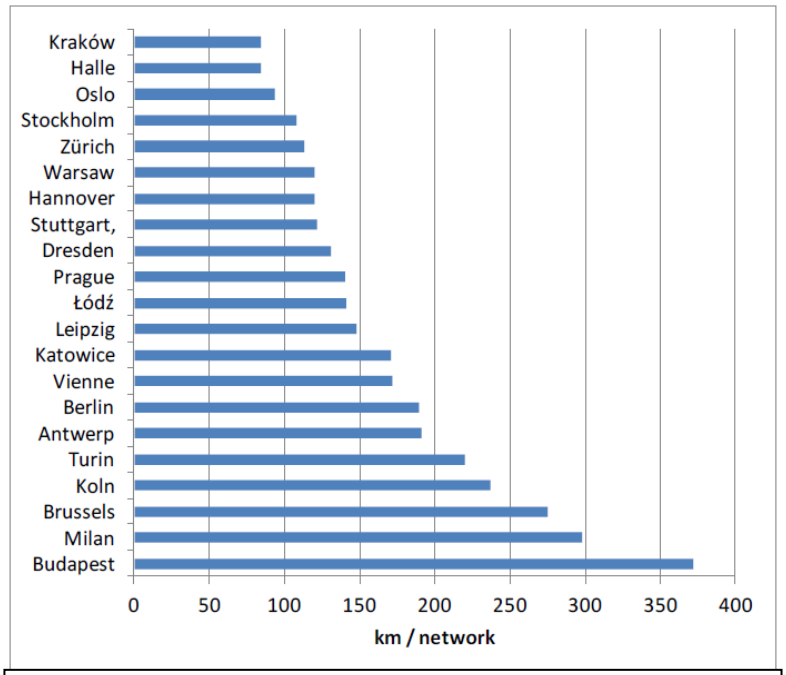


Figure 8 - Top 20 largest networks in Europe

- **Number of tram networks under construction**

7 countries (63%) have networks under construction:

- France has the highest number with 7 networks under construction
- Then, 2 networks under construction (DE + PL)
- 1 network (IT+NL+UK+PT)
- or no network under construction (CZ+CH+IRL+ES)

- **Number of tram networks in extension**

Nine countries are constructing extensions to their tram networks; Germany has more than 20 extensions in progress andFrance and Italy follow with 7 and 6 extensions.

- **General conclusion on European tram networks**

After a period of gradual closure of this mode of urban public transport, new LRT systems are now being constructed and existing ones extended in most medium and big cities of the EU. This sample illustrates how important are the tram systems for cities and countries.

The average is thirteen networks per country, but there is a wide variation. Germany has the most tram networks on its territory (58). However, the countries with the oldest trams do not have the largest networks. The construction of new lines has generally stopped, except in France (7 networks under construction). France presents the highest number of newly built lines and constructions.

Many parameters can explain this diversity:differences in historical context, local and national politics, roles of various players, image of tram systems, sustainable politics…

In last 30 years, most countries have suuported tram networks, not only by improving the PT performance-based system but also by creating more conditions with sustainable cities. This strategical vision becomes a permanent challenge when the integration of transportation systems with urban planning is concerned or when the urban rehabilitation becomes a sustainable strategy with trams on segregated Rights of Way.

The main tramway regulations: style/manner of regulation

- **The main regulation on tram**

The synthesis for the studied countries is as follows:

- 4 railway regulations including trams (IT+UK+IRL+CH)
- 2 follow road laws + railway laws (CZ+PL)
- 2 tram dedicated regulations (DE+FR)
- 1 old regulation (NDL)
- 1 European standardization (PT)
- 1 regional regulations (ES)

- **Style/manner of regulation**

The synthesis for the studied countries is as follows:

- 5 functional regulations concerning safety (=defining safety objectives without defining the means to obtain them)(CH+DE+FR+PT+UK)
- 5 technical guides or standards (IRL+UK+CZ+IT+PL). Onecountry has no national specific guidelines for trams as they are specified at the regional level (ES)
- 1 country is in the process of changing its regulation (NDL)

Tram regulations differ widely across the analysed countries. Some countries have adapted road traffic engineering rules to make them appropriate for a rail-based mode, and vice-versa. So, only a few countries have national regulations specifically made for trams, most of them using a mix of more general railway and road regulations, which also include the tramway system. This depends on particular technical choices, local know-how and habits that have been accumulating across many decades of history of this old transit system.

Regarding the style of regulations, some countries have laws on safety or financial aspects. There is no unique way of managing LRT/tram safety in Europe: at national level, countries have either a functional regulation on LRT safety, or technical guidelines or standards. Some have chosen to define safety objectives without specifying the means to achieve them. This last point provides freedom for innovation and experimentation. Indeed, there are many technical guides dedicated to operators and manufacturers, but sometimes there is no obligation to comply. Operators can offer a different approach, but in return, they must demonstrate that their proposal is effective.

Returning in more detail to these regulatory issues, the diagram below illustrates the organisation between different levels of regulation from the main Act or law to the application by the operator.

The "Main Act" is generally a parliamentary law or a decree. This law is often broad in scope, being not only for trams, but also for other modes of rail or road transportation.

The majority of countries participating in of the Action use a hierarchical approach as illustrated in the diagram below. However, there are differences between countries. For example, in France the "Main Text" is a text at the national level, whereas Spanish texts are regional (one main text for each region).

The elements of this scheme are distinct. There are obligations (the rules which the operator must comply with), and guidance or guidelines. Guidance is a recommended way of complying with the law, but the operator is not obliged to comply with it. It can develop its own system if it is able to demonstrate that it meets the safety objectives. Technical guidelines are a way to achieve it, but their recommendations are neither exhaustive nor compulsory. This is an interesting approach because it enables operators and manufacturers to innovate, allowing them to develop systems that can be even safer or with other technical solutions than those recommended by technical guidelines. Five countries of the Action operate on this principle.

Last but not least, there is a level of European regulation. UITP has produced a document on trams, entitled "Urban Rail Platform: Fundamental Requirements for Urban rail systems". It has the status of "standards for voluntary use". So, it is not mandatory but is a guideline for networks that want to use it as a recommended basic reference. It is intended to serve as recommendations for Competent Authorities responsible for design, construction, operation and maintenance of urban rail systems.

What is the philosophy behind the regulations?

The synthesis for the countries studied is as follows:

- 5 Authorisation for construction by government (DE+CH+FR+IRL+IT)
- 1 Authorisation for construction approved/prepared by local or regional authorities (ES)
- 2 Respect standards (IT+CZ)
- 2 Economic planning (PL+NDL)
- 1 asks the operator to ensure safety by consulting an Independent Competent Person (UK)

All countries have rules to construct a safe LRT and operate it safely. In most cases the location and the alignment of a new line is the result of the interaction between the tram operator and the local authority. A design approval is needed to demonstrate that safety requirements are met, particularly for innovative systems. And all new projects are subject to a form of control from a higher authority. These authorities may be different at geographical or administrative levels from one country to another.

The criteria are always to guarantee a safe system but economic aspects may enter in the philosophy and take into account the needs of efficiency, optimising this safety system management. The philosophy of the main regulation on tramway construction helps to ensure that technological and traffic engineering criteria do not override safety and reliability considerations**.**

Philosophy of the main regulation on tram's operation

Tram operation has various philosophies:

- safe operation (ES+PT+UK+NDL+IT)
- safety operation management (UK+FR+IR+CH+CZ+DE)
- with controls (IT+FR+DE+CH+UK)
- economics philosophy (PL)

Safe operation and safety operation management are closely related but mean different concepts: the first refers to the responsibility for the operator to operate safely and the second expresses a way to achieve this aim.

Once the transport service is authorized, a safe operation is mostly based on the responsibility of the operator and on the quality of its internal regulations and procedures. Some countries require the introduction of a Safety Management System to proactively reduce the risk of accidents, while others rely on a reactive approach based on the investigation of individual accidents to develop a corrective action plan. These considerations are based more on the experience of the members of the Working Group 1 than on a systematic collection of accident data, taken from the results of WG2.

The question is: depending on regulations, can we compare safety results? Is there a link between the number of accidents and the philosophy behind the regulations? The conclusion of the Action is that there is no such link. First of all, there are too many parameters. Besides, a regulation belongs to a history, a context and a process, whereas this Action is a comparison to find out how European countries are organised and what they have in common.

Approach towards tramways as a system

The approach towards tramways as a system varies:

- 4 Global systems (IT+FR+DE+UK)
- 2 Global/sub-systems (CZ+CH)
- 2 No clear approach (NDL+PT)

The prevalent style of regulation is functional, in the sense that it concerns the performance of the overall tramway system, though many technical details about some components can be found in relevant technical standards and norms.

The complexity of urban and suburban systems requires special attention towards the technological innovation and improvement that can be introduced in all PT networks. It requires the development of new disciplines integrated with safety support systems. Tramway operation is more delicate to integrate in urban space, where it interacts with public space with or without rules and where the special requirements of a tramway are in conflict with the historical urban environment which is not adapted to receive this surface system. This is why tram operational conditions and their regulatory regimes are found to be so different.

Which way of safe behaviour is encouraged by regulations?

5 countries say the safe behaviour encouraged by their regulation(s) is to improve the existing safety level of the system (FR+ES+IRL+PT+UK). A distinction is made between existing and new technologies. Regulations aim to improve safety and minimize accidents by preventive means and operators are responsible for safe operation. Each operator is responsible for the safety of its infrastructure.

The European fundamental requirements encourage global safety objectives in operation, control and maintenance.

Actors

There are different actors involved in operation and in the design of the system, and more indirect ones. Obviously, tram operators, local or regional transport authorities and representatives of the Transport Supervisory Authority are always involved. Constructors as rolling stock manufacturers or construction companies, and also project infrastructure managers are involved at the project stage. Street traffic authorities and independent safety assessors are also sometimes included. More indirectly, research bodies, police, insurance companies, as well as politicians (national, regional and local) can participate throughout the life of the tramway.

When an accident occurs, operators and investigation agencies are directly concerned. Depending on the country, police participate in the enforcement and recording of traffic incidents.

Transport Supervisory Authorities can have different names, belong to different Ministries (Transport, Industry, Infrastructure…), play different roles (economic evaluation, planning, environmental objectives).

Accidents

- **Who is responsible for accident investigation?**

- 7 = the operator (IT+DE+UK+IR+CZ+FR+NDL)
- 4 = Investigation or control office (CZ+FR+PT+UK+IR)
- 1 = Local police (ES)
- All three bodies are involved in 3 countries (DE+FR+NDL)

Concerning the investigation of accidents, three main actors are involved: operators, police and investigative control offices. In some countries, all three are led to investigate the same accident. But in others, the distribution is different. In all cases, operators are primarily involved in investigating accidents. This seems logical since they must ensure the safety of their network. Then, investigative offices are also often present. Their presence is legitimate in the sense that they are agencies of the State and they must ensure the proper functioning and quality of its public services on behalf of the public.

- **Who is responsible for accident evaluation?**

    - 5 = the operator (IT+DE+FR+ES+NDL)
    - 6 = Investigation or control office (IT+DE+CZ+FR+PT+UK)
    - 2 = Police headquarters (PL+CZ)

Operators and investigative agencies engage principally in this task. Depending on the country, police can also evaluate accidents. The goal is to identify potential malfunction in order to avoid it in future. This assessment can be the source of new rules (laws, standards...). In any case, the aim is to improve the safety of the tram network.

- **Who is responsible for keeping accident records?**

- 9 = the operator (DE+CZ+FR+ES+PT+UK+CH+NDL+IR)
- 6 = Police (CZ+PL+ES+PT+UK+CH)
- 6 = Investigation or control office (IT+DE+FR+PT+UK+CH)

The three actors are generally also involved with each other. In some countries like Portugal and Switzerland, data are collected both by the operator, the police and the Bureau of Investigation. In France, the police are not involved.

a) **Conclusion on accident investigation/evaluation/record keeping responsibilities**

Several entities and several framework regulations are found in the countries analysed. The operator is involved in all three phases, but it is not the only actor concerned: other second or third points of view exist, depending of the severity of the accident (investigation/control, police) and evaluation and record keeping are mostly in the responsibility of the control offices. But the operator always has a responsibility all along the accident data process.

Actors can have different concerns in investigating: to handle physical damage, to find human causes and effects, to identify those responsible for the accident.

National indicators for tram accidents

All operators collect statistics to compile their indicators. 7 countries have harmonised their set of indicators at a national level and make statistical “reports” (IT+DE+CHE+PL+IR+UK+FR), generally with data provided by operators, and 5 indicate that these reports have to be transmitted to their national safety authority (IT+CH+FR+IR). The remaining four countries have no national indicators because their legislation does not ask for it (CZ+NDL+PT+ES), some because their regulation is predominantly at the regional level and others because tramway legislation is very old and does not provide for national indicators. The information about the indicators used by country can be consulted in the WG2 section.

In most cases there is a general obligation to provide accident data to a control office, but there is no required minimum set of indicators for monitoring system safety.

The philosophy of the main regulation on national indicators on tram accidents tends to be not only to produce a technical report but also to provide a tool that can help the legislator to improve the safety of the operation of each system. Moreover, each technical sub-system of infrastructure or equipment is evaluated according safety criteria.

Generally there are no national databases for accident collection and analysis (except in France) and the approach is reactive, relying on a reactive approach based on the investigation of individual accidents to develop a corrective action plan, except in cases where there is a Safety Management System (e.g. UK + IRL) to proactively reduce the risk of accidents,. The minimum seems to be that operators need to comply with some form of risk-based approach, reactive and/or pro-active, realised in their own set of rules and management of safety.

A question can be raised: is a national vision of accidents necessary to improve tram safety at local and national level?

Tram Priority

Priority is not given to trams in the same way in each country. Globally, 5 countries have legislation giving top priority to trams,and 6 other countries provide only a partial priority as far as legislation is concerned. In Spain, for example, some trams must comply with the Highway Code. However, even if the legislation does not give absolute priority, some tramways get it in practice. This is the case in the UK, which gives priority to trams through markings and signs.. Hence, where "priority" is concerned, it is necessary to distinguish between " priority through legislation" and "priority in practice".

Some reservations exist in relation to the conclusions on this point. The question asked in the questionnaire was: "Does your country give priority to trams?". Partners responded in legal terms. In other words, they mostly described what the law says in their country. However, as shown in the response of the United Kingdom, although in theory trams do not have automatic priority, in practice they normally do have it. Maybe the information gathered (on “priority in practice”) is incomplete. A new question should ask: “Does your country give absolute priority to trams? What about in practice?”

The wide diversity of answers might indicate that the tramway system requires a shared regulation. At least, a deeper investigation and better understanding should be required.

Tram priority is a concept that needs to be clarified and there is a debate on “absolute priority” to be held. The question should be “How does it work when there is neither road signal nor signs, or when in a degraded situation?”.

A reading of the main regulations on tram construction and operation shows that regulations have developed in an uneven way, resulting in different interpretations of the functions and responsibilities of the organsisations involved in a PT network. However, despite this variation, safety requirements ensure that the system generally perfoms well. This resilience derives from the fact that whenever an urban or suburban transport system interacts with the built environment, special attention is paid to all aspects of traffic engineering. In this context, central and local authorities agree on, or are conscious of, the advantages of a well=performing PT system and generally accord the tram system a suitable level of priority.

Interaction between tramway and road traffic

Trams usually have their own traffic signals or signs, mainly based on a road regulation.

In the case of PT networks, the operation of a tram network in an urban space is more sensitive than a surface light rail system, because it is in conflict with historical or unplanned spaces which are unprepared to receive a new technological surface system. Therefore, we find many different tram operating conditions, and so different policies by regulatory authorities in spite of their common preoccupation with safety and reliability rules.

Some details are given here on priority: some countries give absolute priority to trams, and road users must give way to trams. In other countries (perhaps the majority), trams do not have a general priority but often have priority at junctions indicated by signs or signals.

The request was not precise enough and should be reformulated:

- What rules are used to organize the interaction between trams and traffic?
- How it works in practice?

To go further on this issue, the “Theory of shared space”, by Hans Monderman, Dutch engineer, should be studied, and the WG3 results should be exploited.

The Most typical place of accidents

The most typical places of accidents quoted by WG1 members are:

- 9: Intersections/Crossroads (IT+DE+CH+FR+NDL+PL+UK+IRL+ES)
- 3: Turn-left movements with tram in the back (IT+CZ+FR)
- 3: Pedestrian crossing (IT+CH+PL)
- 1: Road junctions where sightlines are restricted (UK)
- 1: Mixed traffic areas (PT)
- 1: Visibility (UK)
- 1: Buses and taxis (PT)

- 1: Tram stations (ES)
- 1: Unprotected crossings (not protected in any way with barriers or traffic lights, so only right-of-way rules apply) (CH)

There are a lot of types of accidents; the big variety is linked to the different locations where tramway and traffic interact, to the degree of track segregation (fully segregated, partially segregated or in mixed traffic), and to the speed of operation. There is no typical accident though the majority of them are obviously connected to intersections. The most typical place of conflict is a turn-left movement with tram in the back, which is separately identified. Cars are the vehicles most implicated in collisions with trams. Pedestrian crossings are also an issue.

Other problems are encountered: lack of attention from other street users, speed, restricted sightline/visibility, traffic jams… Accidents tend to happen because road vehicle drivers are not aware of the presence of a tram or do not treat it with sufficient respect recognising its longer stopping distance or different path. Whatever the regulation, whatever different solutions, all countries face these problems.

But, if many problems are common from one country to another, some seem to be specific to a particular country. For example, Spain has problems at the station stops. For these cases, we must ask why, and why other countries do not meet them.

National difficult points for trams in urban insertion

The difficult points for tramways in urban insertion as quoted by members are:

- 6: Management of the pedestrian crossing (IT+DE+FR+IRL+PT+ES)
- 5: Mixed zones (CH+FR+NDL+UK+PT)
- 4: Visibility between tram and other road users (IT+DE+FR+PT)
- 3: Road geometry (UK+CZ+PT)
- 2: Respect for Signals (FR+IRL)
- 2: narrow streets (CZ+ES)
- 1: Not sufficient priority for tram (PL)

Despite the diversity of situations in all the countries, it should be noticed that the difficulty of insertion of tramways in urban areas is mainly because of the presence of other road users.

Road designers need to recognise how a tramway fits into the urban environment and design roads and junctions accordingly, not simply superimpose a tramway on a junction which has already been designed.

Some particular points can be observed: the three countries which have kept the majority of their trams from the beginning of the twentieth century, have identified the same difficult points on narrow streets and lack of space for exclusive LRT lanes.

One common main difficulty is the management of pedestrians. Pedestrian behaviour is problematic and causes accidents with trams: distractions due to mobile phone use, jaywalking... Pedestrian management is a key issue in urban insertion because it exceeds the scientific and technical point of view, involving actors that all generate different situations.

A second major challenge is the interaction between the tram and other road users in mixed areas. It is certainly related to visibility problems, linked to the notion of understanding constrained spaces. Some sites

are difficult to grasp: eccentric geometry, complex signalling... In fact, users may find it difficult to understand how the site works; this sometimes causes accidents.

7.3.3 Conclusion on Global views

Each of these global views allows the reader to understand better the history, projects, regulations, interactions with urban spaces, accidents, difficult points regarding LRT in each country. But they also allow the identification of common points and issues.
New tramway systems and lines are spreading all over Europe. There is a wide variety of regulations across the countries and the need for a higher degree of understanding of the safety management of tramway system is emerging, as urban mobility and transport safety are relevant issues of European transport policy.
Design regulations are functional, and consider the system as a whole, but many components are regulated by technical standards. Construction and operation are largely affected by urban design and by the operator's experience.
Safety management is mostly based on a reactive approach to reduce the frequency of undesired recurring events in black spots of the networks. Accident data are collected by the operator, but there is no established practice to manage and analyse them in a national database according to common safety indicators, except in one country.
We cannot conclude that there is a need for a higher degree of standardisation. The state of the art has identified many differences between tramway regulations in different countries and these reflect the different conditions and different road regulations. It would be a difficult job to standardise. The aim should be to get the same level of safety, but the method for achieving it is a matter for each country.

The objectives were the expected ones; even though some countries have not yet provided information on some important issues about their country legislation,the objectives have been achieved in that important information has been gathered about the State of the Art on regulation framework and about the main characteristics of urban design and safety conditions applied on tramway construction and operation.

Some important findings can also be collected through direct information and meetings. Through observing specific case studies (Bordeaux, Stuttgart, Dublin, Berlin) different aspects on tramwayconstruction and operation and philosophy in safety management, the different levels on urban insertion on design and safety conditions can be better understood. The illustrated glossary and the information gathered about the existent legislation from the group have met the aims.

7.4 Regulations

One of the Action's objectives is to identify progress and to improve methodological tools, road signals and identification of regulations. Will it be possible? Can one type of regulation be recommended?

In this state of the art presentation on institutional and regulatory aspects, all known regulations (laws, codes, guidelines, decrees…) dealing with trams and also with urban insertion have been gathered, in order to understand better what exists in each country (no global overview was available). This has still to be gathered into a single database and published on the public pages to all.

Moreover, the knowledge of the statutory context is imperative, to avoid too simplistic comparisons and hasty transpositions of configurations or operational methods for the next Work Phases 2 and 3.

So, exploration has concerned the legal and the technical frameworks of LRT systems, and a complete list of regulations concerning tramway systems has been collected for EU level and for each country. All these regulations have been gathered in a single spreadsheet for each participating country:

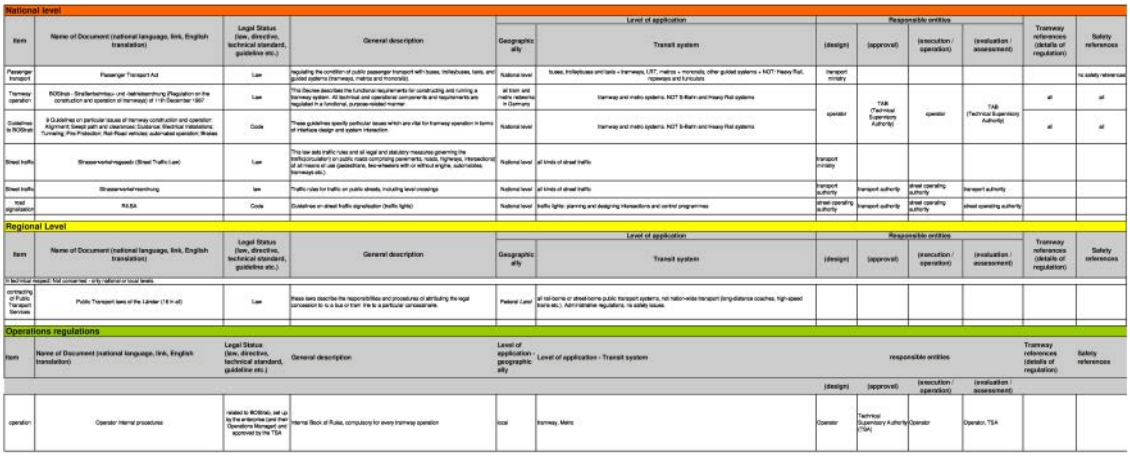


Figure 3 - Example of regulation frame filled in

Synthesis and analysis

There is a wide variety of regulations across the countries. Regarding tramway systems, in the majority of the cases, there is no single code, which collects all the laws concerning the tramway sector, but there are rather interpretations of the laws regarding railway and road sectors. On the contrary, the system components often have norms based on national technical standards, sometimes from European norms, which apply to LRT. Some of them are related to railway statistics and safety management, but most of them concern technical aspects (rolling stock, power supply, track).

All countries have:

- National regulations (for trams, for railways and/or for road)
- Local operational rules

Some as Spain, Switzerland and Germany, have additional and detailed regional level regulations.

- **National level regulation:**
  - Each country has regulations, of varying types
  - Law is a high level of regulation: could it be preferable to make a risk analysis and make the operator responsible?
  - But it is difficult to make a synthesis, and more difficult to make any comparison and evaluation
  - For common recommendations, a document already exists: see the Fundamental Requirements from UITP

- **Regional level regulation:**
  - On specific items (funding, operation, concessions)
  - Or specific Railway Acts (definitions, design, priority, maintenance)

- **Operational regulations:**
  - None, other than at the operator's initiative
  - Or it is goal-setting regulation which sets out what must be achieved without detailing how to achieve it

Furthermore, writing only internal regulations will lead to a practical and very applicable framework, where public risks however ,may not be considered sufficiently. Therefore, the minimum seems to be that operators need to comply with some form of risk based approach, reactive and/or pro-active, realised in their own ruleset and management of safety.

Conclusion

There is a wide variety of regulations across the countries. Regarding tramway systems, in the majority of the cases, there is no single code which collects all the laws concerning the tramway sector, but there are interpretations of the laws regarding railway and road sectors. The system components, on the other hand, often have norms based on national technical standards. However, Germany, UK and France have specific regulations for trams and deal with safety management. A good recommendation to interested readers of this document is to consult and get some knowledge from these regulations if they want to create a specific one or to do some Benchmarking.

However, the design is regulated by national laws, while the operation is in general is regulated by local laws or operator's rules.

It is difficult to make a synthesis from all these regulations, and more difficult to make any comparison and evaluation, as juristic specialists would be necessary to identify common points and philosophy. Moreover, to understand why there are different regulations, the story for each country has to be known, as well as the role of each actor and political aspects, political constraints, needs, consequences of critical accidents. Besides it does not seem possible to make meaningful correlations between the type of regulations and accident occurrences. Nor is it possible to make global conclusions or recommendations on which regulation is the best; this is not the aim of this Action. The huge differences among the regulatory frame of each country can be pointed out as one of the main conclusions of this exploration: there is a wide range in the manner and level of regulation and standardization of each country. However, the main common points observed cover five countries: Germany, Switzerland, UK and France, since they have each a specific regulation for tramways and their safety management. As urban public transport is a strategic issue of European transport policy, it seems that the same level of safety should be the aim. Nevertheless the way to achieve it is still today a matter for each country: the conclusion is that there is no need for a higher degree of standardisation - and this Action does not aim at standardising.

7.5 Conclusion on WG1 results

An overview on the institutional and regulatory aspects of the tramway system has been provided for the countries joining the Action. It was not easy to provide a systematic representation of the regulations collected for each country, but some general considerations are given on design, operation and accident management procedures.

This state of the art on institutional and regulatory aspects, and data collection (at the state level) is means of preparing the next phase of comparison / analysis / best practices and then, recommendations. The working group has done a work of collation and synthesis of the data given by each participating country through the members of the WG.

The result permits us to formulate clearly which risks could be mitigated by a public component (laws and public assessments), and which risks could be mitigated (or alas not) by the internal rules of operators. One must however realize that the link between public operators and the legislative authorities is much closer than the link between private operators and authorities.

8 Working phase 1 outcomes - Data collection on accidents (Working Group 2)

8.1 Introduction

This part of Work phase 1 report is a synthesis of the detailed report of WG2 activities, which was set up mainly for internal use during the next steps of our Action. Detailed elements for each country involved in the Action are gathered in this full report, which is available on demand.

Some information is given here about the organisational aspects and functioning of the working group, with some comments about methods used to proceed in various assigned tasks.

Then follows a summary of what we may consider as being the WG2 results; it concerns the global matter of collecting and use of data and information related to tram safety in interaction with public space, with a focus on indicators.

Afterwards some key-points are highlighted, even if this Work Phase 1 was limited to a review, while deep analysis should occur in Work Phase 2.

Finally, a few pending questions, which have come out from the debates are pointed out, as they are possible items to be treated in the next phase of the Action dedicated to analysis of gathered materials.

8.2 WG2 organisational matters

8.2.1 Objectives of the working group

According to the MoU (Memorandum of Understanding) of the Action, Working Group 2 was set up to deal with accident data during the first phase.

More precisely, WG2's topics were intended to be data collection on accidents, both at national and local level:

- tools and mechanisms for data collection and processing,
- criteria of analysis,
- indicators,
- results.

Beyond the data themselves, it was planned to focus on the monitoring tools, with the idea of identifying their limitations and possible future avenues for improving feedback. To achieve this, the main aspects to be considered were organizational issues and the key players involved, as well as types and forms of data and information being collected in various countries involved in the Action.

However, there has been a consensus in the group that the first subject to focus on is the tools and mechanisms of information collection, and not the gathering of data, and then not to search for these data in

this work phase 1 of "context exploration". Moreover, it soon became obvious that gathering accident data on a large scale would not be possible through this Action.

In the meantime, there has been a large consensus inside the group not only to consider information on accidents, as it appeared rather obvious that other information regarding tramways is useful - and used – to deal with safety issues.

So information about other elements has been searched, such as:

- emergency braking, and more generally near-misses,
- additional information on running conditions and the behaviour of third-parties.

As a result, beside accident data and reporting other information had to be taken into account, such as:

- video recording,
- occurrence books, …

Regarding accidents, qualitative approaches as well as statistical ones have been considered.

8.2.2 Method of working and tools

In common with the other Working Groups, Working group 2 was launched with a few partners, and more and more partners were gathered till the end of Work phase 1. Finally, only 2 – Austria and Hungary - of the 14 countries involved in the Action were not directly involved in WG2, while one (Belgium) joined during the last meeting in Berlin.

Several facts may be identified regarding organisation and means:

- a varying number of participants in and between meetings, some of them joining (very) late,
- some difficulties in gathering information in the way that was decided (respect of guideline, report contents and table form of tables),
- some very heterogeneous contexts and actors in various countries,
- difficulty in getting information and data (in particular figures regarding accidents)

An initial idea was to build and use a questionnaire; however this was not easy to arrange, since a description of different organization and facts in various countries was needed. Then some countries (France, Ireland) began to gather information in order to facilitate the setting up of the WG2 tool.

Rather than a formal questionnaire, an internal guideline was drawn up for general description of safety data processing in countries. This was completed by a table to gather indicators about tram safety, as the decision was to focus on statistical accident data.

8.3 Synthetic overview of gathered information

8.3.1 Available information from partners

Countries	General description	Indicators table	Data available?	Comments
Austria	No	Yes	No	Indicators for Vienna
Belgium	Yes (*)	No	No	* short answers to a questionnaire based on guideline contents
Czech Republic	Yes	Yes	No	
France	Yes	Yes	No	
Germany	Yes (*)	Yes	No	* not exactly according to the guideline's table of contents
Hungary	Yes (*)	No	No	* not exactly according to the guideline's table of contents
Ireland	Yes	No	No	
Italy	Yes	Yes	No	
Netherlands	Yes (*)	Yes	Yes	* not exactly according with the guideline's table of contents
Poland	Yes	Yes (*)	No	*Indicators for Warsaw
Portugal	No	Yes	No	
Spain	Yes	Yes	Yes	
Switzerland	Yes	Yes	No	
United Kingdom	Yes	No	Yes	

Table 2 – Available information from partners

8.3.2 Actors and organisation of safety data management

Detailed information about this item can be found in WG1's report. The information contained here for each country is the actors directly involved in tram safety assessment through accident monitoring and management of data, particularly at a national, federal or regional level.

In all countries, operators essentially are the main providers and users of accident data and other information regarding tram safety. On the other hand, the situation is rather mixed regarding the involvement of national agencies or other entities such as police, hospitals and insurance companies.

Belgium

Five tram networks are currently operated by 3 companies. There is no common standardized process about tram safety and accident data at national level.

Czech Republic

Nine tram networks are currently operated. At national level, tram safety is within the authority of the Rail Safety Inspection Office, which has 5 branches in the country.

Trams are taken into account in road traffic accident data collected by the Police.

France

At the beginning of Year 2012, 21 tramway networks were operating in France.

Since 2001, STRMTG is the State agency dealing with safety of urban guided transport and cableways and other mechanical lifts at national level. At a regional level, It is organized in 4 control offices, also in charge of supervision of cableways, metros and guided bus systems; a standardized process for safety monitoring has been implemented.

A permanent working groups with representatives of tramways operators has been set up by STRMTG to think in a collaborative way and facilitate sharing of information and data.

Trams are partly taken into account in road traffic accident data and reporting gathered by Police.

Germany

Due to the federal organization of the country, which hosts 58 tram networks, technical supervisory authorities are located at regional level (one in each of the 16 States).

The main provider of standardized tram accident data is the Police, through adatabase and reporting of road traffic accidents.

Other data are available from the operators' internal reporting systems, while a statutory insurance firm – VBG for tram operators – manages its own accident database.

Hungary

There are 4 tram networks in Hungarian cities.

The railway department of the Transport Safety Bureau (TSB), an independent entity supervised by the Ministry of National Development, has been in charge of tram safety monitoring since 2006.

Ireland

There is only 1 tram network (LUAS), in Dublin. The RPA (Railway Procurement Agency) is an independent commercial statutory body mandated to deliver new light railway infrastructure and are the asset owners of the LUAS infrastructure and rolling stock. The RPA make contractual arrangements for other railway undertaking(s)/Railway Organisation(s) to operate the Luas and maintain the infrastructure and rolling stock.

The Railway Safety Commission (RSC) is the independent regulatory agency charged with oversight of the safety of all railway activities in Ireland. The Railway Accident Investigation Unit (RAIU) is the independent rail accident investigation unit in Ireland. It is responsible for the investigation of accidents or incidents on the Luas, the national and heritage railways.

Italy

There are 12 tram networks in operation in Italy, where the Ministry of Infrastructures and Transportation (MIT) is officially in charge of tram safety for guided transport. At this point, it is not really involved in accidents data and safety assessment process.

At a regional level, MIT has 5 local divisions in charge of supervision of public transport systems –including tramways - and releasing authorizations.

Netherlands

Five tram networks are in operation.

The Railway Safety Authority is only responsible for tram safety for "interlocal lines", outside city boundaries, so urban tramway safety falls within the authority of regional or local governments.

Poland

There are currently 14 tram networks in operation.

The Police Headquarters are responsible for road traffic accident assessment, including tram accidents.

Portugal

Four tram networks are in operation in 3 cities.

Safety monitoring is by the Mobilty & Transportation Tnstitute (IMT), a supervisory body set up inside the Portuguese Ministry of Economy and Labour, but no information is available.

Spain

There are 14 tram networks in operation.

No supervisory authority has been identified, neither at national nor regional level.

However, all Spanish tramway operators are involved in a Working Group of Alamys (the Association of Latin American Subways and Suburbans) about Light Rail and tramways.

Switzerland

Four tram networks are currently operated by 6 operators.

At a national level 3 actors can be identified:

- The Federal Office of Transport (FOT) is closely involved in public transport safety assessment and accident monitoring, including tram accidents.
- The Swiss Accident Investigation Board (SAIB) deals with serious accidents.

- The Federal Roads Office (FEDRO) manages a road accident database including tram accidents, fed from local or cantonal police data collections.

United Kingdom

There are 6 networks currently in operation.

There is no supervisory authority regarding tram safety at a national or regional level; the Rail Accident Investigation Branch (RAIB) may gather some information on trams running off-highways or railways sections, but not systematically.

When running on highways, trams accidents are recorded as road traffic accidents by Police, but only for fatal or injury accidents.

8.3.3 Process and tools for accidents monitoring

The main points are:

- statistical database and accidents reporting from operators,
- other tram accident data,
- emergency braking recording,
- other sources like occurrence books and automatic parameter recorders ("*black boxes*"),
- video systems.

Statistical tram accident database (from operators)

Belgium

There is no national database; 2 companies (De Lijn and MIVB) manage their own database (no information available for the 3rd company).

Czech Republic

Each of the nine transport companies operating tramways collects data for its own purposes according to its own standards. There is no universally standardized database at the national or regional level.

France

STRMTG (a national State office) is in charge of management of a national database, gathering and processing data recorded by all tramway operators. It produces yearly statistics at a national level, and main results are available in annual reports on STRMTG´s website.

At a local level tramway operators gather and use data regarding their own tramlines (and at an intermediate level for all networks belonging to the same group (i.e. Keolis or Transdev). In general, they work at local level on two bases, one for insurance and one for safety issues.

Germany

Each tramway operator has got its own internal reporting system for accidents, but these are not standardized. In Germany only the general road traffic accident data have been standardized and gathered nationwide by the German Federal Statistical Office.

Hungary

There is a national database managed by the Transport Safety Bureau (TSB), gathering data regarding only serious accidents; in the meantime operators maintain [or are developing] their own databases.

Ireland

There is presently only one network in this country. Both the Operator and the Rail Procurement Agency maintain a database fed by the operator reporting on all accidents and incidents.

Italy

Operators' data on accidents are periodically transmitted by companies to the General Direction of the Transport Ministry. However, the data received so far have not been yet used for any statistical analysis at national level.

Spain

Spain does not have unique national system which gathers together tramway accidents, so there is no national database. Each tramway system has its own way of collecting, processing, analyzing and reporting accident data at a local level.

However, all Spanish operators are involved in the Light Rail Working Group of Alamys (the Association of Latin American subways and suburbans), where data referring to safety as well as to operation and maintenance are shared.

Poland

Each tramway operator has its own internal reporting system for accidents, but methods differ from one to another. There is no database, neither at national nor regional level.

Switzerland

Operators manage their own databases at a local level, but these are not standardized. However, the Federal Office of Transport (FOT) manages a national database (NEDB) fed with operators' entries, and publishes a yearly report on safety in public transport. The incidents that have to be reported to the FOT implicitly form a common minimal standard for all operators' databases.

United Kingdom

There is no national accident database for tram or LRT systems. Operators are responsible for collecting data on their own network, but it is not standardized and generally remains confidential to the operator.

Tram accident reporting from Operators

Belgium

In addition to statistical data, 2 operators produce a report on each accident for internal use (no information available for the 3rd company).

Czech Republic

Operators have to send a report on emergencies to the Rail Safety Inspection Office. Emergencies may include longer delays than those indicated on information boards, injured passengers, road obstacles, and tram damage.

France

In addition to statistical data, operators produce a report on each accident.

In case of a serious accident, they must send a specific report to the State representative and to STRMTG. Definition of a serious event and content of this report are defined by a guideline produced by STRMTG.

Moreover, operators have to produce annual reports on operation and safety on their network, forwarded via the PT authority to State administration and STRMTG.

Hungary

According to the law, operators have to make a report and forward it to the Transport Safety Bureau (TSB), for serious accidents (there is a precise definition of what should be considered as a serious accident).

Germany

Operators have to report serious incidents to the technical supervisory authority (one in each State). There is no complete standardization of reports at the federal level. A harmonization of basic accidents data is done by the police, using nationwide a standardized traffic accident report.

Ireland

Reports on all aspects of their contract including safety are forwarded by operator to the Railway Procurement Agency and when required to the Railway Safety Commission and/or the Railway Accident Investigation Unit. The RAIU investigates all serious accidents, and may investigate some others which could have been serious.

Italy

No specific reporting on accidents outside internal data collection by operators.

Netherlands

No reporting about accidents outside operators' databases.

Poland

PT operators publish yearly reports based on their data analysis.

Moreover, they have to forward to the Chamber of Public Transport an annual summary of key operational and economic indicators, including main safety figures (number of victims).

Spain

No reporting about accidents outside operators databases.

Switzerland

Operators report most types of accidents to the Federal Office of Transport FOT via the NEDB-database. In case of serious incidents or accidents, the same report also has to be submitted to the Swiss Accident Investigation Board (SAIB).

United Kingdom

No specific reporting on accidents outside internal data collection by operators.

Other tram accident data

This mainly concerns data and accident reporting from Police, which generally takes into account tram accidents as far as they occur on public roads. But information is often not so precise, and tram accidents represent a very small proportion of all accidents.

Apart from Germany and Poland, this is not considered as a relevant source of data for statistical or general studies. Regarding this fact, it may be related to the number of tram networks (58) and kilometres run (245 millions in 2011) in Germany, compared with other countries (from 1 network in Ireland to 14 in Poland). However, Police reports may be helpful for local studies, together with operators' internal report systems.

Insurance companies have their own databases, but these are generally only for internal use and not accessible.

8.3.4 Other tools and reporting (apart from accidents)

Emergency braking reporting

Emergency braking has been identified as an important item to deal with. When it does not lead to a passenger accident inside the tram (in which case it should be recorded as an accident), it may be considered as an indicator of a near-miss.,. However, some Action participants consider this is not so relevant, as dangerous spots are usually well known by drivers and operator staff.

A first issue might be to agree a definition of emergency braking, as it can be used in different ways. Rolling stock is generally equipped with two types of devices, sometimes both called "emergency brakes", as well as the use of maximum service braking by drivers.

Then, whatever is considered as an emergency braking, there are two means for reporting it:

- automatic parameter recorders
- occurrence books / warnings by driver to Control Centre

Both ways are more or less used in various countries, depending on the existence of automatic recorders and on their technical possibilities.

This can be summarized in the following table:

Countries	Occurrence book	Comments	Black box	Comments
Austria	?		?	
Belgium (MIVB only)	No		No	No recording apart from accidents
Czech Republic	No		No	
France	Yes		Yes	
Germany	No		No	No recording apart from accidents
Hungary	Yes*	*In case of injured passengers	Yes	
Ireland	Yes		Yes	Recorded (nb, causes, …)
Italy	No		No	
Netherlands	?		?	
Poland	?		?	
Portugal	?		?	
Spain	Yes	Most networks	Yes	A few networks
Switzerland	No		Yes	Not used unless an event occurs
United Kingdom	?		?	

Table 3 – Emergency braking recording

Occurrence books

During the Action's discussion, events other than accidents and operational incidents were pointed out as relevant to deal with safety. So it was decided to try to get information about the way they are monitored through "occurrence books".

However, things are sometimes not so clear, as the definitions of “incidents” or “events” recorded in this tool may have been misunderstood.

Countries	Paper	Computerized	Involved in database	Comments
Austria	?	?	?	
Belgium	Yes	Yes *	Yes*	used for statistics * in case of accidents
Czech Republic	Yes	No	Yes	
France	Yes	Sometimes	No	rather a “warning” tool
Germany		Yes	Yes (ITCS)	
Hungary	?	?	?	
Ireland		Yes	Yes (TED)	Through radio system
Italy				
Netherlands	?	?	?	
Poland	Yes	?	No	
Portugal				
Spain	Yes	No	No	For maintenance issues
Switzerland	No	Yes	Yes	Not standardized
United Kingdom	No	Yes	No	Not standardized

Table 4 – Occurrence book use

Automatic operation parameter recorders ("black boxes")

Even if situations vary from one country to another, this tool is nearly used everywhere; this is sometimes compulsory, and data are rather homogeneous even if not standardized at national level.

Data from "tachographs" or "black boxes" are particularly used to complete (and sometimes verify) drivers' statements in case of accidents.

Countries	All trams	In some trams	data involved in accidents database	Comments
Austria	?	?	?	
Belgium	No	Yes (new generation)	No	Used in case of accidents
Czech Republic	Yes		Yes	"Tachographs"
France	Yes		Yes	Compulsory (standardized parameters)
Germany	Yes			
Hungary	Yes		No	
Ireland	Yes		Yes	
Italy	No	No	No	
Netherlands	?	?	?	
Poland	Yes ?		No	Used in case of legal proceedings
Portugal	?	?	?	
Spain	Yes		Yes	Parameters depending on rolling stock manufacturer
Switzerland	Yes		?	Compulsory
United Kingdom	?	?	?	

Table 5 – Black box use

Video resources

An attempt has been made to distinguish CCTV systems whenever they are installed outside or inside trams, and in the second case by their type of scope (public space in front of tram or interior of vehicles).

Situations are mixed among countries, among networks in a same country and even among vehicles in a network. Implementation of such systems is not so easy in old vehicles.

For the purpose of the Action, the most interesting is the system dedicated to get pictures from outside the front of the tram, pictures from fixed CCTV on streets or inside interior of tramways can also be helpful to analyse accidents.

Countries	Fixed on public space	Inside vehicles	In front of trams	Comments
Austria	?	?	?	
Belgium	Yes	Yes	No	Recorded (48h)
Czech Republic	No	Yes (not all vehicles)	No	No recording
France	Yes	Yes	Yes (not all networks)	more and more used
Germany	No	Yes	No	Recorded (24 to 72 h)
Hungary	?	No*	Yes	* in test, for security matters
Ireland	Yes	Yes	Yes (all trams)	recorded
Italy	No	No	Yes*	* implemented in Turin and Bergamo
Netherlands	?	?	?	
Poland	?	Yes*	Yes*	* new trams & some older ones
Portugal	?	?	?	
Spain	Yes (*)	Yes	No?	* >90% line coverage recorded (4 days – 2 years)
Switzerland	?	Yes	rare	
United Kingdom	Yes	Yes	Yes (not all vehicles)	

Table 6 – CCTV use

8.4 About indicators

Data are available at national level in France, Hungary, Ireland, Switzerland and Poland.

For Czech Republic, Portugal and Switzerland, the Action has gathered some examples from one or two operator(s).

For France, Italy, Poland and Spain, the Action has gathered the synthesis of groups of operators. In France, the Keolis group tries to homogenize operators' practices.

Regarding indicators, no major difference appears between the national level and the individual operators. Each column filled by one country or one operator counts 21 indicators in average.

Two countries record more indicators (Ireland with 40 indicators and Czech Republic with 45 indicators). The operator in Porto (Portugal) only uses 8 indicators.

Beyond indicators, the aim was to capture what data are used to build the indicators. In some countries, some raw data themselves are used such as indicators.

Then indicators have been classified in 4 types:

- global indicators,
- geographical indicators,
- typological indicators
- and economic indicators.

8.4.1 Data

Some definitions are quite similar from one country to another:

- the number of events often includes all the events that may occur on tramway network. Some differences appear in the level of severity of damages,
- Fatalities = persons dying within 30 days after the accident (this is the OECD definition),
- Victims = fatalities + seriously injured + slightly injured,
- Passenger = person travelling in the tram (or waiting at a stop).

In some cases, definitions may be different:

- the types of events –often distinguish collision with a third party, passenger accident, derailment, impact against obstacle,
- seriously injured: often considered as persons hospitalised more than 1 day (OECD definition), but in Czech Republic, the incapacity to work is also used.

Globally, all the countries use the number of events such as indicators at a national or individual level. France and Portugal do not use the remaining data as indicators, nor Spain as far as victims are concerned.

Here are the main "data used as an indicator":

- number of events (total): used in 6 countries and by some operators in 2 others (France, Portugal),
- number of events (by types of events): used in 7 countries – not in Portugal and France,
- number of fatalities: used in 5 countries – not in Portugal and France,
- number of seriously injured people: used in 5 countries – not in Portugal and France,
- number of slightly injured people: used in 4 countries – not in Portugal, France and Czech Republic,
- number of victims: used in Ireland, Poland and Czech Republic and by some operators in Switzerland, Italy and France,
- number of victims (passengers): used in Ireland, Poland and Czech Republic and by some operators in Switzerland, Italy and France,
- number of victims (3rd parties): used in Ireland and Czech Republic and by some operators in Switzerland and France.

8.4.2 Global indicators

Some countries add some indicators only used by this country. So they have not been taken into account in the comparison.

The indicators the most used are:

- **events per km run** (used in 8 countries: Czech Republic, France, Hungary, Italy, Ireland, Portugal, Spain, Switzerland),

  Even if the definition of the "km run" is not really clear, the differences between definitions are not essential.

  For example, in Czech Republic, Portugal, Ireland and Spain, it is all km run by vehicle, even those inside the depot or when running without passengers towards the terminus.

- **collisions per km run** (5 countries – not in Switzerland and Spain).

  But Portuguese operators take into account collisions between 2 tram vehicles.

- **number of accidents divided by number of road junctions** (4 countries – not in Hungary, Italy, Spain, Switzerland),
- **events per passenger-km** (3 countries)

8.4.3 Geographical indicators

The indicators the most used are:

- **Distribution of collisions by type of place** (6 countries - not in Spain nor in Poland),

But the definitions of the types of place are very different from one country to another. For some, it is the distinction between stations, intersections and running sections with several levels of precision. Others only consider major crossings (where the tramway crosses a road or pedestrain crossing) or intersections. Others

determine the type of place as a function of the types of accidents (accidents caused by turning off the road, car drivers failing to stop or jumping the red lights, turn left before tram…).

- several indicators are used by 3 countries (France, Ireland, Czech Republic):
    - distribution of victims of collisions by type of place
    - distribution of collisions with pedestrians by type of place
    - distribution of victims seriously injured in collisions with pedestrians by type of place
    - risk of collision by type of place of collisions
    - risk of victims by type of place of collisions
    - risk of serious collision by type of place of collisions
    - spatial distribution of events

8.4.4 Typological indicators

The most used indicators are:

- **distribution of events by month of year** (7 countries)

  In France, the distribution of events is analysed by time of year. And some other countries analyse the distribution of events by type of day (weekday, weekend) (Portugal, Italy, Switzerland and Czech Republic) or by time of day (Portugal, Ireland, Switzerland and Czech Republic).

- **distribution of collisions by causes** (5 countries – Portugal, France, Italy, Spain, Czech Republic)

  Detail about the causes is not always available to take into account. In France, it is the type of sign or traffic light (stop, R24, R17). (What does this meaN?)

- **relative distribution by type of event** (5 countries – Portugal, France, Italy, Spain, Czech Republic)

  Several definitions for type of event exist but they often distinguish collision with a third party, passenger accident, derailment, impact against obstacle.

- **distribution of collisions by third-parties** (4 countries: France, Ireland, Spain and Czech Republic)

  Third parties are defined as persons other than passengers and tram staff.

8.4.5 Economic indicators

Three countries use cost (rolling stock repair and infrastructure and equipment repair)as an indicator: Portugal, Italy, Czech Republic.

Three countries record the disruption of operation due to accidents: Italy, Spain and Czech Republic.

Two countries analyse the duration of the immobilisation of rolling stock: Portugal and Czech Republic.

8.5 Key points from this state of the art review

As this first step of the Action essentially aimed to gather information in order to prepare analysis to be made in Work phase 2, a final conclusion regarding safety data collection and use in countries involved in the Action has not been achieved yet.

Then some main elements are highlighted that should be researched more particularly during this up-coming phase, in which a working group would be dedicated to safety monitoring tools.

There is a large consensus that the aim of the Action is not to build a European database, nor to compare tramway safety in various countries. However, trying to reach a common language would be useful, while some little differences have been detected regarding definitions (e.g. types of events, emergency braking).

Regarding all data related to events as well as to near-misses or other useful elements, it appears that the main actors for collecting these data are the operators, through the tramway drivers. However, it seems that no standardization exists in most of cases.

On the other hand, many data are collected, but not used as well as might be done, probably to lack of resources (time, money, …), but a question arises about whether some are really useful or not…

Then a first trial for further investigation could be to think about identifying the essential data to be collected and some possible tools to get it in the best conditions.

Regarding statistical accident data, apart from a very few countries (France, Ireland), there is no description of infrastructure, so that statistical use of the data is limited regarding types of configurations. It might be useful for other countries to understand what the advantages of such tools are, but also the means and organisation needed.

A debate was launched about indicators, that some partners consider not so important, as they consider they are not the best way to detect where and why accidents occur.

Then, regarding accident reporting, all partners agree that the most important information is the precise location and scenario of accidents.

During this first phase, the interest in collecting and using information other than accident data has also been highlighted. Most partners agree to consider the location of many near-misses as the place of a potential accident, even if there is no unanimity about that. Then, according to the idea that it is not necessary to wait until an accident happens to solve problems, getting information about this predictive element is something to encourage.

Then reporting of emergency brake applications is an important tool, and ways to improve its efficiency might be investigated.

More other tools like automatic event recorders and CCTV on front of tramways, which are very unevenly used, seem to be relevant as potential sources of progress, and further investigations of the Action might help to implement them.

9 Working phase 1 outcomes - Infrastructure design and running conditions (Working group 3)

9.1 Main Goals

The main objective of WG3 during this WP has been the identification of good and bad practices in LRT infrastructure design in relation to safety of the system in its interaction with public space.

Centring and synthesis on basis of presentation by each country (national and local level) about:

a) Examples of practical aspects (existing configurations, running handling, signage and operational performance) and innovative aspects.

b) Tools (guidelines, regulations).

9.2 Methodology

In order to reach the goals for Working Phase 1 and make a clear state of art of infrastructure design, an approach was developed in 4 steps from general framework to particular details, as follows:.

1. Identification of the existing LRT systems in Europe and understanding of the Infrastructure Conception Process among different countries.
2. Definition of common “Interaction Points” in the LRT lines / networks.
3. Recording of practical examples of Interaction Points.
4. Synthesize the data and prepare inputs for the WP2 - “Analysis”.

The identification of the LRT networks in Europe allows the Action’s members to understand if the cases that are being studied within the working group are sufficiently representative of LRTs across Europe.

At the same time, knowing which are the most common practices of implementation of the LRT projects could open the door to understanding the scale of involvement of urban Insertion experts in projects of this nature, knowing that many of them arrive late in the process to fix some detected problems of urban interaction.

The second and third steps of the methodology were an approach to the operational problems and their solution in the interaction of LRT with the urban dynamics. For that, the research has been structured, identifying the actors that interact with the LRT while it is running, and separating the type of interaction according to the running conditions in station zones and in intermediate sections between stations.

Finally, all the information has been organized and synthesised in a single document, in the hope that it would be a fruitful tool for the next steps in the Action.

9.3 Overview of tram networks in Europe

As the start of the state of the art review, an overview of the LRT networks in Europe and their main characteristics has been made. This overview gives interesting information about the core characteristics of the system, when talking about the interaction of LRT and urban space.

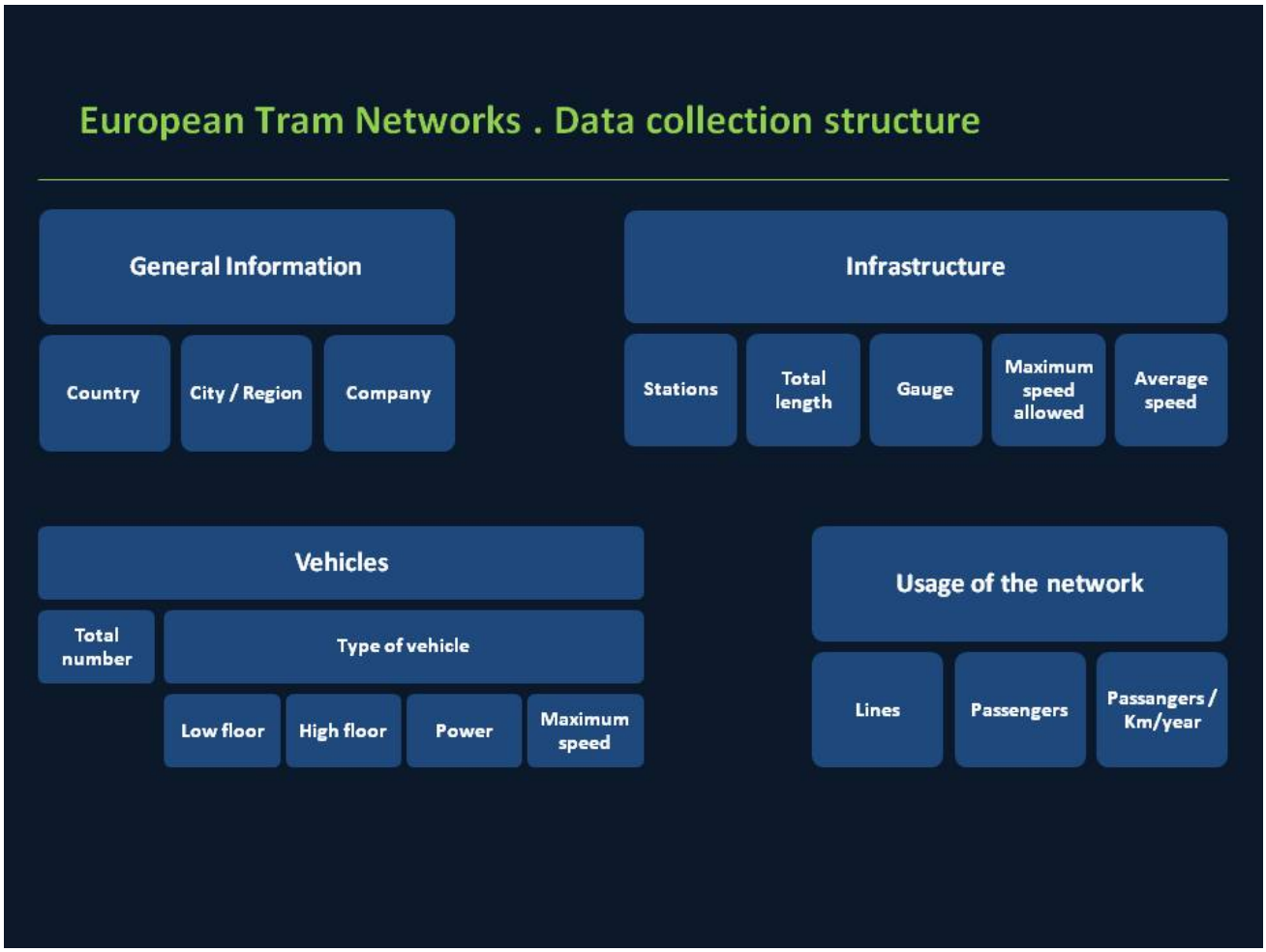


Figure 10 – European tram networks – data collection structure

A. General information about the system

- Entry: Each network gets a code consisting of two letters referring to the country name and a number referring to the network within the country. The same codes, extended with the name of the location, are used for the data collection of the infrastructure examples (see section 9.5.2).
- Country
- City or region: Most networks cross different municipalities. In this column, the main city of the system, or the common name that is used for the system, is entered.
- Company: The name of the company that is responsible for the network.

B. Infrastructure

- Total length (km): The total amount of kilometres of route length in the system.
- Underground: the amount of kilometres underground.
- Surface: the amount of kilometres on surface is divided into the following categories:
    - **Segregated tramway**: corresponds to category B as defined by Vuchic (2007), it is a right of way that is "longitudinally physically separated by curbs, barriers, grade separation, and the like from other traffic but with grade crossings for vehicles and pedestrians, including regular street intersections". So, no bikes, pedestrians or cars are allowed to use the LRT segregated channel.
    - **Mixed zone**: corresponds to category C as defined by Vuchic (2007), representing the use of surface streets with mixed traffic.
    - **Shared space**: LRT vehicles share the lanes with pedestrians and bicycles, but not with cars. This fact leads to the need for limiting the speed of the LRT to guarantee the safety of every user of the street.
- Stations: The number of stations on the network.
- Gauge: The gauge used on the system.
- Maximum speed allowed: The maximum permitted speed on the network, divided for the three types of surface (see above).
- Average speed: The average commercial speed on the network.

C. Vehicles

- Total number: The total number of vehicles operating on the network.
- Type of vehicle
    - **low floor**: Vehicles with at least one section with a low floor allowing level access at stops.
    - **high floor**: Vehicle without a low floor section.
    - **electricity supply**
    - **Maximum speed**: The maximum speed the vehicle is designed for. This can be different from the maximum speed allowed on the network.

D. Usage of the network

- Lines: number of lines that are operating on the whole network which is described.
- Passengers: number of passengers per year on the whole network.
- Passenger-km/year on the network: This number indicates the usage of the network.

9.3.1 LTR networks in Europe: first results

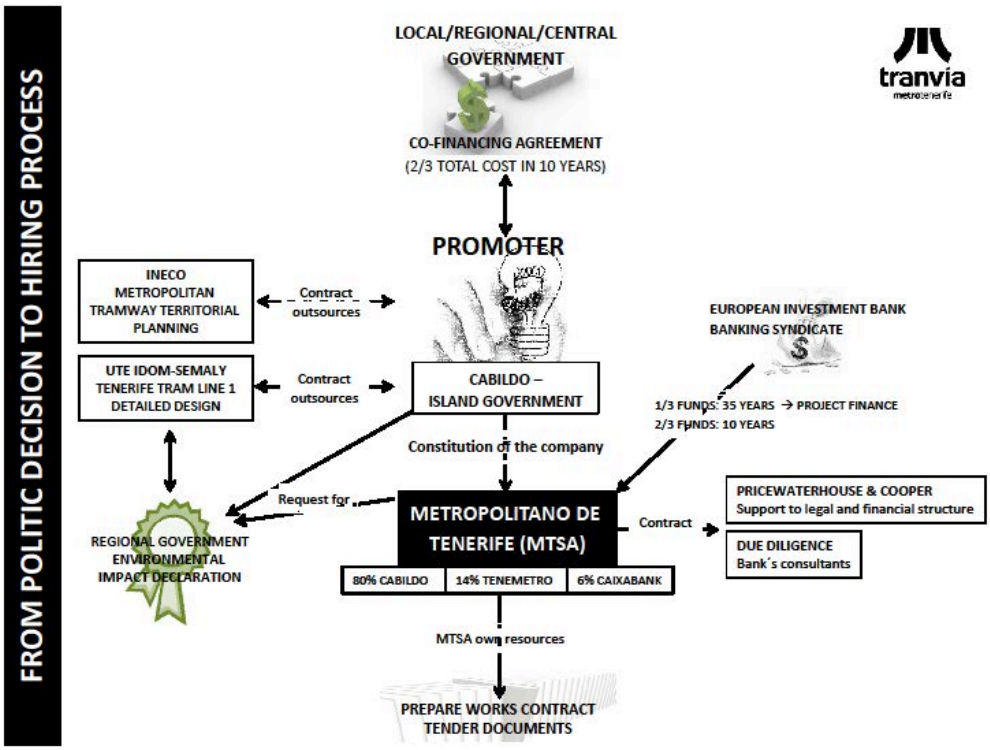
At the moment of writing– June 2013 –information from 18 countries has been gathered. In total there is information about 7345 km of tracks.

The countries with the highest number of networks are France and Germany – also the biggest countries in Europe. A look at the graphs (seen in §7.3.2) reveals that althoughGermany and France have a high number of networks, the networks are relatively small, on average between 20 and 30 kilometres. Belgium and Hungary on the other hand only have respectively 5 and 4 networks, but each network has a lot of kilometres: Belgium has on average 116 kilometres per network and Hungary 111.

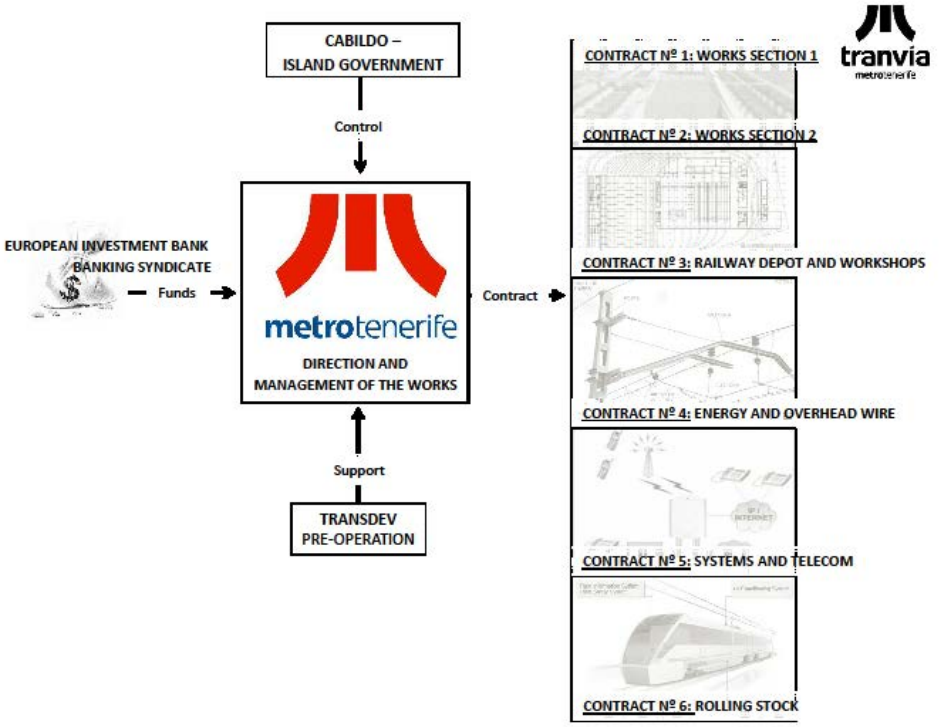
9.4 Developing a network from scratch – some experiences

Also, some research was made into the European practice / culture in the implementation of LRT systems from scratch to construction and operation. Examples from Portugal, Ireland and Spain were gathered.

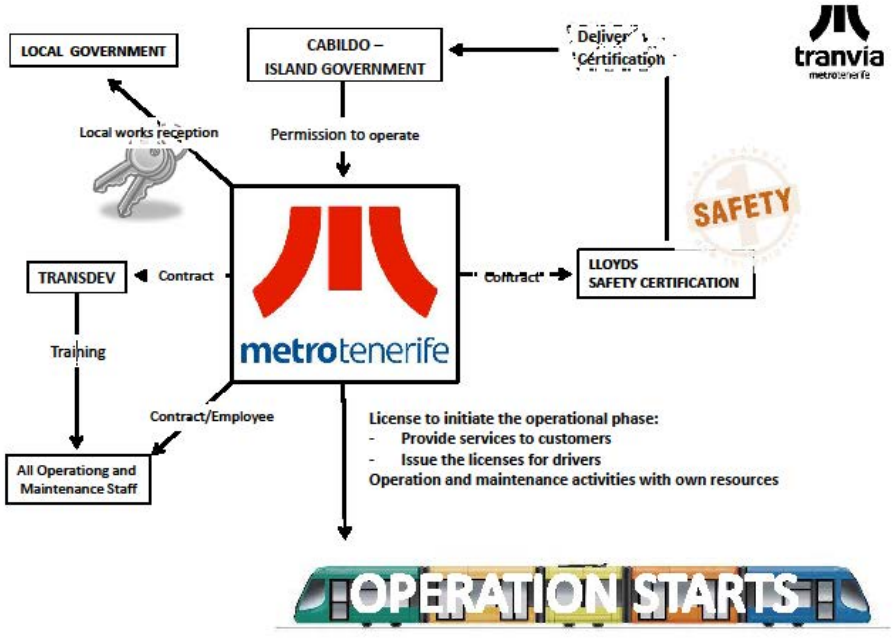
9.4.1 Tenerife



FROM DESIGN PROCESS TO CONSTRUCTION



FROM CONSTRUCTION TO OPERATION



9.5 Interaction Points

The first task carried out by the Working Group members was the identification of the interaction points, that is, the main points of the LRT's infrastructure whose design has to be properly studied in order to guarantee the safety of the system in its interaction with public space. It should be pointed out that the meaning of "interaction point" in this case is wide, including interaction locations but other interaction elements as well, such as signalling and signage.

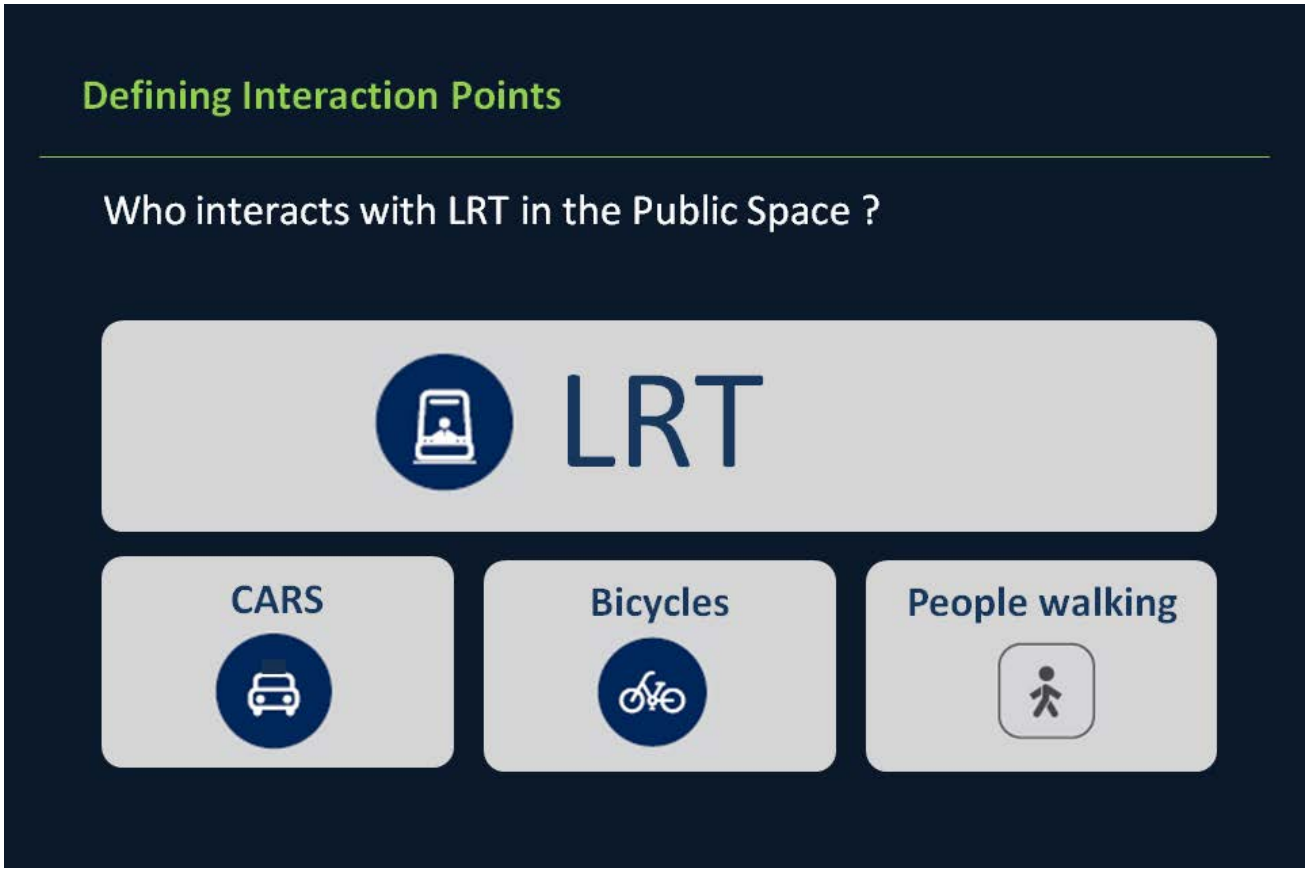


Figure 11 – Defining interaction points

9.5.1 Interaction Point Identification

The first main conclusion is the need to study separately the stations/stops and the rest of the infrastructure (called "between stations"). This distinction is made due to the important differences between those two kinds of zones, both in relation to the operation of the system and to the behaviour of users andpedestrians.

In relation to LRT operation, the speed of the vehicle when approaching stations/stops is usually low, as the vehicle needs to stop in the station for passengers to board and alight. The speed in between station zones will be as high as is allowed by the operating conditions and the speed of adjacent traffic.

In relation to user/pedestrian behaviour, most people around stations/stops are users of the systems, so they are aware of the approaching vehicles as they want to board them. So, it would seem that these zones would be safer because of this awareness. Nevertheless, there are several circumstances that make the stops particularly troublesome points, which are the following:

- Users hurry to catch the vehicle coming, which can lead them to behave in a more risky way.
- The tendency to cross the tracks via inappropriate paths, in order to get a more direct route to or from their platform.
- The accumulation of users during rush hour in the limited space of the platform, with some of them trying to pass each other in the unsafe zone of the platform.
- The possible presence of stationary LRT vehicles which restricts the visibility of other approaching LRT vehicles.

On the other hand, the other street users in between station zones can be less aware of the existence of the LRT system, or, more commonly, of the approaching of a LRT vehicle. This fact can lead to additional different risks in these zones.

Once this distinction between different zones was made, the Working Group members considered which main users of the streets would conflict with the system. This was a pretty simple question, as obviously every one of the other users of the street - road vehicles, pedestrians and cyclists - is a candidate to conflict with the system.

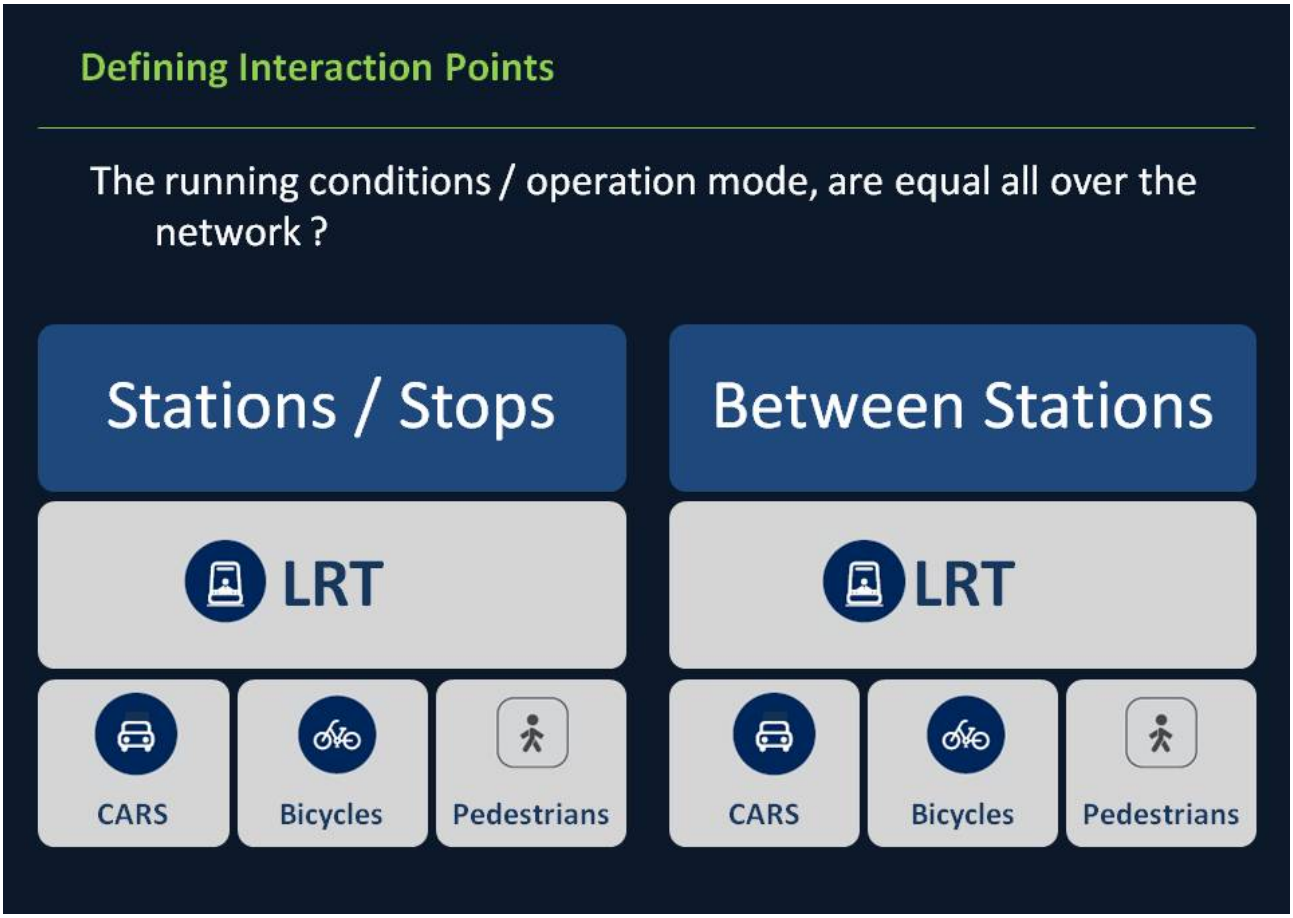


Figure 12 – The running conditions

Finally, a brainstorming was made by the Working Group members in order to identify the interaction points, resulting in the following list of potential interaction points, and the potential conflicting users for each of them:

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 in pedestrians areas	x		
Pedestrian crossings	x		x
Cyclists in segregated areas			x
Stops and their accesses	x	x	x
Interchange areas	x	x	x
Traffic (road & pedestrian) signals	x	x	x
Line signalling	x	x	x

Table 7 – Interaction points accordint to type of mode

9.5.2 Data Collection for Interaction Points

Once the interaction points were identified, the next step was the gathering of information about good and bad design examples for these interaction points in the different countries participating in the Action.

For this purpose, a template sheet was prepared in such a way that the Working Group members from each country could fill it in with their examples, in order to have a standardised source of information for the next phases of the Action. This template sheet was used to generate two documents by each member; the first document was related to urban insertion between stations and the second one to urban insertion in stations.

The template sheet was as follows:

N	Network: Case			
Location	City	Network	Line	Section
Operation Mode	segregated tramway	mixed zone	shared space	
Interaction Points between LRT and	pedestrians	cars	cyclists	
Landscape and surrondings context	Description			
Location	station	between stations		
Description	type of solution_configuration			
	advantages			
	disadvantages			
	innovation aspects			
Images + Plans				

Figure 13 – Template sheet – Interaction points

Each cell of the table has to be filled in as follows:

- "N": is the identification code of each example. The code is something like "XXXn_n", where XXX are two or three letters that identify the country where the example is located, the first n is a number that identifies the example network, and the last n (after the underline) identifies the number of the example in the network.
- "Network: Case" is a short description of the example that gives information about where it is.
- "Location" gives more detailed information about where the example is located, indicating the city, the name of the network, the line of the network and the specific section of the line.
- "Operation Mode" gives information about the kind of interaction between the LRT system and the other users of the street. The Working Group member has to mark the appropriate cell with an x, for indicating if the LRT section is segregated, mixed or shared-space.
- "Interaction points between LRT and" indicates the kind of interaction point that is shown in the example and what other users of the streets are involved in addition to LRT (pedestrians, cars and cyclists). In order to standardize the information, the cells under the labels "pedestrian", "cars" and "cyclist" have a pull-down menu for the Working Group member to select the kind of interaction point. The options for each kind of interaction are as follows:
  - Options for interaction with pedestrians: Tramway segregation along the street (lanes and sidewalks); Tramway perception on pedestrian areas; Pedestrian crossings; Stops and their accesses (stops including accesses?); Interchange areas; Traffic (road & pedestrian) signals; Line signalling.
  - Options for interaction with cars: Road junctions (cars and cyclists) with tramway; Road junctions (cars and cyclists) with a left turn; Roundabouts; Tramway segregation along the street (lanes and sidewalks); Tramway perception on mixed streets (cars and cyclists); Stops and their accesses; Interchange areas; Traffic (road & pedestrian) signals; Line signalling.
  - Options for interaction with cyclists: Road junctions (cars and cyclists) with tramway; Road junctions (cars and cyclists) with a left turn; Roundabouts; Tramway segregation along the street (lanes and sidewalks); Tramway perception on mixed streets (cars and cyclists); Pedestrians level crossings; Cyclists in segregated areas; Stops and their accesses; Interchange areas; Traffic (road & pedestrian) signals; Line signalling.
- "Landscape and surrounding context" is intended for the Working Group member to make a description of the kind of section or station where the example is located, explaining the more important issues that give interest to the situation shown.
- "Location" gives the Working Group member the option to mark with an x to identify the section as a station or a between-stations one.
- The next part of the template is dedicated to the description of the situation, giving the opportunity to the Working Group member to explain the type of solution (configuration) that is shown, highlighting the advantages, disadvantages and innovative aspects of the solution.
- Finally, the last part of the template contains images and plans illustrating the kind of solution and its particularities.

9.5.3 Interaction Points – Stations (first findings)

Although it was not the objective of the first phase of the COST Action to draw conclusions, but to gather information, some advance steps can be made by studying the examples collected from all the Working Group members. Below we present a few examples of the data we collected and the first conclusions we took from them.

Pedestrian pathways at stations

The first conclusion obtained is the need to establish and clearly identify (by means of appropriate signage) a safe pathway for pedestrians to cross the tracks in the stations. This pathway (pedestrian crossing) is usually located at one or both ends of the platforms, and it has to be, in turn, appropriately identified so that the pedestrians and users know where the right place for crossing the tracks is located.

Examples of signing of these pathways are presented in cases from Metro do Porto.

Figure 14 – Signalization of pathways in Porto

This other example from Trambaix Barcelona shows a combination of signages (by means of footpath pedestrian markings) and barriers, clearly indicating to users the correct and safe route to walk. As it is not a common signage in the city, pedestrians usually realize the significance of the signs. On the other hand, the crossing for pedestrians over the LRT tracks is marked by red painting and the tram symbol, So that pedestrians are aware of the risks.

Figure 15 – Signalization of pathways/ crossings

Platform design and stop/station location

Another important issue related to safety at stations is the platform design and the stop location, whether it is a simple LRT stop or an interchange station.

This example from Luas – Dublin, is a good example of platform design in relation to drainage. In this case, the highlighted point is the need for an adequate crossfall at stops in order to get good drainage, but in order to guide users (especially wheelchair users) away from the platform edge, the crossfall should be towards the back of the platform. In order to get a wheelchair-user friendly platform, but still with good characteristics in relation to drainage, the longitudinal slope at stops should preferably be minimum 0.5% and transversal fall 2.5% towards the back of the platform. This design imposes the need for an additional drainage channel on back of platforms, which obviously needs to be maintained.

Figure 16 - Example IRL1_2. Luas (Dublin)

Some examples of poor platform design are shown from Atac (Rome). Example IT1_1 shows an excessively wide horizontal gap between the platform and the vehicle, which leads to dangerous situations during boarding and alighting.

Figure 17 - Example IT1_1. P. le Flaminio – Atac Roma

9.5.4 Interaction points - Between stations (first findings)

9.5.4.1 Pavement treatment in shared space

One way of inserting the light rail system into the urban fabric is the use of streets that are dedicated to pedestrians, cyclists (in this case) and the light rail system itself. Speed must be limited on these zones to values around 10-25 km/h, in order to avoid incidents/accidents from happening.

Another way of improving safety in this kind of street is to use the surface of the pavements in order to ensure that pedestrians and cyclists are well aware of the presence of light rail vehicles running in the street. This pavement differentiation can be achieved by means of its texture or by means of its colour and material.

An example of the use of different textures with the same material (granite) is PT1_7 (Rua Brito Capelo, Metro do Porto). A feature of this street is the lowering of the tracks so that the platforms are at the same level as the sidewalks while still allowing level boarding of the vehicles.

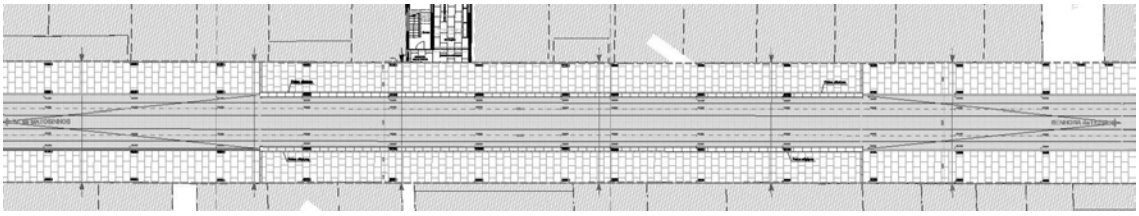


Figure 18 - Example PT1_7. Rua Brito Capelo – Metro do Porto

9.5.4.2 Intersections

Obviously, an important aspect of light rail design in relation to safety concerns intersections, as they are the main points where the light rail interacts with other users (especially when the tram runs on a segregated channel).

This is the reason why many of the examples gathered by the Working Group members are related to intersections. The intersections are classified into: left-turn intersections; roundabouts; intersections between general streets and shared-space channels; pedestrian and cycle crossings; improving visibility at intersections; other innovative solutions at intersections. Examples of the first two are given below

Left-turn intersections

In general, when designing a light rail systems, left-turn (right-turn for Ireland & UK) intersections of road vehicles running over the light rail channel should be avoided whenever possible. The reasons are, on the one hand, that these movements are considered as one of the more dangerous situations of interaction between light rail and the rest of street users (as car-drivers sometimes disobey or misread traffic signals); on the other hand, left-turn intersections generate a more complicated signal cycle which leads to more delays and a more difficult signal priority for light rail.

In order to avoid this kind of movements, left-turns are often transformed into a different manoeuvre. For instance, road traffic may be directed to turn right then return by a parallel street to cross the track at a perpendicular intersection.. Of course, this option has to be adequately indicated by means of fixed signs.

As some car-drivers tend to disobey the left-turn prohibition, sometimes additional measures accompany the signs. That is the case in example ES1_1 (Av. Diagonal/Bac de Roda – Trambesòs, Barcelona), where plastic bollards have been provided along the light rail tracks, allowing vehicles to cross perpendicularly but complicating the prohibited left-turn manoevre.

Figure 19 - Barcelona

In spite of the above, sometimes left-turns over light rail tracks are allowed, either because there is no other convenient option for car-drivers or because the designer considers that the risk is tolerable. In those cases, it is common to make a specific treatment of the intersection in order to guarantee that the traffic lights are properly understood and that car-drivers do not disobey them without realizing.

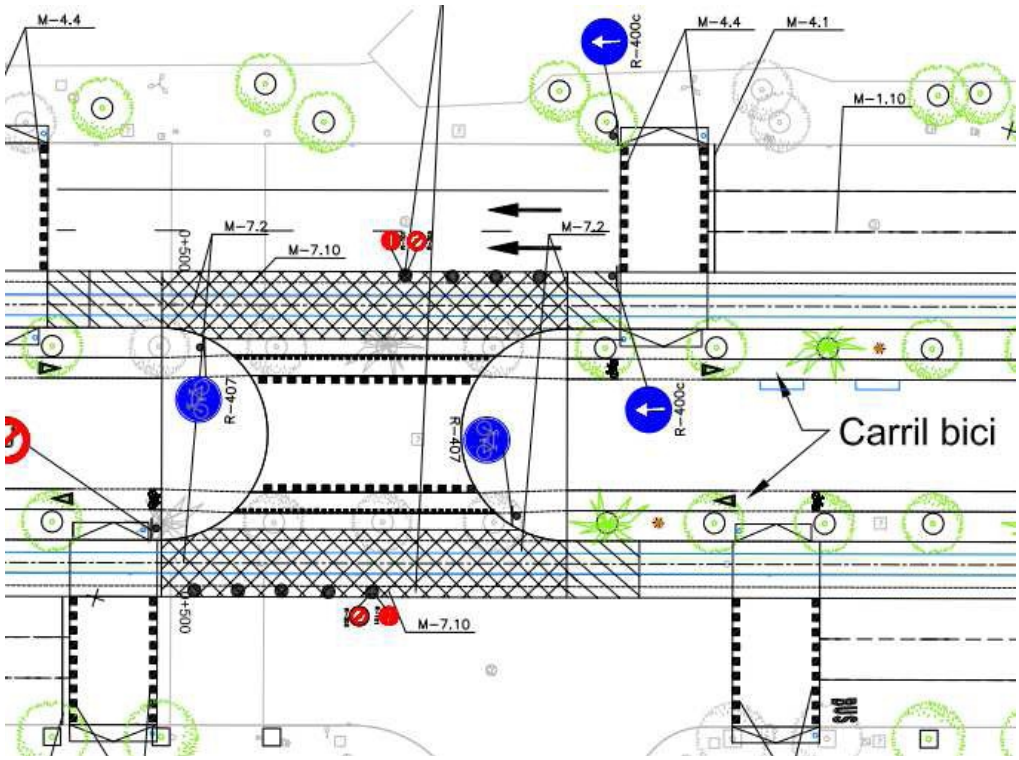


Figure 20 - Example ES1_1. Av. Diagonal/Bac de Roda – Trambesòs

Roundabouts

Roundabouts are a very common solution for road junctions in Europe, as they provide a safe and almost continuous traffic flow. The three main advantages of roundabouts are the following: road vehicle drivers have to reduce their speed when approaching the roundabout, leading to an increase in safety at the junction; management of a junction by means of a roundabout avoids the need for traffic lights, reducing the operation and maintenance costs; finally, the junction capacity increases due to the almost continuous traffic flow and the elimination of dead-times produced by traffic-lights.

Nevertheless, the junction operation changes strongly when a light rail system is added to the roundabout. The usual way of implementing the LRT in the roundabout is running of the tram through the centre of the roundabout. The roundabout works as a conventional one when the tram is not present, but traffic lights are provided to give priority to an approaching tram. One important issue to bear in mind is the need to avoid car drivers misreading the roundabout and the traffic lights, which can easily lead to an accident or incident. On the other hand, it is important that car-drivers encounter the tramway as near to the perpendicular direction as possible, in order to improve the visibility and awareness of the tram presence.

This roundabout example is PT1_9 (Matosinhos Sul/Câmara de Matosinhos – Metro do Porto). In this case the roundabout is inserted at the junction of two busy streets on the centre of Matosinhos (Av. República and Av. D. Afonso Henriques), with high levels of traffic, especially in rush hours. The roundabout solves the intersection between cars and LRT. Road signals regulate the car movement in such a way that car-drivers must stop when LRT passes by. The LRT runs at the centre of Av. República which is aligned with the roundabout centre. All the movements to/from the above streets are made by the roundabout and always perpendicularly to the tramway. This is an important aspect because it forces drivers to be aware of LRT

approaching. One problem of this specific junction is that parking is allowed in the streets just adjacent to the roundabout entry, which causes constraints on traffic flow. Parking should be forbidden on the first 15 m of each adjacent street, so that the traffic can flow more easily.

Figure 21 & 22 – Barecelona roundabouts

9.5.5 The number of examples – interaction points

The number of examples gathered for each interaction point is the following:

Entry	Hotspot ID *	number of examples	
		stations	between stations
pedestrians			
1	Tramway segregation along the street (lanes and sidewalks)	0	23
2	Tramway perception in pedestrian areas	0	10
3	Pedestrian crossings	6	9
4	Stops and acesses	13	0
5	Interchange areas	7	0
6	Traffic (road & pedestrian) signals	1	8
7	Line signalling	2	1
cars			
1	Road junctions (cars and cyclists) with tramway	3	20
2	Road junctions (cars and cyclists) with a left turn	0	7
3	Roundabouts	0	11
4	Tramway segregation along the street (lanes and sidewalks)	0	25
5	Tramway perception on mixed streets (cars and cyclists)	0	5
6	Stops and acesses	0	0
7	Interchange areas	0	0
8	Traffic (road & pedestrian) signals	1	4
9	Line signalling	0	3
cyclists			
1	Road junctions (cars and cyclists) with tramway	2	6
2	Road junctions (cars and cyclists) with a left turn	0	1
3	Roundabouts	0	2
4	Tramway segregation along the street (lanes and sidewalks)	0	3
5	Tramway perception on mixed streets (cars and cyclists)	0	4
6	Pedestrians level crossings	0	2
7	Cyclists in segregated areas	0	3
8	Stops and acesses	0	0
9	Interchange areas	0	0
10	Traffic (road & pedestrian) signals	0	1
11	Line signalling	2	1

Table 8 – Number of examples for each hotspot

9.6 Suggestions for WP2 – "Analysis"

9.6.1 Developing first conclusions

During the research collecting and discussing the Interaction Points, as well as the numerous documents that guide LRT projects at national and regional level, the WG3 members realised that there are several differences between countries in the way of looking to LRT systems.

This is happening not only by the natural differences of culture and lifestyle of the European countries, but mainly by the way the LRT systems have grown in each country. Some of them are looked at as lighter heavy-rail systems, and others like heavier tram systems.

The distance between those two approaches is reflected in the infrastructure as well as in the operational modes, and in the signalling and signage.

Some LRT systems subjugate pedestrian flows and all other traffic to the tramway and its operational rules, ensuring tramways have higher priority of circulation, whether they are in the city centre or in the outskirts.

Others adapt their running conditions to the environment they have, giving full priority to tramways in the suburban areas, and with the tramway sharing the roads with traffic, pedestrians and bicycles in the city centre.

On the other hand, some LRT systems base their signalling and signage on the road / tramway code, while others import some of the heavy rail signalling protection systems.

So how can some good practices be established for a peaceful and safe LRT interaction with the urban space and their citizens?

The answer to that question also came up during the hard discussion between all the WG members. The group tried to find the basic rules that are accepted as a good practice, no matter the way of looking LRT. It is important to consider that no system is 100% safe, and that there always will be people walking, cycling and driving around the LRT; the objective is to agree some measures that will protect those Interaction Points in as natural a way as possible.

10 Conclusions

This public report presents the first conclusions of the state of the art exploration in relation to LRT safety, in relation to three very different subjects: institutional and regulatory aspects; data collection on accidents; and infrastructure design:

- one of the main results achieved in relation to the institutional and regulatory frame is the improvement in knowledge about similarities and dissimilarities among different European countries in this field: there is a wide range in the manner and level of regulation and standardization for light rail systems between countries.
- in relation to data collection on accidents and operation, we have produced an overview of organisational options . But the great variety of data and means of data recording and analysis in different countries shows difficulties in reaching a common approach. The benefits of European wide harmonisation are difficult to determine and would probably be very difficult to achieve. There may however be some lessons to be learnt which could reduce risks on new systems. The common knowledge on safety issues (problems, levels, impacts, indicators, causes of accidents and incidents) will be continued during WP2.
- regarding infrastructure design and urban insertion, the main achievement 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 systems in every country face similar kinds of risky situations, and the study has identified specific design solutions that may be generally considered as safe or dangerous.

The results of the analysis will be recommendations for inserting tramways safely in the urban environment, through guidelines with risks, objectives and possible solutions to cover them, design examples and additional measures, aimed at the safe interaction of new and existing LRT systems with public space.

In the next working phase (WP2) particular attention will be paid to the causes of accidents and efforts will be made to identify the configurations that:

- pose recurrent problems in terms of operation or safety on straight sections as well as at intersections and stations,
- correspond to sections of line that perform well and/or have no accidents,
- are innovative in terms of design.

Appendix

Glossary – main terms and their definitions in English – in alphabetic order

Since a language issue and the potential for misunderstandings or mistranslations has been detected, here is included a glossary (not a dictionary) on the main terms in the original language and their descriptions in English (tramway, LRT, mixed zones, segregated lines...). Here, the terms, their meanings and related photos are presented. In the appendices, the global table with all translations is included.

Globally, no complicated issue occurred but terms such as “Metrobus” or “local authority” have appeared to mean slightly different ideas.

In the appendix, a complete table for each term can be found: its translation in the various languages used by the participants with comments and interesting issues but quite small and detailed.

Accident: collision that involves the tram and a third party (car, pedestrian, bicycle…) with contact, or contact with a fixed object or structure.

Figure 1 a- accident with a car in Berlin, b- car crash demonstration in Warsaw, c- collision in Brussels, d- collision with a bus in Berlin

Figure 2 - Austria

Figure 3 - Portugal

Capacity [vehicle/h/direction]: maximum volume that can be offered per unit time.

Code: any set of standards set forth and enforced by a local government agency for the protection of public safety, health, etc., e.g. in the structural safety of buildings (building code).

Congestion: equivalent to Level of Service when Demand approaches Capacity.

Crossroad, junction or intersection: crossing between the tram lane and one or more roads, mainly managed by road signals, including for the tram. The urban crossroads are generally crossed in speeds between 20 and 40 kph.

Figure 4 a- simple junction in France, b- junction in Warsaw, c- view on a junction from driver cabin in ?

Figure 5 a- Switzerland , b- Switzerland , c- Czech Republic

Crossroad will in this Action, only concern a crossing between trams and road traffic, not trams/trams.

Figure 6- Italy

Left-turn/right-turn intersection: the movement, which consists of turning to the left/right in a crossroad.

Figure 7 a- France, b- Portugal

Event: Any event that has a physical impact on people (in or outside the tram), vehicles (tram or others), fixed equipment of the tram system – without regarding the level of severity. In this report, event does not include collision between trams, derailments, falls inside the tram… Event = accident or incident that involve the tram. More precise definition and typology can vary between countries.

Exclusive right of way, reserved track or segregated track: lane exclusively restricted to public transport and generally used to speed up public transport that would be otherwise held up by traffic congestion. Often the tracks can be used by certain other vehicles, which may include taxis, emergency services, bicycles

Figure 8 a- Czech Republic, b- France, c- Switzerland

Fixed obstacle: any rigid element that can aggravate a collision between car and tram by crushing the car between the tram and this fixed obstacle.

Figure 9 a- France, b- Portugal, c- Czech Republic

Figure 10 - Portugal

Hazard: exposure or vulnerability to injury. Hazard is the potential of damage. Risk=(Hazard)x(Vulnerability)x(Exposure).

Incident: event with no contact between third party and tram: a near-miss accident for example.

Injured person or casualty: victim of an accident.

Killed person or fatality: European regulation on transport statistics Railway (1192/2003 of 3 July 2003): any person killed immediately or dying within 30 days as a result of an injury (except suicide).

Law: the system of rules which a particular country or community recognizes as regulating the actions of its members and which it may enforce by the imposition of penalties.

Level of Service (LoS): physical and/or statistical relation between demand volume and volume offered (capacity). [Note: expressed as a percentage of capacity].

Light Rail Transit or Light Rapid Transit (LRT): system between heavy rail and urban tram systems. In contrast to a tram system, it can have 100% exclusive lanes or a completely segregated track. There is no strict differentiation from tram-systems, though vehicles can normally be longer than trams. Streetcars and trams are subtypes of light rail transit.

Figure 11 a- France, b- Switzerland, c- Italy

Lightly (or slightly) injured people: person who suffered minor injuries that do not require medical assistance or, if they do, do not require to stay at the hospital.

Line-of-sight: railroad operating system imposing on the driver to be able to stop his vehicle at any time in the distance which he can see to be clear ahead. [Note: this wording is from the UK legal definition of a tram]

Figure 12 a- Italy, b- Czech Republic, c- Vienna

Local authority: urban municipality responsible for the LRT or tram system.

Mixed zone: ordinary mixed-traffic site on surface accessible to any vehicles (trams, cars, bicycles…). The tramway can be used also as traffic lane.

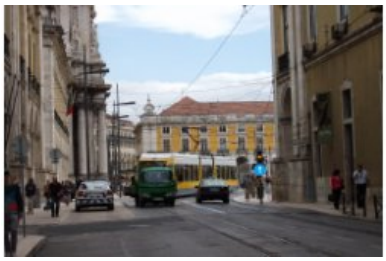


Figure 13 a- Portugal, b- Switzerland, c- Nantes, France

Network: an interconnected system (here: LRT or tram system).

Non-injured person: person involved in an accident but not injured.

Norm: rules harmonized by all countries but not compulsory.

Passenger: person travelling in the tram or waiting at the station.

Pedestrian area: public space reserved to pedestrians only, like walking ways or walking squares. Trams can sometimes share with them this space.

Figure 14 a - Italy, b- Czech Republic

Figure 15 - Vienna

Pedestrian crossing: area where pedestrians can cross the streets, zone where pedestrians can cross the segregated tram-tracks.

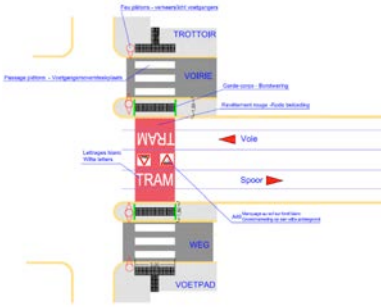


Figure 16 - Brussels

Figure 17 - Vienna

Physical separator: physical layout that divides or keeps apart tram lines from other road users' lanes. The physical separator sometimes takes the form of a low kerb or ramp, which emergency vehicles can cross if necessary.

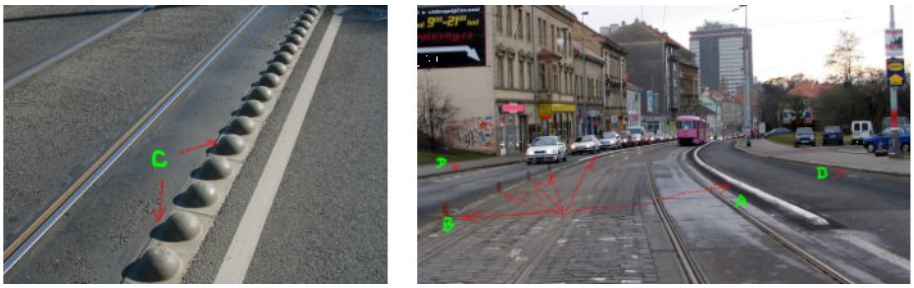


Figure 18 - Czech Republic

Regulation: a rule or directive made and maintained by an authority.

Road signs: board, placard, etc, displayed in public and inscribed with words or designs intended to inform, warn, etc.

Roundabout: is a type of circular intersection, a junction in which road traffic flows in one direction around a central island and where entering traffic must yield to traffic already in the circle.

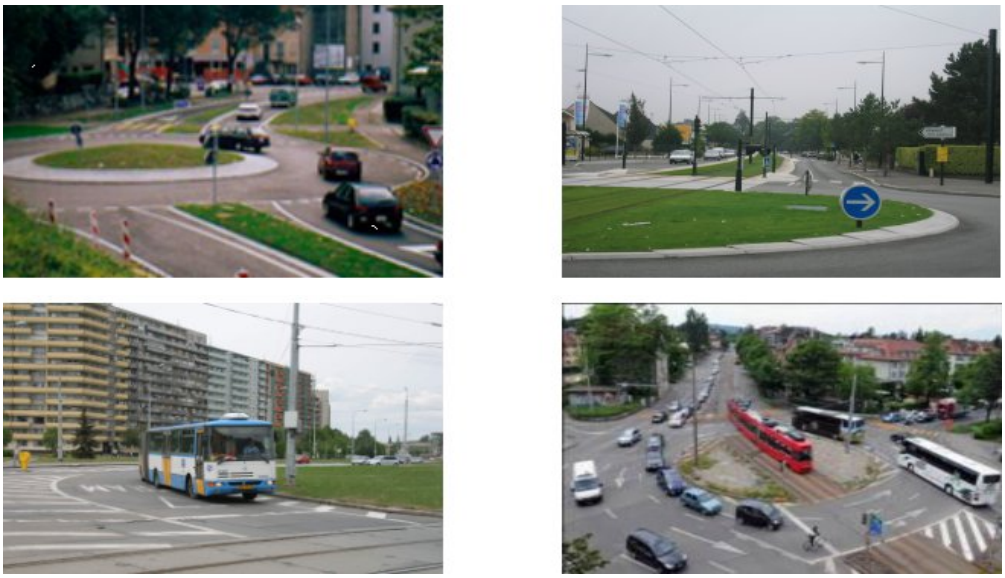


Figure 19 a- Italy, b- France, c- Czech Republic, d- Switzerland

Safety: deals with the level of risk and precautions taken to reduce risk related to human health. But in this Action not dealing with counter-terrorism or health hazards due to pollution and similar.

Safety authority: controls how safety is implemented on tram networks in project and/or operation.

Segregated line: exclusive use to LRT or Tram, normally with right of way over traffic, with specific crossing points to cars/cyclists and pedestrians.

Figure 20 - Warsaw

Figure 21 - Vienna

Seriously injured people: European regulation on transport statistics Railway (1192/2003 - 3 July 2003): any person who was hospitalised for more than 24 hours after injury (except suicide). Recent update on the European definition on serious injury include other characteristics: http://ec.europa.eu/commission_2010-2014/kallas/headlines/news/2013/03/doc/swd(2013)94.pdf

For example, UK definition for road accidents also includes specific injuries such as fractures or internal injuries, whether they require hospitalisation or not.

The definition of serious injury as currently reported for inclusion in the Commission's road accident database differs between the EU Member States. There is not yet any confirmed compilation of the definitions used in all Member States' hospital records, but it is indicated that the most common definitions used in those records are the ICD-9 or ICD-10 and the AIS/MAIS[30].

Country	Seriously Injured
AT	>24 days health impairment
BE	> 24 hours in hospital
BG	As defined in penal code
CH	>= 24hours inability to perform normal activities or in hospital >=24hours
CY	Hospitalised
CZ	As decided by medical doctor or >=24h hospital
DE	>=24h in hospital
DK	According to national definition[31]
EE	Not defined
ES	>=24 hours in hospital
FI	Not defined
FR	>=24 hours in hospital
GB	Hospitalised or according to national definition[32]
GR	Police records; presumed >=24h in hospital
HR	Definition unknown
HU	Injuries needing hospital care or >8 days to heal
IE	Hospitalised or according to national definition[33]
IS	According to national definition[34]
IT	Not defined
LU	>=24 hours in hospital
LV	>=24 hours in hospital
MT	Health department/Police definition
NI	Fractures/concussion/internal injury/severe cuts/lacerations/severe shock
NL	>=24 hours in hospital
NO	Life-threatening, permanent or major injuries
PL	According to national definition[35]
PT	>=24 hours in hospital
RO	Hospitalised or according to national definition[36]
SE	Injuries expected to result in hospitalisation
SI	>=24 hours in hospital
SK	Doctor's opinion + change of state between 1 and 30 days

Source: CARE Database

Shared space: LRT or Trams running at surface, when the tramway is going through a zone it shares with one or several types of space users well defined (e.g. a pedestrian section, and the operation mode is completely on sight with reduced speed).

Figure 22 – shared space with bus in Warsaw

Speed [km/h] or [m/s]: physical and/or statistical relation between space or distance and time to travel that distance.

Third party: other road users than tram passenger – car driver, cyclist and pedestrian...

Traffic lights system, road signals: regulated road traffic signals in crossroad network.

Figure 23 a- UK, b- UK , c- Italy, d- Italy

This Action deals with traffic signals, not railway signals.

Figure 24 – Czech Republic

Traffic Light Cycle (green phase): time Cycle in Traffic Lights System during which a vehicle may proceed across the intersection.

Traffic Light (yellow) Cycle (yellow/amber phase): time Cycle in Traffic Lights System during which a vehicle must stop if possible or may proceed with caution across the intersection.

Traffic Light Cycle (red phase): time Cycle in Traffic Lights System during which a vehicle must not enter the intersection.

Figure 25 a- Switzerland, b- Czech republic

Tram vehicle: rolling stock, tramcar.

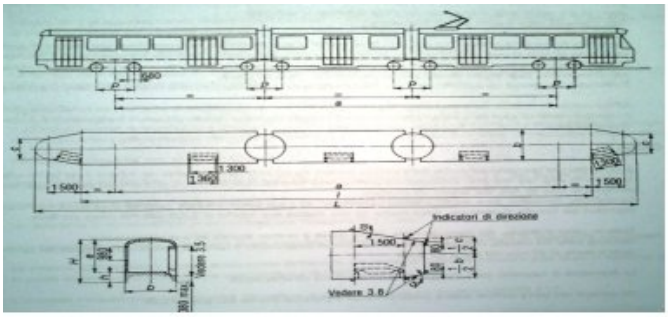


Figure 26 a- Italian scheme, b- Switzerland, c- Switzerland, d- France

Tramway: public guided transport system in urban spaces, sharing its road with other users at least at crossings, driving at line-of-sight for all or part of its length. Tramway is considered as a system, comprising three main sub-systems: the infrastructure and the fixed installations, rolling stock and the operation.

Figure 27 a- Italy, b- Portugal, c- Czech Republic

Victim: is a fatality, a seriously injured person or a lightly injured person.

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