MODSafe

European Commission
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MODSafe Modular Urban Transport Safety and Security Analysis

WP2 – D2.1
First List of Hazards, Preliminary Hazard Analysis (PHA)

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1. Summary of this Document

This Deliverable describes the generation and basic approach of a first list of Hazards, and its extension to a preliminary hazard analysis, respecting the purpose of the MODSafe WP2. The Annex provides the MODSafe Hazard list.

1.1 References

Reference-ID	Document title, identifier and version

/1/ DEL_MODSYSTEM_WP23_D127annex_TUD_080328
/2/ DEL_MODSYSTEM_WP23_D86_TUD_060914
/3/ DEL_MODURBAN-D129_RATP_WP20_090317_V27
/4/ EN 50126, CENELEC, Railway applications - Specification and demonstration of reliability, availability, maintainability and safety (RAMS), 1999
/5/ EN 50129 CENELEC, Railway applications - Communications, signalling and processing systems - Safety related electronic systems for signalling; 2003
/6/ Yellow Book , Engineering Safety Management Issue 4, RSSB 2007
/7/ MODSafe_WP2_D2.1_Annex_Hazard_Analysis

1.2 Terms and Abbreviation

The terms used in this project are explained in the document [GLOSSARY.en] (to be developed by WP10)

In addition, the following terms are used here:

Term	Explanation

The abbreviations used in this project are explained in the document [GLOSSARY.en] (to be developed by WP10)

In addition, the following abbreviations are used here:

Abbreviation	Explanation
BME	Budapest University of Technology and Economics
CE	Clearance Envelope
CSM	Common Safety Methods
ERTMS	European Rail Traffic Management System
EU	European Union
GOA	Grade of Automation
LU	London Underground Ltd
MM	Metro Madrid
OCC	Operations Control Centre
PHA	Preliminary Hazard Analysis
PXCH	Passenger Exchange
RATP	Régie Autonome des Transports Parisiens (Autonomous Paris Transport Authority)

STRMTG	Service Technique des Remontées Mécaniques et des Transports Guidés (French Technical Agency for Ropeways and Guided Transports safety)
UGTMS	Urban Guided Transport Management System

2. Introduction MODSafe WP 2 “Hazard and Risk Analysis”

The European Urban Guided Transport sector (Light rails, Metros, but also Tramways and Regional Commuter trains) is still characterized by a highly diversified landscape of Safety Requirements, Safety Models, Responsibilities and Roles and Safety Approval, Acceptance and Certification Schemes. The main aim of the MODSAFE project is to enhance cross acceptance of once approved and certified urban rail technologies within one country or to another countries of the European Community.

In doing so, the project MODSafe is split into work packages, which are arranged into a V-Model. On the left the Safety Analysis and modelling tasks are arranged, tasks that relate to Verification, Testing, Validation, Approval, Acceptance, Certification procedures etc. are placed at the right. The project addresses the full Safety Life Cycle of an urban guided transport system.

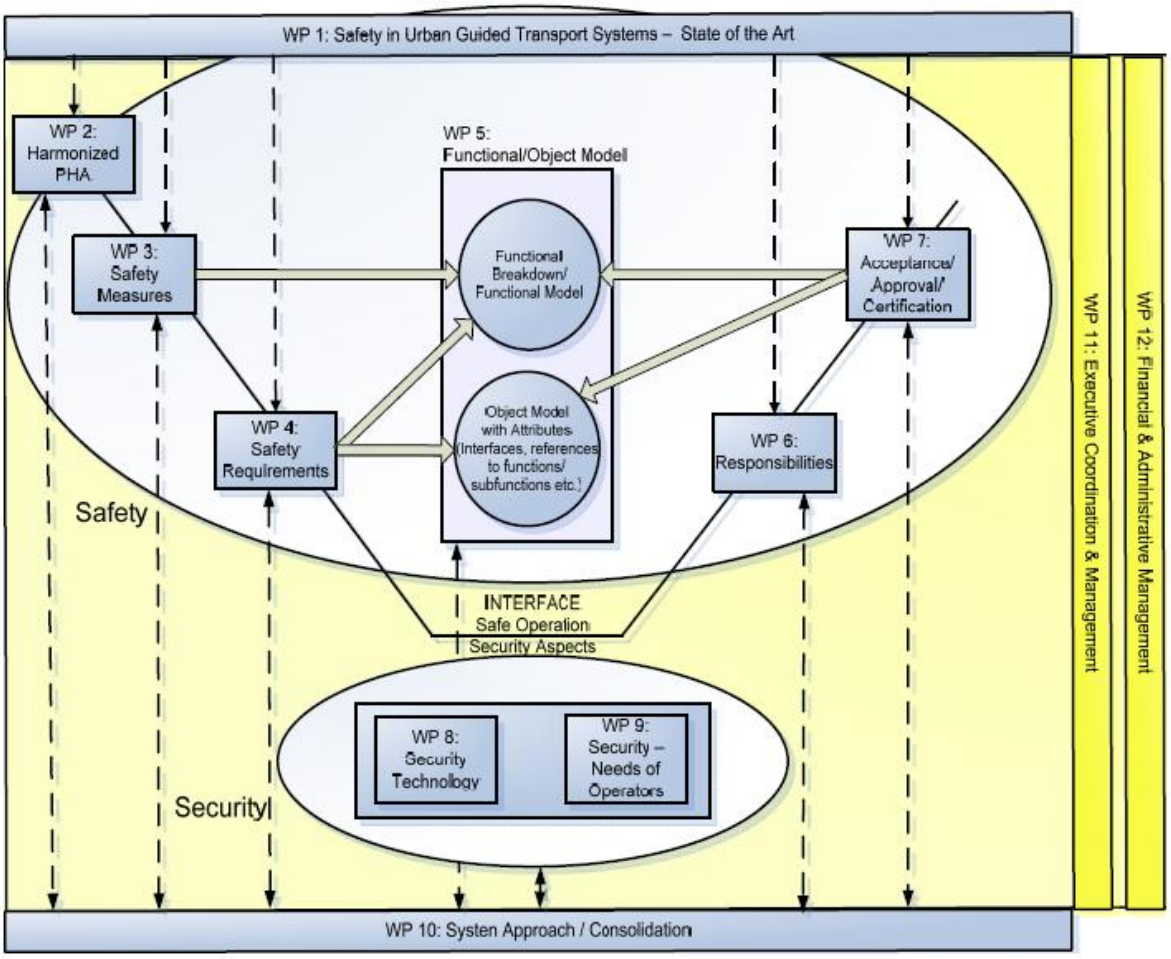


Figure 1 Overview over the MODSafe tasks, arranged into a V-Model like structure

Within the whole MODSafe project as well as in the V-Model, one of the first activities is the “Hazard and Risk Analysis” (MODSafe WP2). Its objective is a proposal of an agreed and harmonized Urban Guided Transport Hazards and Risk Analysis. Therefore, the work package is parted into three tasks:

- Task 2.1: Provision of a First List of Hazards/Preliminary Hazards Analysis
- Task 2.2: Consistency of the Final Hazards Analysis
- Task 2.3: MODSafe Risk Analysis

These tasks result in three deliverables, whereas the first one is presented in this Document.

2.1 Aim

The objective of this deliverable is the preparation of a Preliminary Hazard List. Therefore, the concept and methodology of a hazard analysis is outlined, and used as a basis for the hazard list. Further existing hazard analyses are reviewed. The focus is on such analyses, which are actually used in the European transportation sector. This includes analysis of operators, suppliers and research institutes. Furthermore, results from European research projects are consulted. This collection of the state of the art consolidates into a shared preliminary hazards analysis concept, methodology and database.

This deliverable introduces in the organisation of the MODSafe hazard analysis and results in a structured list of potential hazards. The consideration of different operational user cases aims at the derivation of a harmonization of hazards. The list will be checked against demands/requirements in different countries (e.g. STRMTG proposition).

2.2 Link to other MODSafe WPs

This Deliverable 2.1 itself presents an input for

- WP3 “Hazard Control and Safety Response Analysis”

Furthermore, D2.1 is associated with the following work packages:

- WP4 “Common Safety Requirements”
- WP5 “Functional and Object oriented Safety Model
- WP6 “Safety Life Cycle and Responsibilities”

The WP 2 “Hazard and Risk Analysis” requires no input from other MODSafe work packages. Nevertheless, the WPs dealing with security hazards shall be considered in order to check for consistency:

- WP8 “Level of sophistication and relevant technology of security surveillance systems”
- WP9 “Global approach for Integrated security needs”

Beside the links to the other MODSafe work packages some basic considerations on Task 2.2 and 2.3 influence the organisation of the PHA in Task 2.1.

2.3 Input

External input for this deliverable will be EU research project (e.g. UGTMS, ERTMS), and in particular MODURBAN. Furthermore, the participating operators in WP2 will check the hazard list against their own analyses. Adjustments by e.g. RATP (Paris), LU (London) and MM (Madrid) are considered.

3. The WP2 Hazard Analysis

3.1 Preliminary Hazard Analysis

The initial identification of hazards is elementary for the further risk assessment of a system. The Preliminary Hazard Analysis (PHA) is an inherent part of the risk assessment process (see e.g. /1/;/4/ EN50126; /5/ EN50129, /6/ Yellow Book).

In Urban Transportation Systems, the focus on hazard analysis is on the physical integrity of human and on the undisturbed operation of the transportation system. Therefore, the PHA shall systematically identify potential impacts on the physical integrity. In doing so, processes and operation modes as well as human (staff/passenger) shall be considered. Significant hazards are pointed out. The identified hazards are assessed concerning the severity of their possible consequences. In a further step, the identified hazards are covered by safety measures (see WP3, WP5).

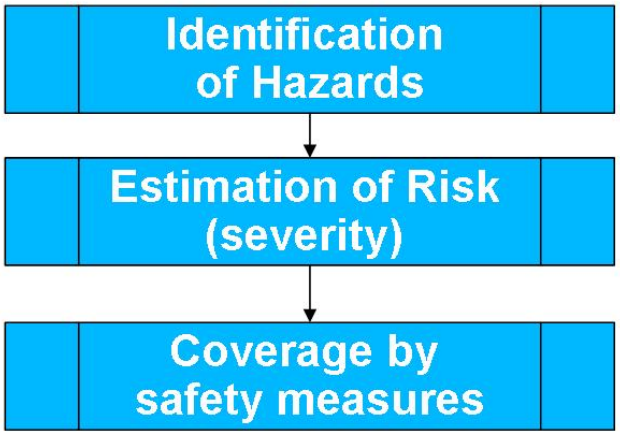


Figure 2 Rough procedure of Hazard Analysis

The complexity of the PHA depends on several boundary conditions. System boundaries (e.g. physical, operational) are assessed as well as the level of detail of the PHA. The aim is to achieve a (almost) complete hazard identification, although the completeness cannot be proved.

The performance of a PHA can be managed in different ways. It can be organised by the consideration of checklists or the breakdown of the considered system into subsystems and finally to concrete functions or objects in order to identify hazards.

Within urban transportation systems, hazards arise from the regular operation as well as consequence from failure of components or from human misbehaviour. The PHA shall detect all kinds of Hazards in a systematic and comprehensible way.

The MODSafe Hazard Analysis aims to prepare several available analyses in such a way that the resulting analysis is well-arranged in order to be applicable for any user. The user of the MODSafe Hazard Analysis shall be able to

- navigate intuitively through the Hazard Analysis
- screen for already considered hazards
- enter not yet considered hazard at an adequate position
- overview the context of hazards, their severity of consequences and possible safety measures at a glance

Hazard analyses can be structured e.g. as Fault Trees or Lists. The requirements on the MODSafe Hazard Analysis above and mainly the last one result in a preference on table structure for the analysis. The order of hazards within a table structure is to be introduced.

3.2 Organisation of the MODSafe Hazard Analysis

The organisation of the MODSafe Hazard Analysis is based on the three segments of a Hazard Analysis shown in Figure 2:

- Identification of Hazards
- Estimation of risk (severity)
- Coverage by safety measures

This segmentation does not fix the modality of how to create the Hazard Analysis. The design of the Hazard Analysis shall satisfy the demands that are made on it. It shall be possible to comprehend the context of hazards, their severity of consequences and possible safety measures at a glance. This demand results in the preference of a table structure instead of a tree structure.

The following clauses present the sub-structures of the three parts of the Hazard Analysis. The essential information per part are defined. Finally, the segments are combined to the overall structure of the MODSafe Hazard Analysis.

3.2.1 Identification of Hazards

The hazard list compiled by the PHA described in chapter 4.1 is used as the basic for the hazard identification. Nevertheless, the hazards are to be linked with further information in order to complete the hazard identification for the purpose of MODSafe WP2. This results in a summary of information to characterise the hazard. The segment “Hazard Identification” includes (see Figure 3):

- Numbering
- Hazard Name
- Hazard Causes
- Type of Accident (primary)
- Possible consequential accident
- Remarks

The numbering serves as an identifier according to the hazard classification and its derived levels. The column “remarks” allows the attachment of further information, if it seems advisable. Thus, this column is appended to every segment.

The hazard consequences are respected by two items: the primary accident category and possible consequential accident. Experience shows, that in some cases consequential accident evolving from primary accidents (e.g. derailment after collision) dominates the hazard consequences (see next clause). Consequential accidents shall be considered which are widely known and which can serve as an example to illustrate the problem

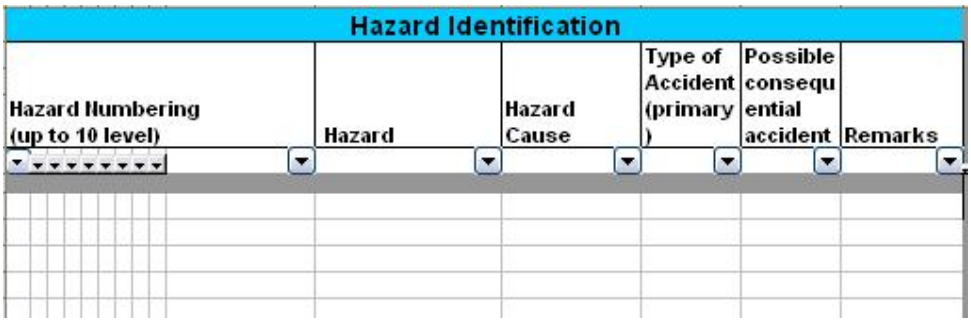


Figure 3 Segment of Hazard Identification

3.2.2 Estimation of Risk

The estimation of risk of the hazards respects the particularity of each single urban railway system. The risk estimation leaves the generic level of the PHA. According to EN 50126-2 the risk is defined as "*the rate of occurrence of accidents and incidents, resulting in harm (caused by a hazard) and the degree of severity of that harm" /2/*.
In the style of the "*risk matrix*" the risk is estimated by the combination of the severity of consequences and their likelihood. It results in the provision of four columns to store the information needed for the segment:

- Severity of consequences
- Likelihood
- Risk
- Remarks

At first the severity of hazard consequences is evaluated. This evaluation is still based on the generic consideration of hazards and their consequences (see chapter 4.2). It is based on the hazard severity levels as described in EN 50126:

- Catastrophic (i.e. Fatalities and/or multiple severe injuries)
- Critical (i.e. Single fatality and/or severe injury and or loss of a major system)
- Marginal (i.e. Minor injury and/or severe system(s) damage)
- Insignificant (i.e. Possible minor injury and/or minor system damage)

The consideration of likelihood puts then the severity into context of a particular urban railway system. Therefore, the frequency of hazard occurrence is estimated. So far, the first estimation of likelihood does not consider the existence of any safety measures. The classification of likelihood is also levelled according to EN 50126:

- Frequent
- Probable
- Occasional
- Remote
- Improbable
- Incredible

The resulting risk level according to the risk matrix gives a first glance on the significance of the hazard.

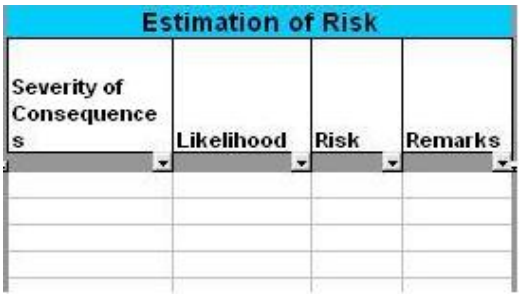


Figure 4 Segment Estimation of Risk

3.2.3 Coverage by safety measures

The third segment deals with safety measures which are able to mitigate the estimated risk. WP2 provides a first set of data for the WP5 “Functional and Object oriented Safety Model”. The basic idea of this segment is to refine generic safety measures according to the operational context wherein a hazard appears (Figure 5). The structure is provided in order to facilitate the link to WP5 “Functional and Object oriented Safety Model”:

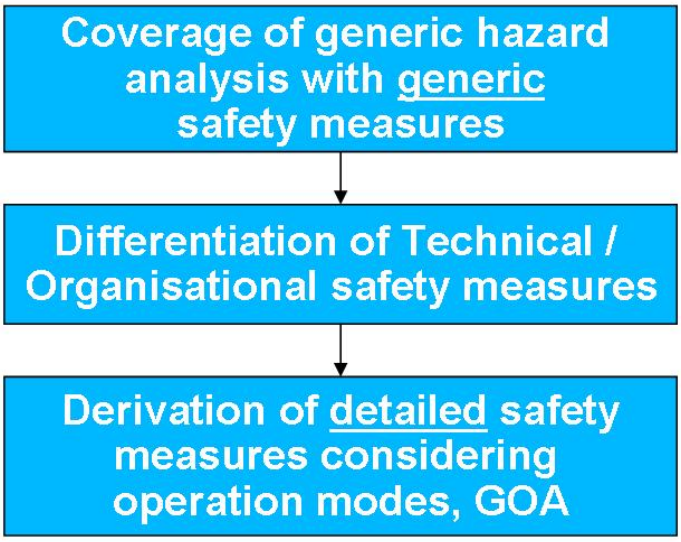


Figure 5 WP5 prospect: Coverage by safety measures

Safety measures are at first described by their functionality in order to cover the generic hazards. Further refinements could be done by the differentiation of technical and organisational safety measures and their allocation according to different operation modes.

For the purpose of the WP2 this grade of detail is beyond the intention. Nevertheless the structure of the segment “Coverage by safety measures” is motivated by WP5:

- Safety Measure
- Grade of Automation
- Responsibilities
- Remarks

Within the segment the safety measures are collected as generic measures. Further information, e.g. their implementations or even realisations per GOA and the responsibility for the measure are given optionally (see Figure 6)

Figure 6 Segment Safety measures

3.2.4 Consolidation of segments

The arrangement of the three segments to one another results in the overall structure of the MODSafe Hazard Analysis. The generic hazard analysis is filled in this structure. The table structure supports the clearness of relation between a hazard, its possible consequences and available safety measures to prevent from the consequences (Figure 7).

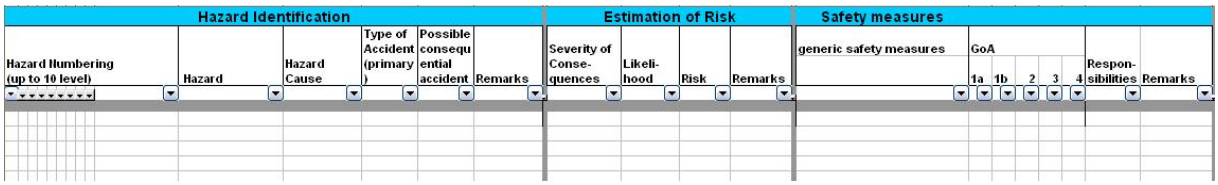


Figure 7 Table Structure MODSafe Hazard Analysis

4. Completion of the MODSafe Hazard Analysis

The table structure for the Hazard Analysis is filled with generic hazards. The results from several hazard analyses are collected in order to achieve an almost complete list of hazards. Induced hazards (by implementation of new safety measures or by their failures) shall be respected.

The hazard analysis shall be clearly arranged. The hazards are classified in several hazard groups. The classification serves to sort the system hazards and enables to check the hazard list against further hazard analysis. This helps to fill in new hazards on adequate positions.

Additional information can be entered as remarks or if necessary, further columns can be added.

4.1 Approach on PHA

The MODSafe PHA is based on an approach which was already applied within the EU-Founded Project MODURBAN /2/.

This approach is based on a global approach to hazard analysis, uncoupled from transportation systems. In the focus of the analysis are the human being and the question which physical effects harm human being. Within these important effects are (see Figure 8):

- Momentum transfer / Inadequate acceleration or jerks
- Burn
- Electrocution
- Toxication
- Temperature
- …

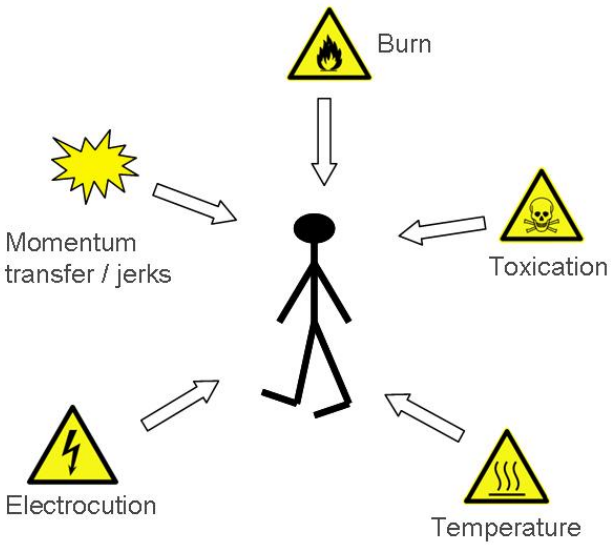


Figure 8 physical impacts on human being

Transferred to a transportation system, the threat of “momentum transfer / inadequate acceleration or jerks” represents the most important group. The transportation of passengers is the core task of urban railway system and requires a detailed examination of impact of train movement to human integrity. The adoption of this approach to the hazard analysis

results in a break down of the hazards related to their operational occurrences respectively to their local appearance:

Table 1 First level categorisation of MODSafe Hazard List

1	Train movement
2	Train interior
3	Train-Station Interface (with train in station)
4	Train-Station Interface (without train in station)
5	Depot
6	Operations Control Centre (OCC)
7	Maintenance
8	Emergency – Evacuation
9	Environment (force of nature)

The detailed breakdown of these categories results in up to nine levels, wherein system hazards appear as well as hazards evoked by security aspects (e.g. sabotage, criminal acts, terrorism). Security aspects itself are in focus of MODSafe WP 8 and WP9. The breakdown of hazard levels stops before a detailed hazard considers a concrete realisation of a system component.

The Figure 9 illustrates the breakdown of the train movement hazards up to the third level. Train movement hazards are linked to the consideration of the infringement of the clearance envelope (CE). The breakdown is motivated by the effort to preserve the hazard analyses as generic as possible:

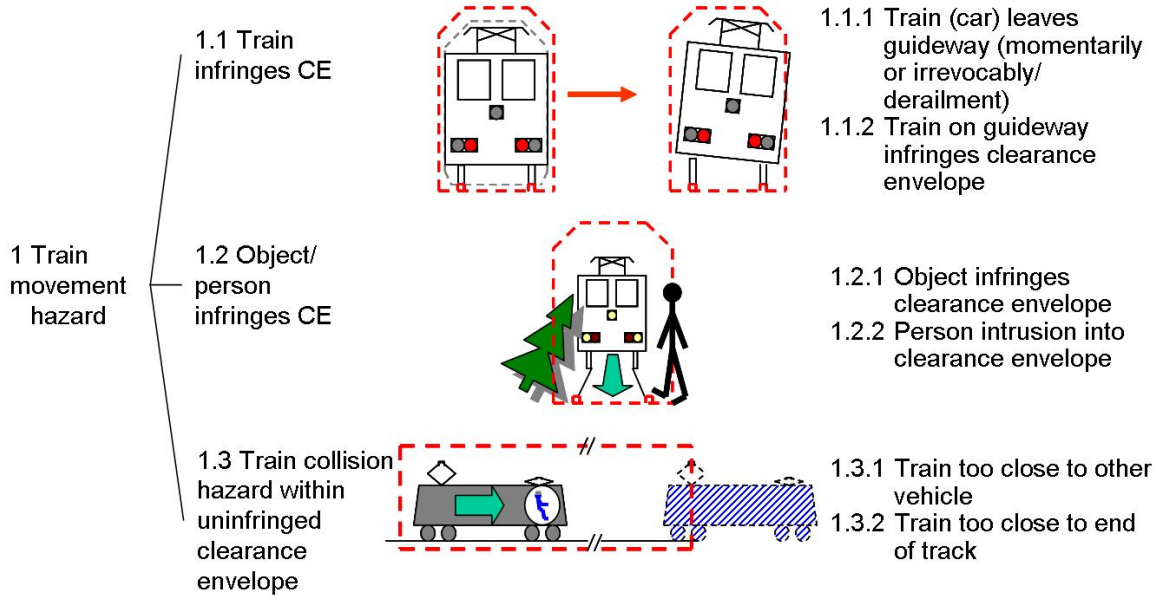


Figure 9 Second and third level categorisation of train movement hazards (Group 1)

Table 2 Second level categorisation of Train Movement hazards (Group 1)

1	**Train Movement**
1.1	Train infringes CE
1.2	Object/person infringes CE
1.3	Train collision hazard within uninfringed CE

While the train movement hazards are dominated by the physical effect of momentum transfer the further hazard groups are not as strictly assignable to one sort of physical impact. For instance, hazards related to fire, heat, electrocution, falling of person etc. may

appear at any time and any place uncoupled from the transportation context. They threaten the integrity of personal health in a general manner.

Nevertheless, the severities of these hazard consequences vary according to their occurrence. Within a train and during train movement, the circumstances are quite different to the same hazards on platform (e.g. means of escape).

Thus, these kinds of hazards appear within the group of train interior hazards (Table 3) as well as within the group of train-station Interface hazard (without train in station) (Table 5):

Table 3 Second level categorisation of train interior hazard (Group 2)

2	**Train interior**
2.1	person struck/hurt by object
2.2	explosion
2.3	person fall in train
2.4	fire
2.5	Inadequate temperature
2.6	asphyxiation
2.7	toxic releases
2.8	radiation
2.9	electrocution in train
2.10	person contact with machinery
2.11	person exposed to noise
2.12	Person needs urgent assistance

Table 4 Second level categorisation of train-station interface hazard (with train in station) (Group 3)

3	**Train -Station interface (with train in station)**
3.1	passenger falls from train on station track
3.2	Passenger injured by door closing
3.3	train departs with passenger trapped in doors
3.4	train moves at passenger exchange
3.5	passenger between Vehicle /Vehicle gaps
3.6	person steps/ falls into Vehicle-Platform gaps
3.7	electrocution

Table 5 Second level categorisation of train-station interface hazard (without train in station) (Group 4)

4	**Train-Station Interface (without train in station)**
4.1	person struck by falling object
4.2	person hit by sharp object
4.3	person hurt by protruding object
4.4	wheelchair hazards
4.5	person fall in station
4.6	person falls/intrudes on station track
4.7	electrocution in station
4.8	smoke
4.9	explosion
4.10	fire in station
4.11	toxic release in station

The third group of hazards considers the train-station interface hazards with train in station, i.e. hazards related to passenger exchange (PXCH). These hazards are typical transportation system hazards similar to the first group of hazards. The focus is on the

question to which hazards is a passenger exposed who enters or exits a train in station. The critical moment for this group of hazards is during the change from train onto platform or vice versa. The occurrence of these hazards is on the platform edge on its length.

The following figure illustrates the breakdown of the train-station interface hazards during passenger exchange (Figure 10). Beside the hazards concerning falling / trapping of person and moving trains or parts of train, the danger of electrocution along the train surface or infrastructure equipment on platform area is respected.

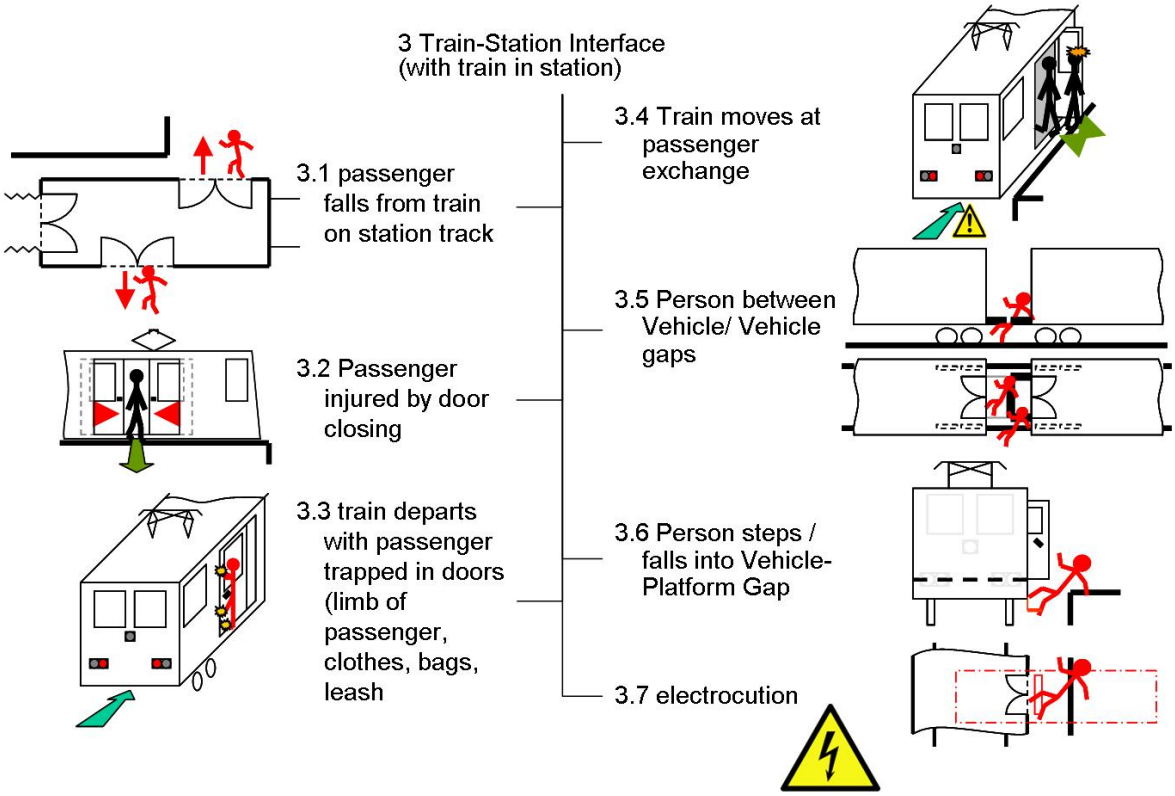


Figure 10 Second level categorisation of train-station interface Hazards (with train in station) (Group 3)

The hazards groups 1 to 4 cover relevant hazards that threaten passengers during regular train operation in public available areas.

The hazard analysis covers also non-public areas of a transportation system, e.g depots (Group 5, see Table 6) and Operations Control Centre (OCC, Group 6, see Table 7). It is assumed that in general only staff is exposed to these areas. However the presence of passengers cannot be excluded (see sub-category 5.4: passenger in depot area).

Table 6 Second level categorisation of depot hazards (Group 5)

5	**Depot**
5.1	Staff injured by operation of machines and equipment
5.2	Shunting hazards
5.3	undue train / vehicle enters operation area
5.4	passenger in depot area
5.5	staff run over by train

Table 7 Second level categorisation of OCC hazards (Group 6)

6	OCC
6.1	Fire in OCC
6.2	Electrocution in OCC
6.3	Explosion in OCC
6.4	Building collapse
6.5	Terrorism, Attacks, Criminal Acts
6.6	Radiation in OCC
6.7	asphyxiation / toxication in OCC

Beside the hazards respecting non-public areas mentioned in the groups of Depot and OCC Hazards, a further category deals with hazardous situations occurring during maintenance actions. These hazards respect the domain of occupational health and safety of staff particularly with regard of a railway system. It includes general threats on the integrity of personal health (see Figure 8) as well as threats linked to the work with railway equipment:

Table 8 Second level categorisation of maintenance hazards (Group 7)

7	Maintenance
7.1	Staff injured by operation of machines and equipment
7.2	Electrocution / Lightning
7.3	staff endangered by moving train
7.4	obstacles on guideway or walkway
7.5	explosion during maintenance
7.6	fire during maintenance
7.7	asphyxiation/ toxication
7.8	inappropriate temperature
7.9	staff in danger cannot escape guideway
7.10	radiation
7.11	Staff caught in machinery

A further category deals with hazards during emergency or evacuation where passengers and staff are exposed to unfamiliar and dangerous situations. The aim is the safe evacuation of person. The provision of escape routes is mandatory. They guide the persons also through original non-public areas. With regard to unskilled persons (e.g. passengers) hazards shall be considered within this group of hazards.

Table 9 Second level categorisation of emergency and evacuation hazards (Group 8)

8	Emergency – Evacuation
8.1	people hit by train: involved / adjacent track
8.2	burn / fire
8.3	asphyxiation / toxication
8.4	electrocution / lightning
8.5	explosion during evacuation
8.6	inappropriate temperature
8.7	radiation
8.8	drowning
8.9	person hurt during evacuation (others)

Finally hazards caused by the force of nature are considered separately. Actually these hazards could already be included in other hazard categories on a lower level as they are the causes for railway system hazards. Nevertheless they cannot be dominated completely by actors of a railway system. In order to highlight this fact these hazards are collected in a

separate group of hazards. The importance of environmental hazards for a specific urban railway system varies according to their geographical position.

Table 10 Second level categorisation of environmental hazards (Group 9)

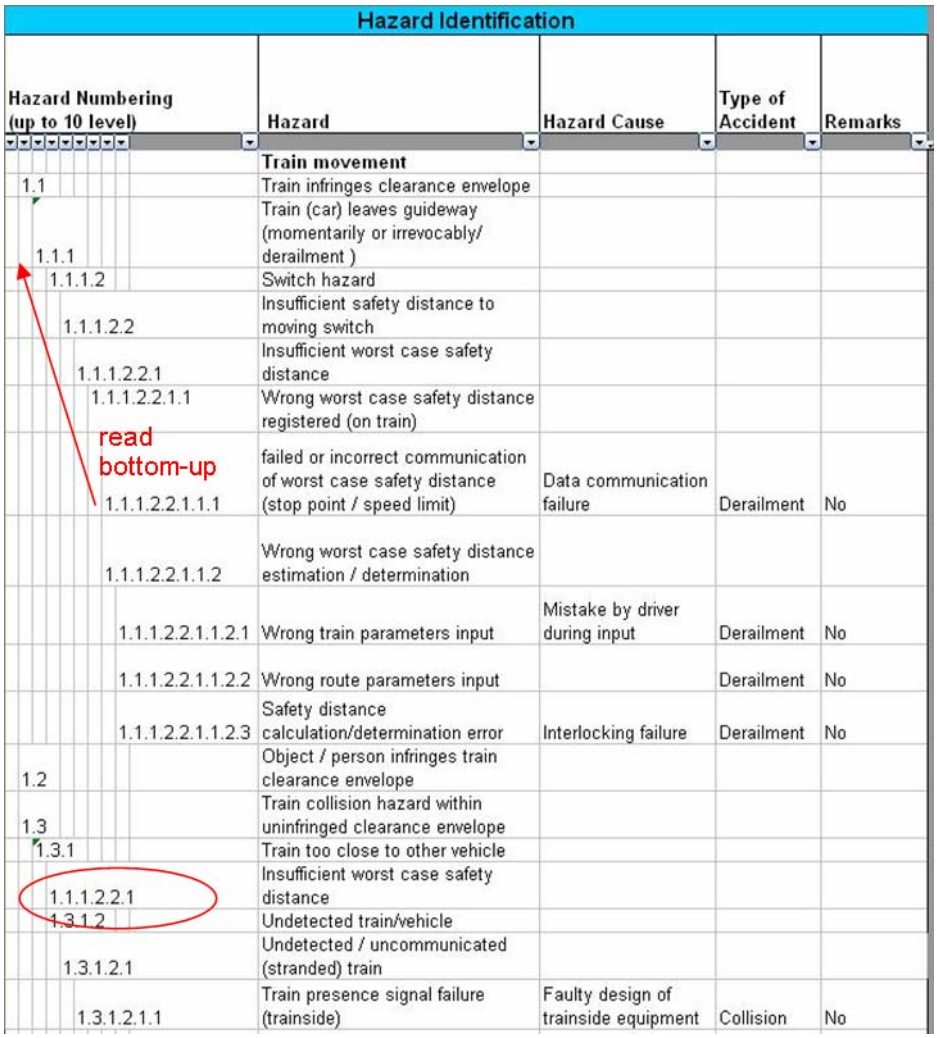
9	**Environment (force of nature)**
9.1	weather conditions (moderate)
9.2	Force of nature

4.2 Deal with the table structure

The transmission of a multi-level hazard analyses into a table structure requires a careful filling of the list and the knowledge about how to use the hazard analysis. This chapter introduces in the usage of the hazard analysis.

The understanding of the context of a hazard within the table includes the knowledge of its superior hazard levels. The first level (e.g. train movement hazards) presents a rough classification of hazard. The second level instead specifies the grouping of the considered hazard and indicates the resulting type of accident. The hazard analysis is read bottom-up, beginning from the lowest level of a subcategory (see Figure 11).

According to the complexity of urban railway systems, some hazards appear in several sub-categories as the consequences or causes of other hazards. The appearance of a hazard twice or more within the hazard list is indicated by the reference of the hazard numbering:



Hazard Identification				
Hazard Numbering (up to 10 level)	Hazard	Hazard Cause	Type of Accident	Remarks
	Train movement			
1.1	Train infringes clearance envelope			
1.1.1	Train (car) leaves guideway (momentarily or irrevocably/ derailment)			
1.1.1.2	Switch hazard			
1.1.1.2.2	Insufficient safety distance to moving switch			
1.1.1.2.2.1	Insufficient worst case safety distance			
1.1.1.2.2.1.1	Wrong worst case safety distance registered (on train)			
1.1.1.2.2.1.1.1	failed or incorrect communication of worst case safety distance (stop point / speed limit)	Data communication failure	Derailment	No
1.1.1.2.2.1.1.2	Wrong worst case safety distance estimation / determination			
1.1.1.2.2.1.1.2.1	Wrong train parameters input	Mistake by driver during input	Derailment	No
1.1.1.2.2.1.1.2.2	Wrong route parameters input		Derailment	No
1.1.1.2.2.1.1.2.3	Safety distance calculation/determination error	Interlocking failure	Derailment	No
1.2	Object / person infringes train clearance envelope			
1.3	Train collision hazard within uninfringed clearance envelope			
1.3.1	Train too close to other vehicle			
1.1.1.2.2.1	Insufficient worst case safety distance			
1.3.1.2	Undetected train/vehicle			
1.3.1.2.1	Undetected / uncommunicated (stranded) train			
1.3.1.2.1.1	Train presence signal failure (trainside)	Faulty design of trainside equipment	Collision	No

Figure 11 Reading of the Hazard List

The estimation of risk and the determination of possible safety measures to prevent the hazard evolution are allocated on the lowest level of the hazard analysis (Figure 12).

The severity of a lowest level hazard is determined respecting this hazard in a generic manner, i.e. its severity is not derived from the current link to upper level hazards.

Hazard Identification		Estimation of Risk				Safety measures							
Hazard Numbering (up to 10 level)	Hazard	Severity of Conse-quences	Likeli-hood	Risk	Remarks	generic safety measures	GoA 1a	1b	2	3	4	Respon-sibilities	Remarks
1.1.1.2	**Switch hazard**												
1.1.1.2.1	**Wrong switch status**												
1.1.1.2.1.1	**undetected misaligned switch**	Catastrophic				Ensure safe switchable route elements - This function is intended to switch switchable route elements (points, diamond crossings with slips, crossings with moveable frogs and derailer) an d ensures the switching is performed under normal (undisturbed) and safe conditions.							
						Regular inspection and maintenance							Preventive maintenance, regular inspections, corrective
1.1.1.2.1.2	**undetected unlocked switch**	Catastrophic				Ensure safe switchable route elements - This function is intended to switch switchable route elements (points, diamond crossings with slips, crossings with moveable frogs and derailer) an d ensures the switching is performed under normal (undisturbed) and safe conditions.							
						Regular inspection and maintenance							Preventive maintenance, regular inspections, corrective maintenance
1.1.1.2.1.3	**undetected broken switch components**	Catastrophic				Supervise other safety relevant Inputs - This function is intended to supervise the detection of hazardous situations by external sensors.							
						Regular inspection and maintenance							Preventive maintenance, regular inspections, corrective maintenance
1.1.1.2.2	**Insufficient safety distance to moving switch**												
1.1.1.2.2.1	**Insufficient worst case safety distance**												
1.1.1.2.2.1.1	**Wrong worst case safety distance registered (on train)**												
1.1.1.2.2.1.1.1	**failed or incorrect communication of worst case safety distance (stop point / speed limit)**	Catastrophic				Supervise data communication equipment - This function is intended to inform staff about availability of functions concerning operation and status of data communication equipment.							

Figure 12 Estimation of Risk and safety measures on the lowest level of the hazard list

5. Conclusion

This deliverable enables to navigate through the Hazard List provided in the Annex of this document /7/. The derivation of the organisation of the hazard list helps to understand the structure of the hazard list and to complete the list. Therefore, the WP2 partners check the list against their own hazard analyses and add generic hazards if something is missing. As every partner has different hazards in focus, the result is a nearly complete hazard list. The importance of a hazard can be managed by its risk estimation: The user can adjust the likelihood according to its task, e.g. having a particular urban train system in mind.