ERMG ADAPTATION TO UTS

Project Title	RESOLUTE
Project number	653460
Deliverable number	D3.7
Version	1-15
State	FINAL
Confidentially Level	PU
WP contributing to the Deliverable	WP3
Contractual Date of Delivery	M12 (30/04/2016)
Finally approved by coordinator	17-05-2016
Actual Date of Delivery	17-05-2016
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Framework Programme of the European Union

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EXECUTIVE SUMMARY

Following the findings of Deliverable D3.5, this document aims to provide the adaptation of the ERMG produced in D3.5 within the concept of the Urban Transport System (UTS), along with operationalization aspects. In fact what this document strives to achieve is a "virtual" application of the suggested recommendations for the case of UTS. Of course, the complexity and uniqueness of each UTS under consideration are such that do not allow going into practical detail.

Thus, each of the guidelines produced in Deliverable D3.5 is presented here in a UTS-oriented "translation", aiming to show an application of the generic guidelines into a specific sector. The generic functions identified in Deliverable D3.5 are here also adapted for the case of UTS (see Annex A). Moreover, some additional aspects are discussed here, namely the criticality of the UTS (in terms of its complexity and exposure to external threats) in the overall CI framework, the role of network analysis in resilience management of UTS, along with the performance conditions of UTS regarding variability and uncertainty. Following all the above, some preliminary scenarios have been constructed and are presented here (the full pilot scenarios are going to be produced in WP5; here only examples are given).

It should be underlined that the contents of both Deliverables D3.5 and D3.7 are planned to be updated by the end of the project, in order to incorporate the findings of the RESOLUTE pilots, as well as the comments of the Advisory Group.

This document is composed by 8 Chapters and 1 Annex.

In the first Chapter an introduction to the document is provided, presenting its scope. Then in Chapter 2, a brief explanation of the resilience criticality of UTS is presented, through the analysis of the characteristics that define it, i.e. the criticality of the system as such, its complexity and its exposure to threats, concluding with underlining the significance of resilience for UTS.

Chapter 3 presents an analysis of the UTS performance conditions in terms of variability and uncertainty, while Chapter 4 discusses the role of network analysis in UTS resilience. In Chapter 5 the ERMG guidelines of D3.5 are presented, adapted based on the needs of UTS, followed by some recommendation for managing interdependencies, both between sub-systems of UTS as well as cross-sectoral ones (Chapter 6).

Finally, in Chapter 7, preliminary operational scenarios are described and the Deliverable closes with the conclusions chapter (Chapter 8).

Last but not least, in Annex A, the generic functions defined within the framework of Deliverable D3.5 are presented, also adapted for the case of UTS.

PROJECT CONTEXT

Workpackage	WP3: European Resilience Management Guidelines
Task	T3.4: ERMG Adaptation to UTS
Dependencies	These guidelines influence the whole project work.

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Version History

Version	Date	Authors	Sections Affected
V1	25/4/2016	E. Gaitanidou, M. Tsami	All
V2	10/5/2016	E. Gaitanidou, M. Tsami	All
V3	13/5/2016	E. Gaitanidou, M. Tsami	All
V4	14/5/2016	E. Gaitanidou, M. Tsami	All
V1.13	16/5/2016	E. Gaitanidou	All
V1.14	17/05/2016	P. Nesi	All
V1.15	31/10/2016	E.Gaitanidou	1, 2, 5, 7 (revision upon request in 1st year Review)

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1 INTRODUCTION

Most of our social and economic activities rely on large scale and highly complex sociotechnical systems. These are characterised by a large number of different automation and information technologies and by the different interactions, dependencies and communications among them. It is these ever-more intensified system interdependencies and tightened couplings that keep adding to the complexity of these systems. The failure of these systems may have catastrophic consequences for the affected populations, which is why new strategies are needed to ensure their resilience.

Enhancing resilience in Urban Transport Systems, UTS, is considered imperative for two main reasons. First of all, such systems provide critical support to every socio-economic activity and are currently themselves one of the most important economic sectors in Europe. Secondly the paths that convey people, goods and information, are the same through which risks are propagated. Transport systems have thus developed a prominent safety and business critical nature, in view of which current management practices have shown evidence of important limitations. In essence, the majority of management practices are based on the assumption that systems and their operations can be fully understood and described and, therefore, a level of operational control deemed appropriate can be perceived, achieved and maintained, mainly by resorting to linear (purely based on cause-effect relations) and probabilistic risk assessment approaches. This does not take into account the underspecified nature of complex sociotechnical systems and the need to cope with fast pace changing environments.

1.1 Scope

RESOLUTE is based on the vision of achieving higher sustainability of operations in European UTS. The project recognises foremost the ongoing profound transformation of urban environments in view of ecological, human and overall safety and security needs, as well as the growing importance of mobility within every human activity. Sustainability is rapidly becoming an imperative need across all economic and social domains. Among many things, this requires overall enhanced operational efficiency, mainly by optimising the allocation and utilisation of available resources (organisational technical and human), whilst striving to continuously minimise any source of waste, namely incidents, accidents and other operational failures. Within this context, RESOLUTE considers resilience as a useful management paradigm, within which adaptability capacities are considered paramount. Rather than targeting continuous economic and financial growth of businesses and market shares, organisations should develop the ability to continuously adjust to ever-changing operational environments.

Within this framework, the main scope of this Deliverable is to adapt the ERMG produced in Deliverable D3.5 within the framework of Urban Transport Systems (UTS), specifying and “translating” the suggested recommendations in terms of the characteristics, the needs and criticalities of UTS. Furthermore, going one step forward, indicative operational scenarios are described, along with discussing the interdependencies of UTS with other critical infrastructures.

The work developed under WP3 is grounded on the RESOLUTE approach to resilience, as outlined in Deliverable D2.1, and was developed in order to match the framework given in Deliverable D2.2. The ERMG are structured in accordance to the four adaptive capacities that complex sociotechnical systems (CSS) should develop to enhance their sustained adaptability. This means that, on the one hand, each guideline individually addresses specific requirements, namely the management and allocation of resources needed. On the other hand, each of the four sets of guidelines aims to produce an integrated, yet flexible operational response to achieve the capacity to which they are assigned.

Each of the guidelines also reflects a specific function identified as operationally critical by means of the FRAM model previously developed. Based on the functional couplings identified, each guideline aims to reproduce fundamental needs for coordination between functions, namely through the development of critical operational flows of information.

The features herein described supported the development of guidance principles towards resilience that significantly innovate current state of the art. Rather than prescribing solutions towards improved protection, mitigation and recovery, in the face of known threats, RESOLUTE ERMG aim to enhance resource planning and allocation, communication and overall system cooperation and coordination, in order to maintain a flexible yet structured proactive response to continuous change. This is in line with project objectives and the innovative approach to resilience that RESOLUTE aims to deliver for the management of critical infrastructures, in particular within the transport sector.

2 UTS – A SYSTEM OF RESILIENCE CRITICALITY

Urban Transport systems today have to cope with significant vulnerabilities: aging infrastructure components, continuously increasing concentration of populations at urban areas, increasing interdependencies among physical and cyber infrastructures, co-location of many transportation systems with large-scale and potentially hazardous production facilities, along with ever growing threats of climate change and terrorism. All these have created significant challenges for the critical infrastructure systems.

A framework for enhancing critical transportation infrastructure resilience could potentially serve as a roadmap for addressing some of these pressing global challenges. The concept of resilience, however, has been broadly used to characterize a system that recovers rapidly from a disruption in order to resume normal operation. And resilience does not only involve recovery. UTS resilience is an overall concept, defining a complex transportation system that is able to better withstand disruptions. The transportation system includes physical, technical, social, and institutional elements that are all critical to resilience.

A resilience framework should not be considered as a way to retain the current status and return the system to a pre-disaster condition. It should be addressed as the framework within which it would become possible (by making the most out of existing capabilities and resources) to create or convert a transportation system into being more effective and much less vulnerable to disruption. A resilient transportation system has own robustness to withstand severe drawbacks, it is adaptable in order to respond appropriately to threats and can mitigate the consequences of threats through response and recovery operations. These three attributes—robustness, adaptiveness, and consequence mitigation—form the foundations of a resilient transportation system. (VOLPE, 2013)

2.1 Why is UTS critical?

Within the urban context, transport systems are today challenged to respond to a wide range of mobility needs, whilst coping with severe constraints of many different kinds, namely geographical, environmental, safety- and security-related, among others. The Urban Transport System (UTS) is a relevant case of an interconnected system where critical infrastructure and multi decision makers (people, civil protection, public administration, etc.) are involved. Moreover, the UTS is linked *to The Four* critical infrastructures (as defined within the new approach to the European Programme for Critical Infrastructure Protection – EPCIP) and following the approach suggested within the EPCIP, the concepts are based on a multidisciplinary holistic view of resilience for critical infrastructure.

The numerous links and interdependencies of UTS make it of major criticality in terms of critical infrastructure resilience. In the case of an emergency, regardless of the system that it may address, the transport system is always affected, either by the emergency itself, or by the actions and measures to prevent or confront it.

Thus, when considering the above mentioned interdependencies, along with the complexity of the system as such and its high exposure to a variety of threats (from system malfunctions to climate disasters and terrorist attacks), managing resilience in the UTS becomes a multi-parametric task of primal criticality.

2.2 System complexity

As indicated above, UTS is a system of high complexity. There are various factors that define it of UTS and, thus, underline its criticality:

- *Large scale networks:* Especially when referring to big cities or metropolitan areas, UTS is composed by networks of great volume and different nature (road, rail, etc.). The management of each type of network has many differences and the bigger the scale the most complex and difficult it is to effectively assure its proper operation. Moreover, impacts migration issues between network components, in case of a disruption in one of them, are making this task even more challenging.

- *Multiple modes*: UTS potentially comprises most of the available transportation modes, including road (private and public transport, cars and two-wheelers), rail (surface and underground), pedestrians and waterways. This characteristic alone is significantly raising the system's complexity, as the needs of each mode (and of each of its components) are different, both in normal operation and in case of an emergency.
- *Multiple industries:* A direct consequence of the variety of modes and actors in UTS is the involvement of a great range of related industries. Vehicle and building are the most evident ones, together with electronics, cyber technologies, fuels, commerce, etc. The list is long and the influence and impact of UTS to each of them is significant and multi-parametrical.
- *Multiple operators – scattered responsibility:* This is directly linked to the above point, as the existence of multiple operators in the system (usually a different one per transportation mode, plus private transport) can be an additional factor of complexity in terms of responsibilities' distribution. This may become more crucial in the case of an emergency, as the management of system actors would require coordination in multiple and different in nature levels.
- *Public-private mix:* The fact that UTS is composed by both public (public transport vehicles, infrastructure, etc.) and private (own vehicles, pedestrian movement) components, is another reason that contributes to its complexity, as there are different rules and means of controlling their application in each case, while managing the whole system demands an overall control function.
- *Multiple recipients* (people, freight): The main recipients of the services offered by UTS are people and goods. In both cases the demanded service can be highly differentiated and unpredictable, in terms of its nature, frequency, duration, location, etc. Moreover, a disruption in the system operation could result in major social and economic consequences.
- *Critical to economy:* The criticality of UTS in the local and, consecutively, the national and international economy is obvious, not only from all the above mentioned factors, but also due to the fact that the urban environment is the core of the economy and UTS is the primary means for any kind of economic activity to flourish and succeed to its targets, e.g. movement of goods, transportation of people to work, leisure, shopping centre, etc.

From all the above, it is evident that dealing with UTS means dealing with a highly complex, multi-actor and multi-parametric system, whose management – especially in terms of resilience – is a critical and challenging task. This complexity is definitely a drawback for achieving absolute control of the system and, in fact, this is not the aim of resilience management. However, it requires the establishment of concrete structures and strong synergies, in terms of envisaging a sustainable and resilient operation.

2.3 Threats exposure

Apart from its high complexity, presented in the previous section, UTS is a critical system in terms of resilience, also due to the fact that it is widely exposed to threats. Due to its multi-operational, multi-actor and multi-component nature, UTS's exposure to threats is really unlimited and characterized by high uncertainty and unpredictability. By the term "threats" it is considered any external event that may lead to the disruption of the normal system operation. For the case of UTS, such events are mainly deriving from natural and man-made threats. Each of these sources of threats may impose a vast variety of events that the UTS would need to face; thus, enhancement of UTS resilience is aiming to secure the optimum level of system operation in a great variety of possible situations. What is of course of utmost significance, and is where resilience management is mainly targeting, are the threats that are rather unpredictable, unexpected and without any precedent. Thus, a resilient UTS should be organised and managed in a way that it would be ready to react, adapt and retain its operability under any kind of threat, either expected or unexpected (see also D2.1). In the following sub-sections, the most common types of threats that UTS are facing are briefly described.

2.3.1 Natural disasters

Natural disasters can come in numerous different forms; the ones that could actually affect UTS can be distinguished in two main categories:

- **Extreme weather events**
- **Geophysical**:

2.3.1.1 Extreme weather events

Weather events can be of different nature and magnitude. The most usual ones, like storms and heavy snowfalls result in small-scale impacts on the UTS, such us congestions or other delays, road closures or diversion of traffic, etc. However, there are more intense weather phenomena (e.g. hurricanes, floods, etc.) that can result in significant impacts on the operation of the UTS, as they usually affect a great area and the system needs substantial time and effort to regain its regular operability.

There are concerns that climate change may be linked with more recurrent extreme weather events. Beyond this debate the fact remains that extreme weather events will continue to occur, but their frequency and scale is uncertain. (Rodrigue, 2017)

As stressed out in the (EC, 2001) climate change is underway and cannot be stopped completely. Action to mitigate greenhouse gas emissions is essential to avoid even worse long-term impacts. However, some changes occurred in the climate system are already irreversible, with inevitable consequences. Unless the vulnerabilities and risks are managed appropriately, climate change will increasingly affect performance of any kind of human activity and the investments made for facilitating them.

Standard climate conditions are expected to change and extreme climatic events are going to be of greater frequency and intensity. Extreme events are also expected to be met in locations where previously have not and which were not considered as vulnerable. The climate system is gradually expected to reach a new, different equilibrium, thus future projections deriving from climatic historical data may no more be valid. For example, events that today are marked as 1 in 500 years (like the hot summer in Europe in 2003 that was responsible for more than 35,000 deaths) are expected to become less unexpected events (estimated to be a 1 in 2 year event by 2040).

This situation is prone to significantly affect the urban environment and UTS in specific, especially regarding its infrastructure components. Table 1 includes the most important severe weather events by geographical and seasonal relevance and the changes that are expected until 2050, along with their impacts on road transportation. Climate change may result in breaching design thresholds or even threshold failures, thus leading to forming a smaller "gap" between normal operation and critical situation. Climate change is also expected to modify the interactions of the UTS with the rest of environmental and social systems.

From all the above the necessity for adapting an integrated, cross-sectorial approach towards climatic risk management and resilient design, is becoming evident.

Table 1: The most important severe weather events by geographical and seasonal relevance, changes until the 2050s (2041–2070), duration and warning time and main impacts (EWENT project, 2011)

Extreme weather event	Geographical and seasonal relevance	Likely changes until the 2050s	Duration and warning time	Impact on road transportation

Extreme weather event	Geographical and seasonal relevance	Likely changes until the 2050s	Duration and warning time	Impact on road transportation
Heat waves	Most frequent and extreme in southern Europe, especially Iberian Peninsula, Greece Turkey; Common in central and eastern Europe; Summer phenomenon	Significant increase in the probability of hot days across Europe, especially in currently hot regions	Depending on the region – from days to several weeks; Several days of warning time	Damage of pavement; Vehicle failure (Tires); Forest fires; Fatigue among the drivers
Cold waves	Most frequent and extreme in Scandinavia and alpine regions; Decrease toward south; Winter phenomenon	General decrease all over Europe, especially in currently most affected areas	Depending on the region from days to several weeks; Several days of warning time	Reduced surface friction; Road maintenance; Technical failure of vehicles and infrastructure; Deterioration of pavement
Heavy precipitation (large-scale systems)	Most frequent in south western Norway, Alps, Gulf of Genoa and British Isles; All year phenomenon with strongest events mostly during winter	Slight mean increase for most regions; Slight decrease in some Mediterranean areas; Climate models disagree to some extent	Duration of several hours to days; Warning time of days	Reduced visibility and surface friction; Floods and landslides
Snowfall	Most frequent in northern Europe, alpine regions, eastern Europe; Relevant also for southern Europe; Winter phenomenon	Overall decrease in snowfall events over Europe strongest in northern Europe; More frequent strong events over the Scandes and parts of eastern Europe	Duration between hours and several days; Warning time of days	Reduced visibility and surface friction; Obstacles on roads due to snowdrift and broken branches
Large-scale storms and wind	Most affected areas are the British Isles, Iceland and the western coastal areas; Relevant for the whole continent; Strongest events occurring during winter months	Slight increase in most western, central and southern European regions for the 2020s, decrease over the inland Iberian Peninsula and eastern Europe; General decrease for the 2050s; Climate models disagree to some extent	Duration of several hours up to days; Warning times of days	Difficult driving conditions due to gusts; Obstacles on the road due to fallen trees and other objects
Thunder-storms (strong wind gusts, lightning, intense precipitation, hail)	Most frequently over the Mediterranean region, the Balkan and east-central Europe; Relevant for the whole continent; Summer phenomenon	Slight general increase over Europe; Difficult to capture with currently available climate models	Duration of tens of minutes to a few hours; Warning times of hours to a day depending on the spatial precision	Reduced visibility and surface friction; Obstacles on roads; Failures in transport control systems
Blizzards (strong wind gusts, lightning, intense snowfall)	Predominantly in the Alps and northern Europe; Most affected areas are the western coast of Norway and Iceland; Winter phenomenon	Slight general decrease in the currently affected areas; Difficult to capture with the currently available climate models	Duration between hours and a day or more; Warning times of about one day; Generally difficult to forecast	Reduced visibility and surface friction; Obstacles on roads; Failures in transport control systems

Extreme weather event	Geographical and seasonal relevance	Likely changes until the 2050s	Duration and warning time	Impact on road transportation
Fog	Mainly local phenomenon; Rather relevant in moderate and cold regions; Rare in the Mediterranean region; More common in late autumn and winter	General increase as observed in the last decade; Difficult to capture with the currently available climate models	Duration of several hours; Warning times of about a day (regiona warnings); Local forecasts challenging	Reduced visibility

2.3.1.2 Geophysical

Geophysical threats mostly consist in the consequences of tectonic activity, resulting in earthquakes and, in some cases, consecutive tsunamis.

The UTS is affected by this kind of threat mainly to what refers to its hosting infrastructure, due to disasters to roads, bridges, tunnels, etc. that can come after an earthquake, which can have a significant impact on the operation of the network as a whole, during both the crisis and the recovery period. Although areas of high earthquake occurrence are mostly known, the specific location and magnitude of an upcoming earthquake is not yet possible to accurately predict, thus inserts a factor of uncertainty in design and management of relevant transport infrastructure. A the consequences of an earthquake to the infrastructure usually imply the need for rebuilding, the disruption in the system operation can be of different levels, varying from short-term lane closure to long term total closure of the affected road/bridge/tunnel, which of course would result in needs for rerouting, possible consecutive congestion, etc.

To this respect, a series of methodologies, software and special tools have been developed world-wide for the assessment of seismic risk, based on network analysis, seismic hazard assessment, vulnerability assessment for each network component and estimation of the direct and indirect earthquake loss. A relevant example is the development of the widely used HAZUS methodology (HAZUS-MH, 2004). HAZUS provides estimates of physical damage, as well as functionality, of the different components of the roadway network, while it also supports consideration of multiple hazard sources (i.e., floods, tornados, earthquakes) (Kappos et. al, 2014).

2.3.2 Man-made threats

In terms of man-made threats, these can be of different nature, frequency, magnitude of event and severity of consequences. In principal, the following can be considered as main types of man-made threats for the UTS:

- **Accidents**
- **Infrastructure failure**
- **Conflicts, cyber-attacks and terrorism**
- **Economic and political instability**.

2.3.2.1 Accidents

Probably the most common threats in UTS are the ones related to accidents. These are usually due to either technical failure or human error. They can of course vary in gravity, most of them not directly considered as a major threat, as they do not impose significant disruption to the operation of the total system. However, there can be accidents of large magnitude (e.g. in a terminal, in a metro, or in a tunnel and most significantly when hazardous material transportation is involved) that can cause a major disruption to the overall UTS operation, resulting in closing roads, need for mode shift, serious damages to the infrastructure and numerous injuries or even loss of lives. These kinds of accidents are considered as disasters and require adequate preparedness in terms of both prevention and immediate response, so as to minimize to the possible extend their harmful impacts.

2.3.2.2 Infrastructure failure

Partial or total failure of any item of the transportation infrastructure is expected to cause significant disruption in the operation of the overall UTS. This can be caused by different factors like problematic design, limited or no maintenance, overuse, etc. The impacts of this kind of threat are maximised in the case of natural disasters. The most critical infrastructure elements are considered to be bridges, tunnels, terminals and any other infrastructure whose failure may create multiple cascading effects to the rest of the UTS infrastructure, while implying major impacts in terms of loss of both lives and property.

2.3.2.3 Conflicts, cyber-attacks and terrorism

Conflicts such as wars and civil unrest often result in the damaging of infrastructure with transportation commonly a voluntary or involuntary target. Even smaller in scale conflicts, like protests, strikes, etc. can be a significant threat to the operation of the UTS.

Cyber threats: Today's transportation networks highly depend on information systems and networks, therefore cyber-attacks have become a scary reality. In today's trend of creating "Smart" cities, of which transportation systems are considered as a cornerstone, digital infrastructure is dominant and interconnections between different services and actors may become target of cyber-attacks. The core of information and communication systems is data; such data may contain information on tracking the location, status, and condition of physical assets and associated infrastructure, and thus provide the capability of control of the different assets. This implies a series of minor or major threats to the safety and security of transportation systems upon a cyber-attack. Key risks deriving from cyber-attacks can be considered the following: **(1)** Physical asset damage and associated loss of use; (**2**) Unavailability of IT systems and networks; **(3)** Loss or deletion of data including data corruption or loss of data integrity; **(4)** Data breach leading to the compromise of third-party confidential information, including personal data; **(5)** Cyber espionage resulting in the compromise of trade secrets, and other sensitive information and **(6)** Extortion demands to cease a cyber-attack along with direct financial loss and damage of reputation.

Terrorism: Ever since 9/11 event in New York and with the more recent attacks in Europe and elsewhere, terrorism has become a major concern for Governments worldwide, in terms of protecting the security of their citizens, as well as their environment, from the consequences of such attacks.

A cross-continental approach on this issue is the Terrorist Finance Tracking Programme (TFTP), which has generated significant intelligence that has helped detecting terrorist plots and tracing their authors. An EU-US Agreement on the exchange of financial information ensures protection of EU citizens' privacy and gives the U.S. and EU law enforcement authorities a powerful tool in the fight against terrorism. The Commission has assessed the possible options for an EU Terrorist Finance Tracking System (EU TFTS) with regard to their necessity, proportionality, cost-effectiveness and respect of fundamental rights.

UTS is a system that is highly vulnerable to terrorist attacks, as it involves the movement and gathering of crowds and systematic control of the system's users is not usually possible. Buses, trains, airports in London, Madrid, Moscow, Paris, Tokyo, Brussels and many other cities have been sites for terrorist attacks in recent years. Acts of terrorism intersect with transportation systems in three ways:

- When transportation is the means by which a terrorist attack is executed;
- When transportation is the end, or target, of a terrorist attack; or
- When the crowds that many transportation modes generate are the focus of a terrorist attack.

As indicated by Schupp et al., the incidence of attacks on road transport is globally not higher than 100 events in the decade 1996-2006 (Schupp et al., 2006), though it seems to has grown within the next decade. Also it has been remarked to have a greater growing rate relatively to other forms of terrorism and, thus, is becoming more popular with terrorists.

2.3.2.4 Economic and political instability.

The impacts of this kind of threat are rather indirect, as, in the case of economic and/or political instability it is expected that there would be limited budget available for the maintenance or reconstruction of transport infrastructure and vehicles, thus rendering the threats of accident and/or infrastructure failure more possible. It could also have an impact on the expenditure for protection of the UTS against any other kind of threat, either natural or man-made.

Even though, as mentioned above, this is an indirect threat, it is considered important as the current political and economic situation in the EU (and beyond), with the economic crisis at its peak and several political issues directly or indirectly affecting the social and economic stability, this threat is expected to be one of most crucial ones in the years to come.

2.4 UTS resilience

Resilience design and management for UTS is nowadays a necessity, in order to effectively confront the difficulties arising from UTS system complexity and exposure to threats, as analysed above. The general principles that should be followed could be summarized in the following:

- Prevent incidents within control and responsibility, effectively protect critical assets.
- Respond decisively to events that cannot be prevented, mitigate loss and protect employees, passengers and emergency respondents.
- Support response to events that impact local communities, integrating equipment and capabilities seamlessly into the total effort.
- Recover from major events, taking full advantage of available resources and programs.

These issues are tackled in detail in the ERMG, presented upon adaptation for the UTS in Chapter 5 of the present Deliverable.

3 UTS PERFORMANCE CONDITIONS ANALYSIS IN TERMS OF VARIABILITY AND UNCERTAINTY

Within the scope of Deliverable D3.5 a matrix was built to facilitate the relation between the functional system description and the human, technical and organisational features that may give shape to critical infrastructures. This matrix related each of the CI sectors to the set of eleven performance conditions. A similar approach is here used with a specific focus on Urban Transport Systems (UTS). The performance conditions are here described in relation to four different components of UTS: light and heavy rail, public road transport and private road transport. The distinction between these four components was built based the contents of Deliverables D2.1 and D2.2. The criteria mainly relate to structural human, organisational and technological elements, as well as operational aspects, and can be summarised as follows:

- Light rail systems are characterised by the use of lighter rolling stock, similar to “tramway” or “streetcar” vehicles. Light rail mainly operate on exclusive right-of-way and more and more frequently are found along pathways that are shared with road traffic and even pedestrian use. This is at the source of many system complexities and degrees of variability that are very distinct from heavy rail systems such as underground metro networks, suburban commuter trains or national and international rail. More importantly, when compared with heavy rail, these lighter transport systems adopt a fundamentally different operational concept, as traffic is not controlled by conventional “absolute block” rail signalling systems. Semaphore aspects may be used, in many cases within the same ruling as road traffic, and the “drive-on-sight” principle applies at all times.
- Heavy rail systems operate within entirely isolated and exclusive right-of-way. All areas of the infrastructure, apart from stations and train access platforms, are restricted access areas. All train movements are bounded by traffic control systems, which still operate on the principle of “one train, one section” that forms that basis of “absolute block”.
- Public road transport has developed various aspects of operational control (even if they remain inherently open to strong interdependencies within their environment). They possess well established organisations, centralised control structures, skilled professionals, communication facilities and well defined safety and security procedures to be activated as necessary.
- On the other hand, private road transport remains strongly grounded on individual action and decision-making, even if recent technological developments around vehicles and infrastructure are likely to rapidly and profoundly shift the paradigm of private vehicle use.

Table 2: UTS – Performance conditions analysis in terms of variability and uncertainty

	UTS – Performance conditions analysis in terms of variability and uncertainty			
	Light rail	**Heavy rail**	**Road Public**	**Road Private**
Resources availability	Resources needs are significantly diverse: human (drivers, traffic controllers, engineers, managers, other); technological (circulating infrastructure, stations, vehicles, ICT assets, ticketing technology, etc.), and organisational (network definition, operations and maintenance planning, safety and security policy, budget). As light rail may circulate on an urban space, there is room for interactions with road users, creating a need for strict safety-related regulations and some effort to avoid shared space. New technological developments towards the autonomy of vehicles require significant improvement on technology together with appropriate safety-related regulations. Resources variability & transport dynamics increase complexity and uncertainty.	Identical resources needs as light rail but always operating on a closed space, thus without any urban insertion. Users accede to heavy rail on closed stations. Heavy rail can circulate on different infrastructures: underground tunnel or open-air infrastructure depending on the operating area: large size cities or suburban and interurban connections or rural areas. The variability of operating conditions and the different required resources is a source of variability and thus, generating complexity and uncertainty. Resource needs are significantly diverse and sometimes reliant on different stakeholders, rendering their management and availability considerably more uncertain.	Road public transport requires the same types of resources as described for rail transport mode, except the infrastructure, which is shared with every road user. Bus corridors exist in most cities, particularly in more congested areas, allowing for better efficiency of operations (less travel time and fuel consumption). Large size cities may have partial concessions to different operators, which cooperate to provide the required service. This cooperation requires special management resources and adds complexity and more variability and uncertainty to the system. Safety and security policy require additional human and technological resources.	Totally open system accommodating a great variety of users: drivers of different types of vehicles (private cars, buses, taxis, trucks, ambulances, police vehicles), bikers, motorcyclists, pedestrians, mobility scooters, etc. This requires different types of resources to regulate traffic (human and technological). New technological developments towards the autonomy of vehicles require new safety-related regulations. Resources needs are significantly diverse and tend to be reliant on different stakeholders, rendering traffic management considerably uncertain. Road private transport is extremely variable and unpredictable, which together with the transport dynamics, increases complexity and uncertainty.

	UTS – Performance conditions analysis in terms of variability and uncertainty			
	Light rail	**Heavy rail**	**Road Public**	**Road Private**
Training & Experience	Strongly reliant on highly qualified personnel and expertise for all tasks performance within the transport mode. The quality of training, as well as its update and adaptation to a new reality in terms of new technological developments, particularly, the vehicles automation, is required. The great diversity of training needs in the sector require the necessary budget, the required technological tools (computer-based simulations, driving simulators, augmented reality) and management decisions for updating training on a regular basis. Lifelong training for every professional in the sector and users' awareness about risks is also required. Experience among public transport professionals (drivers, traffic controllers and other experts) should be valorised and used as a major resource.	Strongly reliant on highly qualified personnel and expertise for all tasks performance within the transport mode. The quality of training, as well as its update and adaptation to a new reality in terms of new technological developments, particularly, the vehicles automation, is required. The great diversity of training needs in the sector require the necessary budget, the required technological tools (computer-based simulations, driving simulators, augmented reality) and management decisions for updating training on a regular basis. Lifelong training for every professional in the sector and users' awareness about risks is also required. Experience among public transport professionals (drivers, traffic controllers and other experts) should be valorised and used as a major resource.	Strongly reliant on highly qualified personnel and expertise for all tasks performance within the transport mode. The quality of training, as well as its update and adaptation to a new reality in terms of new technological developments, particularly, the vehicles automation, is required. The great diversity of training needs in the sector require the necessary budget, the required technological tools (computer-based simulations, driving simulators, augmented reality) and management decisions for updating training on a regular basis. Lifelong training for every professional in the sector and general users' awareness about risks is also required. Experience among public transport professionals (drivers, traffic controllers and other experts) should be valorised and used as a major resource.	Every road user, except pedestrians, must be licensed to drive/ride a specific type of vehicle. The licensing process involves training and the approval in a final exam. During a lifespan there will be periods for renewing each license, sometimes requiring re-training. Updating skills and training refreshments according to technological and environmental changes on the infrastructure and traffic laws are being necessary. Voluntary retraining for older drivers is a new issue that should be broadly applied. The existence of a national regulation of the driving licensing procedure should harmonise drivers' or riders' behaviour on the road. However, being the road system so open, there is a great variability of behaviours resulting from different levels of training and experience and leading to variability and uncertainty on the road environment.

	UTS – Performance conditions analysis in terms of variability and uncertainty			
	Light rail	**Heavy rail**	**Road Public**	**Road Private**
Quality of Communication	Communications are very critical in every public transport mode and must be optimised for the best efficiency. Main communications occur frequently between the driver and the traffic control centre; between the driver and the on board ticketing inspector; between the operator, the driver or the traffic control centre to the emergency service; to users and public in general. As the information or communication contents are crucial, its quality must be high in order to avoid any misunderstanding. This is even more crucial in systems operating with automatic vehicles, which tend to be more dependent on real time communication. Railway signalling must be clear and easily visible to the driver, particularly when circulating in urban insertion sharing the space with road users. ITS provides the technology for all communication requests with the aim of improving safety and efficiency but increasing variability and thus, the system complexity and uncertainty.	As for light rail systems, communications are highly critical in heavy rail systems operating in any type of infrastructure. Main and frequent communications occur between the driver and the traffic control centre; between the driver and the on board ticketing inspector; between the driver and the next or last station; between the operator, the driver or the traffic control centre to the emergency service; to users and public in general. As the information or communication contents are crucial, its quality must be high in order to avoid any misunderstanding. This is even more crucial in high velocity trains, which are more dependent on real time communication. Railway signalling must be clear and easily visible to the driver. ITS provides the technology for all communication requests with the aim of improving safety and efficiency but increasing variability and thus, the system complexity and uncertainty.	As communications are also very critical for road public transport, their quality must be high in terms of clear and precise contents, the types of displays, as well as the place and timing of displaying. Communications between the driver and traffic control centre and from the traffic control centre to stops with real time information technology are nowadays automatic and based on management software. For that, vehicles are equipped with GPS technology and monitored along the service hours. As vehicles share the infrastructure with all road users, drivers must follow traffic laws and common signalling on the infrastructure. ITS provides the technology for all communication requests with the aim of improving safety and efficiency but increasing variability and thus, the system complexity and uncertainty.	Road private transport is subject to traffic laws, which regulate every communication from and to the driver or rider when driving or riding. These regulations define precise conditions for allowing such communications. GPS allow for assistance to navigation but the system must be activated and set up just before starting. Nowadays drivers and riders can get every communication on their smart phones during driving/riding (phone calls, emails, SMS) which represent additional tasks to driving/riding and may create a shift from the secondary task to driving or riding according to the importance of the communication content. This has a negative impact on human functional abilities, skills and attention availability increasing risks. Filtering the relevant information to driving or riding and delaying the irrelevant one could increase safety and security. Being a totally open system, the huge variability associated to its dynamics increases complexity and uncertainty.

	UTS – Performance conditions analysis in terms of variability and uncertainty			
	Light rail	**Heavy rail**	**Road Public**	**Road Private**
Human Computer Interaction and operational support	In this context, drivers, traffic controllers, every operator, as well as users, interact with computer systems on a regular basis to perform any transport-related task. These interactions are regulated for each transport mode. Thus, interfaces and the software contents should follow a human-centred design approach in order to allow for easy, comfort, safe and secure interactions. International standards for interfaces design should be applied and usability requests should be identified and taken into account for the system design. Light rail systems are regulated by a traffic control centre providing the necessary support during the entire operation. Human computer interactions in the transport sector are varied and subject to a wide variability related to each technology and its context of use. Furthermore, these vehicles can circulate on an urban environment being regulated by traffic lights, which increases variability, and thus, complexity and uncertainty.	In this context, drivers, traffic controllers, every operator, as well as users, interact with computer systems on a regular basis to perform any transport-related task. These interactions are regulated for each transport mode. Thus, interfaces and software contents should follow a human-centred design approach in order to allow for easy, comfort, safe and secure interactions. International standards for interfaces design should be applied and usability requests should be identified and taken into account for the system design. Heavy rail systems are regulated by a traffic control centre providing the necessary support during the entire operation. Human computer interactions in the transport sector are varied and subject to a wide variability related to each technology and the context of use.	In the context of road public transport, drivers and most operators, as well as users, interact with several technologies on a regular basis. Safety and efficiency of these interactions require compliance of design, communication contents and conditions of use with international standards, usability requests and road transport regulations. Nowadays road public transport is supported by ICT in terms of location (GPS), movement of passengers (ticketing technology) and real time information to users inside the vehicle and outside (dynamic information on waiting times displayed on stops). Thus, different human-computer interactions directly related with the operations occur in this transport mode and involve the following areas: traffic control centre, drivers and users. Additional interactions related to displayed traffic information occur in the shared environment with the private road transport. Due to the different technologies in use, the different types of communication and information, the variety of professionals and users and the dynamics of traffic, the variability of the system is huge increasing its complexity and uncertainty.	In the road private system traffic controllers operate on a continuous human-computer interaction basis. Drivers and riders perform their driving/riding task interacting with different ICT: in the vehicle and in the environment. Other human-computer interactions not related to the driving/riding task are available (GPS, phone calls, SMS, email, etc.) but the GPS configuration and the use of communication technologies during driving or riding is strictly regulated for safety reasons. Thus, interfaces and software contents should follow a human-centred design approach in order to allow for easy, comfort, safe and secure interactions. International standards for interfaces design should be applied and usability requests should be identified and taken into account for the system design. In addition, every road user must obey traffic laws and traffic lights using both visual and auditive sensorial channels. The variability is huge in this context increasing complexity and uncertainty.

	UTS – Performance conditions analysis in terms of variability and uncertainty			
	Light rail	**Heavy rail**	**Road Public**	**Road Private**
Availability of procedures and plans	Light rail systems may have isolated and protected paths, but typically, they operate alongside multiple other urban infrastructures. This means that they often interact with road traffic and pedestrians. The shift from one type of environment to another may occur within very short distances and timeframes. For instance, this means that drives may go from a signalling system based operation to one based on a "drive on site" performance. This imposes additional complexities on procedures and on the planning of operations, as additional variables must be taken into account and integrated.	Since their early days, heavy rail systems have evolved towards a "rigid" mode of operation. Signalling systems remain firmly grounded on the principle of absolute blocks, on which at any given time, only one train may enter (Only recently this is being profoundly modified by ERTMS). Every failsafe principle leads to the red aspect on a signal and thus, operation is stop until it may be resumed under safe conditions. Operation degraded modes are well defined and known. Rules and procedures are detailed and formalised, even if in some aspects they may be quite numerous.	Road public transport abides by the same rules than private transport but it deals with additional safety and operation procedures that mainly enforce legal responsibility towards passengers and the wider public. For instance, in some cities, bus drivers are not authorised to drive on reverse without the presence of a bus marshal. The existence of restricted bus lanes facilitates the planning of operations, as it reduces the impact of overall road traffic on bus services. Despite this, road public transport tends to be severely impacted by the high variability of overall road systems. Procedures tend to clearly establish the boundaries of "normal" operation under which bus drivers may perform, and beyond which additional marshalling and support services are activated, and situations are dealt as an emergency or incident scenario.	Private road traffic remains strongly grounded on individual initiative and abidance by rules. The high complexity and variability of many urban environments, and the continuously growing pressure on overall road transport, renders traffic rules and laws ineffective, which can be easily observed on most road safety performance indicators across European cities. Higher performance coordination mechanisms are needed. The increased automation of road vehicles is rapidly enhancing the potential for an increased operational synchronisation and coordination. This will severely impact on road traffic rules, procedures and planning.

	UTS – Performance conditions analysis in terms of variability and uncertainty			
	Light rail	**Heavy rail**	**Road Public**	**Road Private**
Conditions of work	Working schedules in every public transport mode are very irregular involving night and shift work in order to cover the duration of the defined service. Being the system efficiency the main concern for the service provider, the human side of every operation is a key issue. So, technical, environmental and organisational working conditions must comply with human factors related requests for the tasks performance in safe conditions, as well as health and safety regulations. Driving or piloting vehicles or controlling traffic requires continuous work focusing attention for long periods, which create conditions for passive fatigue, drowsiness and loss of control. Breaks and the required sleep hours are the main request for operational conditions of every actor in this sector. The wide variability of schedules and working conditions are also issues to be considered.	Irregular working schedules and trips covering sometimes longer distances and often involving night work occur in a regular basis. Being the system efficiency the main concern for the service provider, the human side of every operation is a key issue. So, technical, environmental and organisational working conditions must comply with human factors related requests for the tasks performance in safe conditions, as well as health and safety regulations. Driving or piloting vehicles or controlling traffic requires continuous work focusing attention for long periods, which create conditions for passive fatigue, drowsiness and loss of control. Breaks are not supposed to be regular due to trips duration but the required sleep hours are the main request for operational conditions of every actor in this sector. The wide variability of schedules and working conditions are also issues to be considered.	Working schedules are very irregular involving night and shift work. Being the system efficiency the main concern for the service provider, the human side of every operation is a key issue. So, technical, environmental and organisational working conditions must comply with human factors related requests for the tasks performance in safe conditions, as well as health and safety regulations. Controlling traffic requires continuous work focusing attention for long periods, which create conditions for passive fatigue leading to drowsiness and inattention, which increase risks of errors or omissions. Driving buses requires also continuous work focusing attention on traffic and, additionally, on the movement of passengers. Due to urban traffic conditions, particularly in rush hours, there is no room for passive fatigue and drowsiness but those conditions lead to active fatigue and stress. The wide variability of schedules and working conditions, as well as the dynamic and complexity of the environment lead to a great uncertainty.	Drivers and riders circulate on urban environment for commuting, as well as business, shopping, or health purposes, emergency assistance, hygiene services, etc. So, they are not subject to any driving or riding-related work schedule. They have other tasks assigned and drive or ride to reach the environment for their tasks performance. In these cases, the driving or riding activity doesn't fit the requests of a repetitive job task. However, the dynamics of traffic and its high complexity give rise to high levels of stress increasing risks of errors, omissions and accidents. In traffic control, emergency services and police supervision, operators are subject to 24h schedules requiring that working conditions must comply with human factors related requests for the tasks performance in safe conditions, as well as health and safety regulations. The wide variability of conditions, as well as the dynamic and complexity of the environment lead to a great uncertainty.

	UTS – Performance conditions analysis in terms of variability and uncertainty			
	Light rail	**Heavy rail**	**Road Public**	**Road Private**
Number of goals and conflict resolution	Light rail systems interact with many other urban infrastructures and services. In addition to road traffic and pedestrians, access (i.e., for maintenance or redevelopment) to power supply, water distribution and sewers facilities is often found on shared infrastructures. This requires dealing with multiple and often conflicting goals both at strategic and operational level.	Heavy rail services operate within self-contained and restricted access infrastructures. This limits goals and conflicts to those that are typically related to operation planning and the response to engineering requirements (maintenance and renewals, enhancement and redevelopment projects, among others). Because urban heavy rail systems often operate in underground infrastructures, maintenance and in particular redevelopment projects may be challenged by the presence of other underground urban facilities.	Urban road public transport is currently challenged mainly for environmental reasons and in some cities, also for cost and efficiency reasons. Despite improvements, the levels of gas emissions and noise produced by buses remains a source of conflict with many other urban services and users. The renewal of bus fleets requires substantial investments and may be difficult to justify in view of other options. Bus access to some older and aged cities may also be a source of conflicting scenarios that challenge the continuity of road public transport. The use of smaller vehicles is often used as a solution but this may be challenged by losses of operational efficiency.	The use of private motor vehicles is at the source of many conflicts within urban areas. Particularly in Europe, many cities are imposing severe restrictions to the use of private vehicles within urban areas, aiming to respond, not only to environmental issues and reduced emissions objectives, but also in view of improved quality in the use of urban facilities and overall well-being of citizens. In addition to its higher environmental, social and economic costs, the use of private car in cities is increasingly recognised as one of the most significant problems in terms of land use and planning. Its growth and behaviour remains difficult to forecast and plan. In particular under emergency scenarios or severe weather conditions, private car use raises many safety issues.

	UTS – Performance conditions analysis in terms of variability and uncertainty			
	Light rail	**Heavy rail**	**Road Public**	**Road Private**
Available time and time pressure	The planned services for light rail systems run usually under the schedule with a relative time pressure to be on the schedule. The occurrence of any incident, accident or technical problem will impose some interruption creating some time pressure to recover from a delay and arrive on the schedule. As these systems can operate alongside multiple urban infrastructures, sometimes sharing the space with road users, time-related constraints result from urban traffic although the priority of public transport on the traffic lights regulation. Some weather conditions can also cause delays. In addition, the movement of passengers is also a factor of short delays. These aspects reflect the variability of the system and the uncertainty related to the operational schedule.	The planned services for heavy rail systems run usually under the schedule with a relative time pressure to be on the schedule. The movement of passengers, particularly during rush hours, is a factor of delays, particularly in subway and suburban systems, but the service frequency is higher to maintain the provision of the required service. The occurrence of any incident, accident or technical problem on the vehicles, infrastructure or energy supply, will impose longer interruptions that can create some time pressure to recover from a delay and arrive on the schedule. These aspects reflect the variability of the system and the uncertainty related to the operational schedule.	As urban road public transport systems share the infrastructure with private road traffic, the uncertainty related to the planned schedules is very high although the existence of bus lanes in busier urban areas. Thus, delays are very common in these services and impose an additional stress to drivers who try to recover and finalise the shift on the schedule. Traffic jams or the occurrence of any incident, accident or technical problem in the vehicles give rise to interruptions that can create additional time pressure to recover from a delay and arrive on the schedule. These aspects reflect the variability of the system and the uncertainty related to the operational schedule.	Private road systems are subject to delays regarding the planned travel times. Rush hours and the related traffic conditions create traffic jams increasing the planned travel time. These conditions lead to high levels of stress with negative effects on decision making and behaviour increasing the driving related risks. Furthermore, these conditions represent the roots for many accidents that result directly from drivers' or riders' unsafe acts. The planned and available time for a trip, even short, are subject to a huge variability increased by the characteristics of the system (totally open), its dynamics and extreme uncertainty.

	UTS – Performance conditions analysis in terms of variability and uncertainty			
	Light rail	**Heavy rail**	**Road Public**	**Road Private**
Circadian rhythm and stress	Urban light rail systems involve almost around the clock operational schedules creating conditions for drivers' and other operators' sleep debt and giving rise to circadian rhythm desynchrony. As every operator in this system must be in good conditions for the tasks performance, working schedules and trip planning must comply with regulations and human factors requests for the best performance. Furthermore, fighting fatigue and drowsiness occurring during very late or early hours represents and additional stress factor to every operator. The variability results from the human adaptability to stressors and the different operational conditions together with their variation along the work schedule.	Urban heavy rail systems involve almost around the clock operational schedules creating conditions for drivers' and other operators' sleep debt and giving rise to circadian rhythm desynchrony. As every operator in this system must be in good conditions for the tasks performance, working schedules and trip planning must comply with regulations and human factors requests for the best performance. Furthermore, fighting fatigue and drowsiness occurring during very late or early hours represents and additional stress factor to every operator. The variability results from the human adaptability to stressors and the different operational conditions together with their variation along the work schedule.	Urban road public transport systems involve almost around the clock operational schedules creating conditions for drivers' and other operators' sleep debt and giving rise to circadian rhythm desynchrony. As every operator in this system must be in good conditions for the tasks performance, working schedules and trip planning must comply with regulations and human factors requests for the best performance. Furthermore, fighting fatigue and drowsiness occurring during very late or early hours represents and additional stress factor to every operator. In this context, the variability results from the human adaptability to stressors and the different traffic conditions together with their variation along the work schedule. Coping with these conditions represents an additional stressor and increases variability and uncertainty.	In the urban road private system trips are more or less short and rarely give rise to drowsiness resulting from sleep debt and related circadian rhythms desynchrony. Therefore, each driver or rider must be aware of his/her own performance conditions to initiate a trip and make the a decision accordingly. On the opposite side, traffic jams and intensive urban traffic give rise to stress and sometimes inappropriate and risky behaviour. Being this system totally open, it is a matter of the self-evaluation of conditions to initiate a trip and the own decision about the existing conditions for the best performance. As said above, the variability is huge and the related uncertainty in such a complex system is very high.

	UTS – Performance conditions analysis in terms of variability and uncertainty			
	Light rail	**Heavy rail**	**Road Public**	**Road Private**
Team collaboration quality	Daily cooperation and teamwork involving multiple stakeholders is a critical operational requirement. The clear understanding and sharing of goals and priorities at institutional level constitutes a fundamental support for the quality of teamwork. Resolving situations that often involve conflicting goals can only be achieved through high quality team collaboration. The operation under highly complex and shared urban environments is at generates safety critical scenarios that must be managed under thorough coordination amongst accountable stakeholders.	Heavy rail systems may be less prone to close and continuous interactions amongst multiple stakeholders, when compared to light rail systems. However, as a transport service provider, they remain strongly exposed to user behaviour trends and the public in general. Providing a reliable service transport and in particular at the high capacity standards under which urban rail tends to operate, requires high quality teamwork amongst multiple service stakeholders.	The operation of road public transport is highly exposed to the remaining stakeholders within overall road transport systems. Within this context private car use often competes and exerts tremendous pressure over public transport. The setting of priorities and the delivery of a reliable bus service requires real-time cooperation amongst service providers and often various other city and road traffic authorities.	The openness of road transport systems generates many complex issues in terms of operational control. Managing road system operation and in particular the flows of private motor vehicles remain essentially grounded on autonomous action and decision-making. However, team collaboration issues are rapidly emerging as traffic monitoring capabilities are significantly enhanced, which generates enhanced potential for rapid response and adaptation to changes in system operation as a whole. Under emergency and accident scenarios, collaboration and coordination amongst multiple public safety and law enforcement agents is required. Contrary to other transport systems, in many cases road operation stakeholders do not possess dedicated resources. For instance, while aviation, maritime and rail transport is supported by dedicated and specially trained emergency staff, in the case of road transport, this many such resources are provided by general public emergency response units. This may place additional pressures on coordination and collaboration issues.

	UTS – Performance conditions analysis in terms of variability and uncertainty			
	Light rail	**Heavy rail**	**Road Public**	**Road Private**
Quality and support of the organisation	Light rail systems are less likely to have multiple operators and often the infrastructure manager may be a different branch but nevertheless, the same as the operator company. This would be the case for instance in cities where the light rail infrastructure and operation are integrated in a municipal public service entity. This may contribute to minimise disparity and variability of organisational directives to operational staff.	Contrary to light rail, heavy rail systems may be more likely to have the participation of multiple and private capital organisations, namely because costs and investments tend to be much more significant. In such cases and because the scope of business and operation tends to be much smaller than in national or international level operations, organisational pressures may tend to be more significant and reflect on operational staff and their relations.	Road public transport tends to be very competitive, except in cities where it remains under the scope of public municipal services. Pressures for cost reduction and increased efficiency can be significant and impact negatively on organisational relations.	For many professionals in urban areas, driving occupies a substantial part of their working day or roster. This includes freight or parcel delivery or many other services that operate within cities. People operating such services may experience the high variability and uncertainty of road traffic under the strong pressure of tight working schedules and the volume of planned work. Organisational support and coordination is fundamental to provide the means to adjust to the highly unpredictable operation of road systems, without compromising safety of those involved and the quality of services being provided.

4 NETWORK ANALYSIS IN UTS RESILIENCE

Modelling and evaluating the resilience of systems, potentially complex and large-scale in nature, has recently raised significant interest among both practitioners and researchers. This recent interest has resulted in several definitions of the concept of resilience and several approaches to measuring this concept, across several application domains (Seyedmohsen *et.al*, 2016).

Several definitions of resilience have been offered. Many are similar, though many overlap with a number of already existing concepts such as robustness, fault-tolerance, flexibility, survivability, and agility, among others.

The review of resilience definitions indicates that there is no unique insight about how to define the resilience, however several similarities can be observed across these resilience definitions. The main highlights of resilience definitions reviewed above are summarized as follows:

- Some definitions do not specify mechanisms to achieve resilience; however many of them focus on the capability of system to “absorb” and “adapt” to disruptive events, and “recovery” is considered as the critical part of resilience.
- For engineered systems, such as nuclear power systems, reliability is often considered to be an important feature to measure an ability to stave off disruption.
- Some definitions, such as those of (Sheffi, 2005.) and (ASME, 2009.), emphasize that returning to steady state performance level is needed for resilience, while other definitions do not impose that the system (e.g., infrastructure, enterprise, community) return to pre-disaster state.
- The definition offered by (Haimes, 2009) suggests that the quantification of resilience is multi-dimensional, in the sense that particular states of a system are inherently more resilient than others. Further, Haimes stresses that the resilience of a system is threat-dependent.
- Some definitions such as (Pregenzer, 2011.) define resilience in terms of preparedness (pre-disaster) activities, while the role of recovery (post-disaster) activities is discarded. Definitions presented by organizations such as National Infrastructure Advisory Council (NIAC, 2009) emphasized on the role of both preparedness and recovery activities to achieve resilience.

In general, the resilience evaluation procedure can be separated into two major categories: qualitative and quantitative.

The qualitative category which includes methods that tend to assess the resilience of a system without using numerical descriptors contains two sub-categories: (i) conceptual frameworks that offer best practices and (ii) semi-quantitative indicators that offer expert assessments of different qualitative aspects of resilience.

The quantitative methods include two sub-categories: (i) general resilience approaches that offer domain-agnostic measures to quantify resilience across applications, and (ii) structural-based modeling approaches that model domain-specific representations of the resilience components.

General resilience measures provide a quantitative means to assess resilience by measuring system performance, regardless of the system structure. These measures are comparable across different system contexts with similar underlying logic. As they have been defined, generic resilience metrics determine resilience by comparing the performance of system before and after disruption, without concentrating on system-specific characteristics (though modelling performance may require understanding underlying system behaviour).

Network/graph analysis approaches are in particular adopted in order to provide quantitative evaluation to support resilience management in complex networked infrastructures, where graph invariants are usually used as deterministic measures. Such graph invariants often include graph theoretic measures (e.g., centrality, diameter) (Johansson and Hassel, 2010; Johansson et.al, 2013; Wu et.al, 2011).

In (Seyedmohsen et.al, 2016) these general measures are characterised as deterministic and stochastic, each of which have been used to describe static and dynamic system behaviour.

- Deterministic vs. probabilistic: a deterministic performance-based approach does not incorporate uncertainty (e.g., probability of disruption) into the metric, while a probabilistic performance-based approach captures the stochastic nature associated with system behaviour.
- Dynamic vs. static: a dynamic performance-based approach accounts for time-dependent behaviour, while a static performance-based approach is free of time dependent measures of resilience

4.1 General/topological analysis

Transportation systems are often modelled using graphs when quantifying their resilience. Many approaches (Albert and Barabási, 2002; Dorbritz, 2011; Reggiani, 2013) assume that the graph modelling the transportation system is a scale-free graph. Scale-free graphs are such that the proportion (P(k)) of nodes of degree 1 k follows a power law: P(k) ~ k -γ, where γ varies in the range [2, 3].

This scale-free graph nature of transportation systems provides them with the following properties:

- The presence of hubs in these graphs. Hubs are nodes with high degree.
- They are more vulnerable to targeted attacks such as terrorist attacks on hubs.
- In terms of connectivity, Transportation Systems are built to be locally more sensitive and globally robust to perturbations.

Identifying critical components can enable stakeholders to prioritize protection initiatives or add necessary redundancy to maximize network resilience during a disruptive event. The role that a component plays in a network system has been measured by various so-called centrality measures, looking from the point of view of the complex interaction and communication flow in the network (Kröger and Zi, 2011).

Classical topological centrality measures are the degree centrality (Nieminen, 1974; Freeman, 1979), the closeness centrality (Freeman, 1979; Sabidussi, 1966; Wasserman and Faust, 1994), the betweenness centrality (Freeman, 1979), and the information centrality (Latora and Marchiori, 2007).

They specifically rely on topological information to qualify the importance of a network component. Additionally, Freeman et.al (Freeman et.al, 1991) proposed a flow betweenness centrality measure based on the idea of maximum network flow; Newman (Newman, 2005) suggested a random walk betweenness measure that counts essentially all paths between vertices and which makes no assumptions of optimality; Jenelius et.al. (Jenelius et.al, 2006) proposed several vulnerability-based importance measures for transportation networks; Hines and Blumsack (Hines and Blumsack, 2008) introduced an “electrical centrality” measure for electrical networks by taking into account the electrical topology of the network.

With respect to topological analysis, two concepts of resilience are usually addressed: vulnerability and recoverability. Several works have examined the identification of important components in a network with respect to vulnerability. Jonsson et.al (Jonsson et.al 2008) define vulnerability as the magnitude of damage given the occurrence of a particular disruptive event, noting that the vulnerability of a network is highly dependent upon the type and extent of disruption, e.g., measuring vulnerability as network performance after the removal of a set of nodes or links based only on topological features (i.e., without load redistribution leading to potential cascading failures).

Nagurney and Qiang (Nagurney and Qiang, 2007a, Nagurney and Qiang, 2007b) develop a measure of network efficiency to describe the performance of a network when disrupted or congested, as well as an identification of the individual components that lead to adverse network performance, with mention given to applications in network vulnerability and robustness. Rodriguez-Nunez and Garcia-Palomares (Rodriguez-Nunez and Garcia-Palomares, 2014) developed vulnerability component importance measures for transportation networks based on travel time, while others have considered cost of travel time (Sullivan et.al, 2010) and accessibility, or the ease of reaching components of the network (Chen et.al, 2007). Ouyang et.al, (Ouyang et.al, 2014) examine the flow-based vulnerability of train networks.

Omer et.al (Omer et.al, 2014) proposed a metric for resilience of infrastructure networks, calculated as the ratio of the closeness centrality of the network before and after disruption respectively. The closeness centrality is determined based on the accessibility of a node to the rest of the network. This resilience metric gives a value between 0 and 1, where the larger value is more desirable.

Nevertheless, none of these analyses takes into account the dynamics of system recovery from the effects of a disruptive event.

Resilience-based metrics of component criticality with respect to their influence on the overall resilience of the system (i.e., on the system's ability to quickly recover from a disruptive event) can be helpful for preparing an efficient component repair checklist in the event of system failure (Natvig et.al, 2011). Natvig et al. introduced a dual extended Natvig measure for repairable systems: according to this measure, the components that are considered important are those whose repair reduces significantly the expected time of residence of the system in the worst conditions (Natvig et.al, 2011). Hence, this dual Natvig measure is a resilience measure for multistate components in a multistate system. A dual extension of the Barlow-Proschan measure has also been suggested for multistate repairable systems, based on the probability that the repair of the i-th component is the cause of a system state improvement, given that this has occurred (Natvig, 2011).

Fang et.al proposed two metrics, i.e., the optimal repair time and the resilience reduction worth, to measure the criticality of the components of a network system from the perspective of their contribution to system resilience. Specifically, the two metrics quantify: 1) the priority with which a failed component should be repaired and re-installed into the network and 2) the potential loss in the optimal system resilience due to a time delay in the recovery of a failed component, respectively (Fang et.al, 2016).

4.2 Modelling/simulation approaches

The structural-based approaches examine how the structure of a system impacts its resilience. System behaviour must be observed and characteristics of a system must be modelled or simulated.

Most transportation system resilience assessment models in the literature focus on the topological and connectivity aspects of transportation system. Usually, the problem of resilience in transportation systems is modelled by optimising their passengers/freight flow and analysing the flow when a perturbation is simulated (the removal of edges and/or nodes of the graph) (Ash and Newth, 2007; Ip and Wang, 2011).

Khaled et.al proposed a mathematical model and solution approach for evaluating critical railroad infrastructures to maximize rail network resilience. In this paper, the criticality of an infrastructure element is evaluated based on the increased delay incurred when that element is disrupted. The mathematical model considers individual component (links and nodes) disruptions separately to determine the impact, where considering multiple component disruptions simultaneously might be more meaningful as a disruptive event may realistically impact multiple adjacent components (Khaled et.al, 2015).

With respect to critical infrastructure networks, Adjetey-Bahun et.al used a time-dependent simulation model to measure the resilience indicators of a railway transportation system (Adjetey-Bahun et.al, 2014). A set of disruptive events are modelled through simulation model with consequences of increase of travel time and reduction of train capacity. Sterbenz et.al proposed an approach based on integrating analytical simulation, topology generation, and experimental emulation to improve the resilience and survivability of Internet networks (Sterbenz et.al, 2010). The resilience of the Internet network is defined as the ability of the network to provide a desired service level when it is challenged by large-scale disasters or intense failures.

Charles et.al developed and compared several flow-based vulnerability measures to prioritize important network edges for the implementation of preparedness options. These network vulnerability measures quantify different characteristics and perspectives on enabling maximum flow, creating bottlenecks, and partitioning into cut-sets, among others. The efficacy of these vulnerability measures to motivate preparedness options against experimental geographically located disruption simulations is measured (Charles et.al, 2016).

Results suggest that a weighted flow capacity rate, which accounts for both (i) the contribution of an edge to maximum network flow and (ii) the extent to which the edge is a bottleneck in the network, shows most promise across four instances of varying network sizes and densities.

Chen and Miller-Hooks introduced an indicator for measuring resilience in transportation networks (Chen and Miller-Hooks, 2012). The resilience indicator quantifies the post-disruption expected fraction of demand that, for a given network, can be satisfied within pre-determined recovery budgets. Parameter d_w quantifies the maximum demand that can be satisfied for origin–destination (O–D) pair w following a disruption, and Dw is demand that can be satisfied for O–D pair w prior to the disruption. A limitation of this formulation includes its lack of specificity of the contribution of pre-disaster and post-disaster recovery activities, specifically in accounting for recovery time.

More recently, a simulation-based model for quantifying resilience in mass railway transportation systems has been proposed by quantifying passenger delay and passenger load as the system's performance indicators (Adjetey-Bahun et.al, 2016). The approach integrates all subsystems that make up mass railway transportation systems (transportation, power, telecommunication and organisation subsystems) and their interdependencies. The model is applied to the Paris mass railway transportation system. The model's results show that since trains continue running within the system even by decreasing their speed, the system remains resilient. During the normal operation of the system as well as during perturbation, the model shows similarities with reality. The perturbation management plan that consists of setting up temporary train services on part of the impacted line while repairing the failed system's component is considered in this work. We also assess the extent to which some resilient system's capacities (i.e. absorption, adaptation and recovery) can increase the resilience of the system.

During perturbation, passengers very often try to change their path by using other lines in order to avoid the perturbation.

Generally this ensures that the network is still globally robust. Due to these scale-free graph properties, risk and/or crisis managers of transportation systems should pay more attention to hubs when managing risk/crisis in order to increase the resilience of their systems.

4.3 Cascading effects and multiplex networks

Cascading failures are very common in power transmission, communication, and transportation networks. Cascading failures usually triggers by failing a node of network due to overloading and its effect nonlinearly propagate through network that eventually may results in network shutdown.

Zio and Sansavini introduced component criticality measures from the cascade failure process point of view, for general network systems (Zio and Sansavini, 2011).

Many efforts have been put to study the behaviour of cascading failure in complex interdependent networks (Hernandez-Fajardo and Duenas-Osorio, 2013; Cupac et.al, 2013; Koc et.al, 2013; Su et.al, 2014; Wang et.al, 2014; Ouyang and Duenas-Osorio, 2014).

Ash and Newth first modelled cascading failures and then developed failure resilient networks based the notion of network topology indices including common neighbours, modularity, and assortativeness (Ash and Newth, 2007).

Complex networks have become a natural abstraction of the interactions between elements in complex systems (Newman, 2010). When the type of interaction is essentially identical between any two elements, the theory of complex networks provides a wide set of tools and diagnostics that turn out to be very useful to gain insight in the system under study. However, there are particular cases where this classical approach may lead to misleading results, e.g., when the entities under study are related to each other using different types of relations in what is being called multilayer interconnected networks (De Domenico et.al, 2013; Kivelä et.al, 2014; Boccaletti et.al, 2014). Representative examples are multimodal transportation networks (De Domenico, 2014; Strano et.al, 2015) where two geographic places may be connected by different transport modes, or social networks (Mucha et.al, 2010; Magnani and Rossi, 2011) where users are connected using several platforms or different categorical layers.

Transportation dynamics on networks can be, in general, interpreted as the flow of elements from an origin node to a destination node. When the network is facing a number of simultaneous transportation processes, we find that many elements travel through the same node or link. This, in combination with the possible physical constraints of the nodes and links, can lead to network congestion, in which the number of elements in transit on the network grows proportionally with time (Zhao et.al, 2005). Usually, to analyse the phenomenon, a discrete abstraction of the transportation dynamics in networks is used (Cardillo et.al, 2013).

Multimodal transportation can also be mathematically abstracted as transportation dynamics on top of a multiplex structure. Note that routings on the multilayer transportation system are substantially different with respect to routings on single layer transportation networks. In the multilayer case, each location of the system (e.g., geographical location) has different replicas that represent each entry point to the system using the different transportation media. Thus, each element with the intention of traveling between locations i and j has the option to choose between the most appropriate media to start and end its traversal. We assume that elements traverse the network using the shortest paths, so each element chooses the starting and ending media that minimize the distance between the starting or ending locations. This “selfish” behaviour provokes an unbalance in the load of the transportation layers inducing congestion.

Note that in a multiplex network we can have two types of shortest paths: paths that only use a single layer (intra-layer paths) and paths that use more than one layer (interlayer paths). Hereafter, we develop the analysis of transportation in multiplex networks, consisting of N locations (nodes per layer) and L layers, and quantify when this structure will induce congestion (Solé-Ribalta et.al, 2016).

5 UTS ADAPTED GUIDELINES

Following Deliverable D3.5, this deliverable D3.7 is consistent with the FRAM methodology to develop guidelines for the Urban Transport System. The guidelines developed in terms of the present document consist of an application of the generic guidelines for resilience management in the specific case study of the Urban Transport System, in accordance with existing practices, lessons learnt and national approaches worldwide. Hence, the aim of these guidelines is to provide guidance under the EU perspective, taking into account the already existing EU initiatives on Urban Transport System Resilience. The guidelines presented above, follow the structure of Deliverable D3.5 and are organized under the four categories: Anticipate, Monitor, Respond and Learn.

Regarding the operationalisation of the guidelines, apart from what is indicated per case in each function's guidelines, the general rules introduced in D3.5 are also valid here. These consist in some general framework on how to use the guidelines that are included in this section. More specifically, a self-evaluated multilevel gap analysis is encouraged to be performed by the UTS manager (or, in general, the decision maker in charge), in what concerns the state of practice in the organisation. The UTS adapted ERMG are aiming exactly to facilitate and support this process. Three levels of analysis may be distinguished:

- **Level I:** The first level of analysis can be carried out by the comparison between the "desired functions" defined in UTS-ERMG against the functions identified through a FRAM analysis of the UTS under assessment. Should one or more functions be missing, this constitutes a trigger for the decision makers towards its implementation as applicable for the needs and status of their UTS. This preliminary assessment is able to highlight relevant issues in the organization.
- **Level II:** The second level of analysis is carried out by the assessment about how the functions implemented in the assessed UTS are actually aligned with the UTS-ERMG recommendations. The readers should be able to understand if general as well as common conditions and recommendations are applied and at which level of detail. Moreover, indications and insights on how to improve the existing ones to manage the variability of functions' output can be retrieved by the document.
- **Level III:** The third level of analysis is oriented to the function interdependencies assessment. The UTS-ERMG provides a number of desired interdependencies that are able to increase the system resilience. The missing connections between functions in the CI assessed may suggest that information or resources are not properly supplied or shared, creating vulnerability in the system. Moreover, a function that is coupled with another may be prevented from providing the expected outcome if the variability of the upstream function exceeds the capacity of the downstream function to manage it. Thus, in order to manage such functional resonance, the UTS-ERMG provides to readers recommendations about how to manage variability at function level coming from the upstream functions.

The synthesis of the gap analysis is obtained adopting the Resilience Analyses Grid tool (see D3.5).

At the end of the assessment, the reader will be more aware about the importance of the resilience thinking in the UTS domain, what is the status of the UTS analysed and what to do at operational, tactical and strategic level to increase the resilience of the system. Of course, as the magnitude and complexity, as well as the organisational structure of each UTS may vary significantly, the actual implementation of the guidelines provided here should adapt to the particularities of each individual system.

5.1 ANTICIPATE

5.1.1 Develop Strategic Plan for UTS

5.1.1.1 Background facts

Within this risk environment, our critical infrastructures are inherently interdependent—domestically and internationally—and vulnerable both within and across sectors due to the nature of their physical attributes operational environments, international supply chains, and logical interconnections. Hence, the critical infrastructure mission area requires a focused national strategy and supporting plans and operational structures appropriately balancing resilience with risk-informed prevention, protection, and mitigations activities that allow us to manage the most serious risks.

In the specific case of Urban Transportation Systems, strategic planning should aim to:

- ensure the level of performance regarding mobility in the addressed urban area,
- ensure the safety of the transportation network: this means ensuring transportation routes are available during a catastrophe and ensuring emergency access to the involved urban area. It also means sidewalks where children can play and on-street bike lanes where bicyclists can get to work safely,
- create new opportunities, and
- build a comfortable, healthy and green mobility urban environment.

Strategic planning involves a structure or framework, a set of procedures (both formal and informal), and of course content. Beyond these basic elements, the underlying assumptions about strategic planning are that the future can be anticipated, forecasted, managed or even controlled, and the best way to do so is to have a formal and integrated plan about it in place. Planning simply introduces a formal "discipline" for conducting long-term thinking about an institution, and for recognizing opportunities in and for minimizing risks from the external and internal environments in terms of both normal operation and emergency management situations.

5.1.1.2 General Recommendations

In the UTS, the responsible mobility agency should ensure the alignment of all mobility operators/actors internal operation when defining strategic plans, through:

- Attempting to gather board members and key employees together for planning.
- Establishing the overall mobility goals for the alignment. Mission statement should be reviewed periodically between ten or twenty years and the objectives must be finite, feasible, suitable, acceptable and achievable.
- Analyzing which internal operations are most directly aligned with achieving that goal, and which are not
- Establishing adaptive capacities goals to more effectively align operations to achieving the overall goal. Methods to achieving the goals might include organizational performance management models that might imply the evaluation of specific mobility-related KPIs.
- Incorporating a "flexible" decision making process that does not lock the company's future development into a rigid path, but rather constantly evolves to reflect information learned to make the best possible decisions.
- Securing the continuity to deliver cash generation through sustainable organization grow resources in view of including that information in the Strategic Plan.
- Producing quantitative measures in order to monitor the evolution derived from the Strategic Planning
- Establish an effective business-government partnership with critical infrastructure owners and operators

Besides these general recommendations, it can be said that strategic planning in UTS is a continual process of examining the transportation challenges facing and identifying a plan of action to improve transportation system performance. Strategic planning in UTS is a process that develops information to help make decisions on the future development and management of transportation systems. It expanded the determination of the need for new or expanded highways, transit systems, freight facilities, and transportation terminals, their location, their capacity and the management of their demand. Typically transportation planning involves a forecast of travel patterns 15 to 25 years into the future with an aim to develop a future transportation system that will work effectively at that time. Strategic planning in UTS will have significant effects on mobility, economic development, environmental quality, government finance and the quality of life. Wise planning is needed to help create high quality transportation facilities and services and guarantee the resilience of the UTS infrastructure in case of disasters, at a reasonable cost with minimal environmental impact and at the same time while enhancing the economic activity.

5.1.1.3 Common Conditions Recommendation

1. Availability of resources

Humans (labour) – skills/competence

- Key members of responsible mobility agency should be involved in the process of policy and vision definition.
- Consult with the relevant stakeholders involved in operational aspects of mobility management at the addressed urban area.

Data & Algorithm:

- Rely the strategic planning on statistics derived from historical data.
- Collect that in multiple places and allow integrate and correlate transport data with data related to events, weather, people flow, etc.
- Use of standard documentation for processes definition and for data management (e.g., standard protocols for exchange of traffic-related data like DATEX).
- Use of official concepts and definitions.

2. Training and experience

- N/A

3. Quality of communication

- *Support the planning activity by efficient shareholders and (internal and external) experts coordination and cooperation.*
- *Guarantee the availability, accuracy and understandability of the communication through standardized communication tools, protocols and languages among all actors involved in the mobility management in the addressed urban area.*

4. Human Computer Interaction and operational support

- N/A

5. Availability of procedures and plans

- Creating an integrated strategic planning process to support the integrated framework.
- Defining a strategic plan, coupled with review and maintenance of the strategy to ensure that they stay relevant over time in compliance to existing procedures and plans.

6. Conditions of work

- N/A

7. Number of goals and conflict resolution

- Planning teams should be built taking into account the scale and timeline of the plan and should make goal statements that should be reviewed periodically between ten or twenty years; these objectives must be finite, feasible, suitable, acceptable and achievable.

8. Available time and time pressure

- Planning milestones and deadlines should integrate degrees of flexibility to cope with planning quality requirements.

9. Circadian rhythm and stress

- N/A

10. Team collaboration quality

- Adherence to the principles of collaborative planning through the development of mutual benefit relations.

11. Quality and support of the organization

- Clear decision making process and alignment of responsibility with accountability.
- Establish a Public-Private Sector Partnership Framework to provide an excellent collaborative mechanism for improving infrastructure resilience.
- Ensure senior sponsorship.
- Financial capacity of each stakeholder and emergency unit should be included in the Strategic Plan including the level of financial involvement of each stakeholder.
- Service delivery cost, replacement service (e.g. buses in case of subway unavailability) should be evaluated and included in Strategic Plan. In order to make this evaluation, time for full repair of system and full recovery should be known from involved stakeholders.

5.1.1.4 Interdependencies recommendations

- If the related variability exceeds threshold of acceptance in relation to adaptation and improvement, the strategic planning should overcome such issues establishing and promoting an enabling management culture on self-protecting, so that appropriate adaptation action is undertaken.

5.1.1.5 Limitations

The guideline only highlights how a generic strategic plan for UTS should be produced. Nevertheless, the efficiency of the Strategic Plan itself depends of the quality of the defined strategies.

5.1.1.6 Examples

- The Transportation Strategic Plan (TSP) is the 20-year functional work plan for the Seattle Department of Transportation (SDOT). The TSP describes the actions SDOT will take to accomplish the goals and policies in the Comprehensive Plan over the next twenty years. Therefore it can be stated that The Transportation Strategic Plan (TSP) will be the City's guide for managing Seattle's transportation system. http://www.seattle.gov/transportation/tsp_2005.htm

5.1.2 Manage financial affairs

5.1.2.1 Background facts

States, regions and cities are largely responsible for arranging public services funding and management together with private, as well as public local, companies, such as urban transportation companies. It is important to know in advance the amount of resources available to fund any recovery effort and understand any eligibility or documentation requirements for obtaining the funding.

Staff with knowledge of financial resources should be included as part of the pre-event recovery planning team to ensure that disaster assistance is effectively utilized.

Financial affairs function is one of the prerequisites for any system current functioning and/or recovery as funds will be needed for managing full system recovery. Furthermore, financial affairs refer to urban road agencies (public administration/private concessionaire), urban rail (metro, LRT, tramway), bus operators, transit authorities, transportation hub operators (terminals, P+R), parking operators, city (air-) ports as urban gates.

This function interacts with all involved shareholders (new income, market extension, protect from finances loss, etc.) as well as with market and socioeconomic trends (user needs, new products/services, economic situations) and financial adaptation.

This function is activated during normal operation as well as for emergency cases. In the latter case, it must be activated from the very beginning of the emergency, receiving requests from emergency teams and analysing priorities. It would be appropriate not to end this function before critical emergency is finished and full recovery is attained.

To correctly operate, this function needs appropriate funding based on the strategic plan.

This function must provide the highest possible feedback to Coordinate Service delivery, Coordinate emergency actions, Monitor Resources availability, Use of services and Supply financial resources functions so that it can coordinate the financial management. This can be performed by direct communication or by continuously monitoring the operations.

It is also recommended that this function is particularly communicating and coordinated with Supply financial resources function.

During current operation, financial data should always be available for analysis in order to improve current functioning. In the case of an emergency, after the end of operations and full system recovery, all financial data should be made available in order to allow for analysis and possible improvement for the future.

5.1.2.2 General recommendations

The aspects that should be targeted in managing financial affairs in order to increase resilience of the Urban Transport Systems critical infrastructure can be summarised in the following:

- Assess disaster impacts.
- Assess private disaster risk financing markets and financial sector resilience.
- Know and be able to use Governmental disaster risk financing tools, at local, national and community level.
- Identify disaster risk financing markets and institutional arrangements.
- Investigate government compensation and financial assistance arrangements.
- Ensure a fair and efficient deployment of funds.

- Raise sufficient funds for improvement of public awareness.
- Develop financial control and plan financial assets in accordance to financial needs of the operation and financial obligations.
- Evaluate financial needs for emergency.
- Evaluate financial needs for complete system recovery.
- Analyse financial capacity of each involved stakeholder.
- Analyse capacity and financial resources possibly called (at institutional level e.g. county, city, state, etc.).
- Identify and analyse ways to obtain necessary funds.
- Plan budget reserve in case of emergency needs.
- Plan cost-sharing procedures between involved stakeholders.
- Try to manage planning and costs in order to avoid overpayment needs.
- Manage over-payment situations if any.
- Revise financial needs regularly in accordance with system evolution.

OECD Methodological framework can be used to assess and finance risk, as shown in Figure 1.

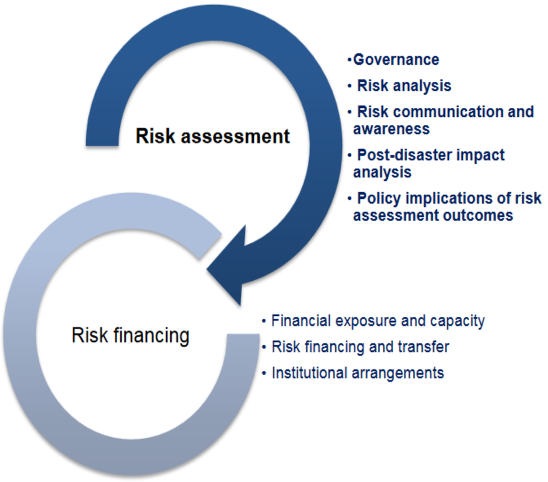


Figure 1: OECD Methodological framework

5.1.2.3 Common Conditions recommendations

1. **Availability of resources**

Humans (labour) – skills/competence

- Persons in charge of financial affairs for each department of the organization should be assigned.
- One person to be named and able to decide for the entire operation and a secondment able to immediately overtake the operations in case of deficiency from the first one. Both not in the same place and reasonably far from potential crisis points in order to be kept safe for ruling operations.
- Directory of names, telephone numbers, email, and alternative communication channels to reach them.

Budget:

- Availability of budget reserves for emergency cases.
- Awareness of structures from which funds are available and how to recover them.
- Conflicting objectives should be managed during the strategic plan phase, in order to define priorities order and allocate funds accordingly. This strategic plan should be agreed by all involved parties in order to avoid conflicts during the crisis management.

- Budget allocation should be revised once a year in order to take into account all possible evolutions for each of the involved parties.
- Planning should allow a perfect matching between available and necessary resources. The matching between the two has to be taken into account during planning phase so that resources should be available quickly.
- Each involved party has to calculate the necessary budget for recovery (emergency costs, repair costs etc.), communicate these costs to the monitoring party who will compile the information. Matching between necessary costs and available resources should be calculated in the strategic plan, taking into account resources available from each stakeholder but also from cities, regions, states, etc.
- Reserve funds control during and after the crisis management, in order to avoid overpayments needs. In any case funds should be ready to finance full recovery even if this means more payments than planned reserved.
- The allocation of supporting funds should be budgeted in relation to the UTS condition and relative risks for adverse/disruptive events. The portfolio should also have a wide margin of use because of the variability of each possible event in terms of typology, level of criticalities, extension and propagation from/to other urban Cis

Data & Algorithm:

- Use of project management concept and models to collect and monitor financial data.
- Use data coming from all the systems collected to monitor and control the critical infrastructure during normal operation.
- Reliability, Availability, Maintainability and Safety (RAMS) practices and algorithms for calculating the target thresholds according to the maintenance objectives.
- Data/information collected by on field operators and citizens during standard infrastructure operation.
- Collect and monitor financial data during & after emergency operation.
- Analyse data after operation in order to obtain re-usable statistical data for the future, potential predictive models can be create, and unexpected relationships of those that with the events and actions.

2. Training and experience

Training in terms of financial affairs, should be focused in the following areas:

- Financial management skills
- Project management skills
- Cooperation skills
- Public security, operational head skills
- Crisis management (well trained and experienced personnel in this field should head the operations)
- Current operation skills
- Adaptability & capacity to adapt current functioning to possible emergency needs

3. Quality of communication

- Communicate available resources to involved stakeholders.
- Communicate with stakeholders where resources are available in order to get funds quickly.
- Ability to communicate quickly with operational teams in order to manage funds availability and fair distribution until full recovery.

4. Human Computer Interaction and operational support

- Utilization of software tools to analyse financial data.
- Utilization of software tools to plan and monitor budget and resources availability.
- Utilisation of software tools to communicate with all function and allocate funds according to the plan and the emergency needs.
- Utilization of software tools to analyse cost of disrupted system and evaluate economic impact on the society.

5. Availability of procedures and plans

- Strategic financial plan in case of emergency ready.

- Operational plan ready.
- Fast availability of necessary resources.

6. **Conditions of work**

- Emergency work during crisis.
- Ability to know priorities for recovery after crisis in order to disseminate funds properly.
- Work in teams, able to immediately take over the current operations, in case of long recovery.

7. **Number of goals and conflict resolution**

- Necessary to define priorities in order to stop possible conflict in advance.
- Define strategic plan and communicate it to involved parties so that they know where funds will go first and avoid conflict.
- Give decision power to experienced people in order to avoid conflicts.

8. **Available time and time pressure**

- During current operation, work is made under normal time pressure.
- In case of emergency, immediate response is needed in order to call for necessary funds as quickly as possible and be able to give appropriate answer to operational teams.

9. **Circadian rhythm and stress**

- NA

10. **Team collaboration quality**

- Adherence to the principles of collaborative financial planning through the development of mutual benefit relations.
- Preliminary analysis of capacity in team working in order to avoid conflicts and conflicting payment orders.

11. **Quality and support of the organization**

- Clear decision making process and alignment of responsibility with accountability.
- Alignment of decisions with available resources.
- Alignment of decisions with defined priorities.
- Measurement of performance will be made after the emergency situation, in an early phase, in order to analyse used resources and remaining ones. Comparison should be made with what was planned in order to assess the validity of planning that was made and allow necessary adjustments to be made for future strategic plans. Second phase of analysis should be made after full recovery together with final used budget accounting. Financial reports have to be provided to each involved party and necessary adjustments have to be made in future plans based on final financial results. Deviations from initial planning should be analysed (why, how, how much) in order to better take them into account in future planning.
- Interpretation of financial results should be made immediately after full recovery in order to allow improving the strategic plan quickly and be ready in case of a new emergency situation
- Coordination between all stakeholders should be ensured by knowing in advance the financial capacity of each one of them and producing a financial plan accounting the level of financial involvement of each entity in case of emergency and recovery procedures.
- Cost of emergency action and cost of UTS full recovery should be evaluated in advance and financial planning should take this evaluation into account.
- Constant monitoring of financial resources (incomes, expenses, financial involvement of each involved party) should be conducted during and after the emergency, during the recovery phase, until full UTS recovery.
- Monitoring of the use of financial resources should be centralized to only one point in order to allow better resources allocation depending on the urgent needs. Monitoring should respect what is planned in strategic plan but should also be able to adapt to urgency and reallocate resources quickly enough in

case of urgent need that was originally not planned. Should also be able to adapt financial plan in case of re-allocation needs.
- The supply of resources should come from involved parties and stakeholders: service providers, cities, region, etc. Monitoring entity should be able to request funds quickly enough in order to be able to allocate resources in due time. It is needed to know in advance the way to obtain funds in order not to lose time during normal or emergency operation.

5.1.2.4 Interdependencies recommendations

- In order to manage the potential issues generated by the strategy planning function, an organization should consider applying the Corporate Social Responsibility (CSR); this is a corporate self-regulation, to align the business model to goals that emphasise accountability for the impact of actions taken on stakeholders and the broader community in which business operate. CSR encourages efforts to achieve a sustainable, positive impact through corporate activities. It provides opportunities to enhance the perception of a company's integrity and reputation, and can help increase brand recognition.
- To operate correctly this function needs appropriate funding based on the strategic plan.
- This function must provide the highest possible feedback to Coordinate Service delivery, Coordinate emergency actions, Monitor Resources availability, Use of services and Supply financial resources functions so that it can coordinate the financial management. This can be performed by direct communication or by continuously monitoring the operations.
- It is recommended that this function is particularly communicating and coordinated with Supply financial resources function

5.1.2.5 Limitations

- Possible limited financial resources of involved parties
- Possible barriers to plan a budget reserve in advance

5.1.2.6 Examples

Infrastructure Australia: Urban Transport Strategy from Federal government of Australia *(http://infrastructureaustralia.gov.au/policy-publications/publications/Infrastructure-Australias-Urban-Transport-Strategy-December-2013.aspx)*

- This report discusses the development of a strategy for a national framework for planning, financing and managing urban transport infrastructure.

  Key points

  - The strategy would target city planning, transport services and investment in road and rail infrastructure. It would complement national strategies for ports, airports and freight.
  - The report raises issues relating to the development of a national urban transport infrastructure strategy and suggests key principles to guide its development, considered with reference to systems, economic, social, environmental and governance criteria

A Pre-Event Recovery Planning Guide for Transportation, TRB report
(http://www.trb.org/Publications/Blurbs/169296.aspx)

- The Guide is intended to provide a single resource for understanding the principles and processes to be used for pre-event recovery planning for transportation infrastructure. In addition to the principles and processes, the Guide contains checklists, decision support tools, and resources to support pre-event recovery planning. The Guide will be of interest to transportation infrastructure owners/operators, transportation planners, and practitioners at the state and local levels.

5.1.3 Perform Risk Assessment for the UTS

5.1.3.1 Background facts

Risk assessment serves the fundamental purpose of supporting both the definition of priorities for action and the determination of the nature and course of such action. Since its origins, risk management has evolved very differently depending mainly on the domain (i.e. industry, health care, services, etc.) and the nature (i.e. industrial safety, occupational safety and health, security, economic and financial risk, etc.) of risk. This has resulted in a highly fragmented approach to risk assessment, which is reflected at normative and legislation levels.

High system complexity poses many challenges for risk assessment in all industry sectors. Transport systems may be increasingly challenging, mainly as a result of the strong and close interactions that occur between their operation, the service user and often the wider public. In addition, such interactions tend to take place beyond the scope of any organisational and geographical boundaries. Within this context, multiple risk factors emerging from system interdependencies require assessment tools that not only support integrated risk management practices but also, are effectively embedded into operational processes.

5.1.3.2 General recommendations

Risk assessment should take into account the following:

- The need for shared risk related knowledge amongst multiple transport stakeholders. In particular within the domain of security, it becomes critical to balance the sharing of information against the need to protect sensitive operational knowledge. Regular stakeholder meetings or task forces oriented to specific risk assessment and management needs, may provide the necessary information sharing basis, whilst insuring that such information remains contained within a restricted number of people.
- Increased need for integrated risk assessment in order to facilitate coordinated risk management actions and measures. Within transport systems, a wide diversity of risk factors emanating from different risk domains may interact at different operational levels (i.e. weather related, passenger safety and security, operation related). The regular and integrated assessment of such risk factors requires dedicated human, organisational and perhaps even technical resources. In particular, safety and security requirements often overlap, namely as the result of the need to provide a safe access to transport services and all related infrastructures, whilst ensuring the protection of restricted areas.
- Shift from single “all purpose” tools to a set of integrated tools that respond to different risk assessment needs (i.e. local specific operations, global and interdependent overview of risks). Particularly as transport services become increasingly reliant on close cooperation between multiple stakeholders, for instance, across infrastructures managed by different entities, where operation control system may use different technologies, at transport hubs where modal shifts must take place as seamlessly as possible.
- Develop and monitor the availability of dedicated resources and specially trained staff for carrying out risk assessment, particularly regarding operations involving critical and/or complex technology, among others.

5.1.3.3 Common Conditions recommendations

***1.* Availability of resources**

- Risk assessment may require measurement or detection equipment but often sufficiently precise assessment methods may be used. This may be particularly relevant for the gathering of data on transport infrastructures and other engineering assets.

- ***Humans (labour) – skills/competence***
  - Risk assessment activities should be carried out by qualified dedicated teams but always in coordination and relation with local operational staff. When the commissioning of new assets (i.e. vehicles of infrastructure equipment), or changes to procedures and rules are involved, most transport sectors

require risk assessments to be carried out by certified experts, often acting as the regulators or on his behalf.
- Resorting to third party experts may provide a fundamental independent perspective on complex risk factors, which may prove more difficult to achieve when assessment is carried out from within the operation. This may be supported by a sector level cooperation, namely through industry associations such as the UIC (International Union of Railways) or even with the support of national regulators and other international certifying associations.
- To any possible extent, assessment activities should be carried out within teams that gather various relevant expertise, ranging from engineering (e.g. mechanical, chemical, etc.), and human factors, among others. An in-depth knowledge of processes and operations is fundamental. As urban transport systems tend to operate across many different organisations and administrative regions (i.e. counties or boroughs), people benefiting of local knowledge are also fundamental.

- ***Budget***
  - Risk assessment budget should account for the possibility of instrumentation and external expertise needs.

- ***Data & Algorithm:***

Historic and statistical data provide essential support for risk assessment procedures:
- Data sets should be reviewed periodically, in order to integrate new potentially relevant risk variables. This provides the means to integrate changes in risk models.
- Data sets should include relevant variables of operational environment, namely economic and social outsets and forecasts.
- Follow EU guidelines on Risk Assessment.
- Within transport the crossing between asset performance data, service level and event related information offers valuable insight on the potential impacts and relations amongst multiple risk factors.
- Plan periodic data analysis for detecting unexpected correlations and emerging situations.

2. **Training and experience**
- Subject matter experts should be consulted in order to validate hazard identification.
- Resorting to local staff is vital, as transport systems operate across many different organisations, and administrative regions. This renders knowledge and understanding of local operational practices a fundamental input to risk assessment.

3. **Quality of communication**
- Real time and accurate communication is critical for transport operations.
- Ensure the accuracy of data and risk assessment outcome

4. **Human Computer Interaction and operational support**
- NA

5. **Availability of procedures and plans**
- Assessment needs must be contemplated and integrated in process description as needed, as opposed to independent or “stand-alone” activities.
- In addition to periodical needs, operation and process change control processes must call on risk assessment and determine when such activities are required. While transport authorities in most sectors and member states may impose risk assessment requirements for these cases, stakeholders directly involved with transport operations and dealing with operational assets should set the conditions for mandated risk assessment.

6. **Conditions of work**
- A suitable level of independency and autonomy should be ensured to risk assessment teams.
- Within transport, risk assessment may be carried out in the close proximity of moving vehicles or within transport infrastructures open to traffic, namely in connection with maintenance activities. The setting up

of dedicated and planned safe conditions of work should be contemplated (this is often mandated by regulations).

7. **Number of goals and conflict resolution**

- One of the sources of conflicts amongst transport stakeholders relates to the attribution of costs for service failure, namely what can be referred to as delay attribution. For instance, demonstrating a comprehensive risk assessment for the delivery of engineering and maintenance projects can be decisive if and when accountabilities and responsibilities for a (possibly related) disruption to transport service are investigated.
- Tools that respond to assessment needs of different process stages: planning, operation, maintenance, decommissioning, etc.
- Precision (quantitative, qualitative…) of risk assessment must match process stage requirements and objectives

8. **Available time and time pressure**

- While time requirements for risk assessment may not vary significantly, time pressure should be kept to a minimum, so as to not compromise thoroughness and validity of risk reporting.

9. **Circadian rhythm and stress**

- NA

10. **Team collaboration quality**

- Team work may be particularly relevant when assessing more complex operations and when producing risk reports. These should be shared amongst transport stakeholders as deemed appropriate, as information sharing constitutes one of the fundamental cornerstones for team collaboration and coordination, in particular when multiple stakeholders and goals are involved.

11. **Quality and support of the organization**

- Interactions and interdependencies between transport stakeholders tend to be considerably dynamic and complex, particularly between those that are more directly involved in the delivery of the transport service, such as infrastructure managers, maintainers and operators. The ability of regulators to act upon such tight coupled relations may be limited and seeking an alignment between stakeholder expectations and needs, and the best interest of the end-users and the wider public, can be very challenging. It is important to establishing formal principles of cooperation and coordination amongst key stakeholders and ensuring that such principles are put into practice as organisational support to operational staff that, despite responding to different organisations and responsibilities, must work as a cohesive team, often under time pressure and high risk exposure circumstances.
- The clear and explicit organisational recognition of the critical role of risk assessment is a fundamental contribution for the robustness of risk assessment activities and their outcome
- Some interaction with stakeholders may be relevant in view of estimating supply chain related risks, which may require some formal pre-established organisational setting.

5.1.3.4 Interdependencies recommendations

- Hindsight on events constitutes a fundamental input to risk assessment. This requires reliable relations both within the organisation and often amongst stakeholders. Beyond the description of linear relations of causality, this should support the identification of interdependencies and their impacts in terms of performance variability. This requires more than conventional accident and incident investigations. Team reviews and discussions based on a thorough description of events (as opposed to an identification of failures) can produce valuable learning experiences and support the development of adaptive capacities. Risk assessment activities should be developed based on multi-disciplinary teams and integrate stakeholders as relevant. It should also feed into all management and operation practices namely through the identification of the need for procedure reviews, or the redesign of operation or technology, among others.

5.1.3.5 Limitations

- Resources are inherently finite. For risk assessment, this means that, on the one hand, assessment must be built and adapted to the inevitable limitations of available information, both quantitatively (the amount and volume of information) and qualitatively (the accuracy and reliability of information). On the other hand, assessment activities must always adjust to time limitations in terms of, both the different time scales at which assessments are needed (different stages and levels of decision making processes and operations), and the timeframe within which an estimation must be produced to support decision making.

5.1.3.6 Examples

- Risk forums that bring together teams involved in managing different risk domains, addressing in particular, the potential need to review risk models and assessment tools.
- Team reviews of risk analysis activities, mainly focusing on the interpretation of risk factors and their mapping onto real operational context and specific scenarios.

5.1.4 Training staff

5.1.4.1 Background facts

Training is defined as all activities deliberately performed to enhance knowledge, skills, and abilities of UTS employees with the aim of enabling them to better perform their specific job and to contribute to urban transport system resilience. Training staff function needs to be analysed per transport infrastructure and service provider category and per staff category. The aim is to train staff for routine operations, safety and security issues and emergencies. The intention is to motivate properly the staff in order to reduce risk behaviour and increase the effectiveness of their responses at emergency situations.

Staff categories pertain to Operations & Maintenance (transport service providers), Engineering studies & Construction site overseeing (transport infrastructure providers) as well as Administration. Staff can be in-house or subcontracted.

Training staff of Urban Transport System mean to provide adequate knowledge to perform their job, develop skills and abilities along with perception of the impact their performance has on the UTS and its end users. A critical issue here is to make UTS personnel act responsible and professionally supporting and promoting the image and in accordance strategic aims of the UTS.

Following the description of training staff in D3.5: A training *curriculum* is a description of how the training is done and includes a specification of when, where, how, using which materials and based on which scenarios the participant is expected to acquire the desired knowledge, skills, and abilities" Therefore in the UTS case it is important to decide who are the involved trainees (bus drivers, transit hub staff, transit operators etc.), where the training will be located (transit hub, office, pilot study etc.), how the training will be executed (in phases, participatory, surveying, assessing simulations etc) and with which material and scenarios will be used. For example to train staff responsible for monitoring safety and security at a hub we need to use data form CCTV cameras, to collect and analyse them, to simulate a response alert activation system, communicating data to police, traffic police and station security (agency and employees), to record system performance timing, to assess after the trial response time, quality of communication, execution performance, automated system performance etc. and to collect feedback from trainees and trainers to enhance the process. This could be part of a more complete training program that will be periodically performed in the hub and results and performance will be correlated.

Training is a key element to ensure resilience. In emergency situations, different actors from different organizations need to collaborate efficiently in order to maintain or restore the UTS operation and performance and therefore it is important to include in the training process collective exercises including difference stakeholder categories. For example in case of an event to terminal 1 of a metro station, the involved stakeholders are: metro terminal 1 security responsible staff, metro terminal 1 information displays monitoring staff, metro bus drivers reaching terminal 1 at a specific time period, station security monitoring office, complaints office of the station, travellers using metros form terminal 1 and general public in the terminal 1, ticketing machines responsible staff etc. All these actors need to communicate and collaborate effectively and timely to handle the event optimally.

5.1.4.2 General recommendations

It is important to develop and test the training material considering the aim of training, the potential results in the UTS resilience and examining alternative methods to deliver the UTS resilience level that meets the UTS targets. Therefore, validating plans; rehearsing key staff; and testing systems which are relied upon to deliver resilience is crucial. This means that the personnel need to be trained so as to keep uninterrupted the general public when the monitoring safety and security mechanism suspects a terrorism attempt. The staff should be trained to deal with the event optimally without spreading panic to the general public and timely to eliminate risks and disasters. The frequency of exercises and training depends on the needs the threats and the statistics (fatal road accidents, station attacks etc.), but should take into account the rate of change (to the organisation or risk profile) and outcomes of previous exercises (if particular weaknesses have been identified and changes performed).Optimally, if there is adequate budget, training should be a priority for the UTS and take place periodically with high frequencies for all UTS staff.

To contribute to the resilience of the system, training activities need to be organized in a manner that fulfils the following criteria, ensuring that:

- the allocation of resources to training is coherent with the overall strategical planning,
- undesired variability in the training's outcomes is reduced, and
- training activities are revised to take newly discovered requirements into account.

Citizens need to be adequately trained to take part in the collective responsibility of creating disasterresilient cities. Therefore, the entire community must be informed about Urban Transport Risks (from traffic collisions to metro/airport terrorist attacks) to which they are exposed, in order to be better prepared and take measures to cope with potential UTS disasters. The trainng should cover awareness, education and capacity building/hub programmes on disaster risk and mitigation measures in order to improve preparedness and help citizens respond to local early warnings

To achieve training objectives for the UTS is important to:

- Integrate disaster risk reduction into formal education programmes, i.e training on trial simulations of traffic assignment after events, information polices to ensure safe movements in a transport hub in risky situations, VMS guidance to exit collision roads after event occurance
- Work with educational authorities, key transport experts, transport researchers to include disaster risk reduction at all levels of the school curriculum and in all UTS related public and private institutions.
- Seek necessary technical support for curriculum development from UTS related institutions and agencies.
- Collect and learn from past experiences, use UTS events as traning case studies to dirive knowledge from lessons learnt
- Examine similar training programms, their results in UTS resilience and follow the best practices.
- Develop risk reduction training and capacity UTS infrastructure (within a hub, road selection etc.) at the city level
- Work with local resources such as the Red Cross, universities, NGOs, teachers and others for a horizontal knowledge delivery approach. For example hub personell should be aware of CPR as the majority oft he elderly movements are assigned to public transportation.
- Focus on training priority target groups such as: public transport authorities and UTS emergency management authorities; monitoring safety and security fort he UTS responsibles; etc.

5.1.4.3 Common Conditions Recommendation

1. Availability of resources

Humans (labour) – skills/competence

- The collection of training requirements should be linked to feedback processes available to all members of the Urban Transport Systems and based on mobility data and events that considered being risky.

Budget:

- Budget planning should account for the working hours spent on training by both trainers and trainees, including external trainers, training materials, UTS event simulation trials budget needs, training locations and/or infrastructure, working hours of HR specialists updating training procedures, and auditing or certification costs.

Data & Algorithm:

- Use official and standardized formats to describe training requirements and test procedures where applicable.
- Store documentation of trainings and tests according to legal regulations.
- Make collected data available for the general data aggregator to allow verifying eventual correlation of training and skill with performed experiences.

2. Training and experience

- Collect feedback from trainers and mobility simulation trials in order to improve the training process and material
- Prioritize training actions considering the role of involved parties (key actors to eliminate disasters and vulnerable target groups first) and critical role of transport infrastructures/services (for example in terms of a terrorist attack in a transport hub it is crucial to prioritize information delivery services to people in order to provide safety exit guidance)

3. Quality of communication

- Support efficient shareholders and (internal and external) stakeholders/experts coordination and cooperation among different stakeholder categories and promote a “single window” information framework in order to avail combined information for all transport choices, modes, activities, processes.
- Guarantee the accuracy and understandability of the communication through standardized communication tools, protocols and languages. Use the same transport environment simulation trials, Unicode strategies and training material.

4. Human Computer Interaction and operational support

When choosing the method for delivering the training, the following recommendations should be taken into account:

- Classroom training should be chosen if basic knowledge needs to be learned and if individual differences between trainees do not seem to influence training efficiency.
- Simulator training should be used for practical skill acquisition if training with real-world objects is related to high risks concerning the health of persons or the destruction of costly equipment.
- On-the-job-training or drills and exercises should be used for practical skill acquisition if training with real-world objects is not related to high risks concerning the health of persons or the destruction of costly equipment.
- E-learning may be used if the contents of training are assumed to be relatively stable over longer periods of time.
- Game based training, simulating traffic and transit volumes in cases of events in urban road network and delivering messages to VMSs
- On-line assessment tools to evaluate the critical level of UTS events and prioritize movements
- Smartphone UTS applications usage and assessment
- Safety and security at hubs trials under different scenarios of events
- Collaborative games/procedures/communication trials among UTS stakeholders that need to deal with the same event and timely respond from different perspectives
- Store data from UTS games training and analyses them considering the travel strategies of each UTS staff category developed in the game decision nodes. For example in a simulation of movements in the

road network in a decision node the VMS signal might be "fatal accident, exit from the second exit ahead". Collect reactions and strategies developed.

5. Availability of procedures and plans

- The definition of training objectives and curricula, as recommended in the general recommendations, should be formalized and be embedded within the organization's UTS HR procedures (such as personnel acquisition, promotions, etc.) . The procedures must be clear and properly communicated to trainers and trainees who participate in training activities.

6. Conditions of work

- It is recommended to appoint the head of UTS HR as a responsible to ensure that the conditions necessary to perform the trainings. This includes the provision of space, materials such as media and consumables, budget and buffer personnel to account for the temporal unavailability of trainers and trainees to standard operations. In cases of trials at stops, road and hubs training activities must ensure that do not impede travelers' movements and do not affect nonparticipants (testing trial terrorist attack in a hub terminal should not affect hub users and spread panic- should be communicated to the general public that it is a trial and if appropriate encourage them to "watch" the trial training of the personnel in order to aware and inform them as well).

7. Number of goals and conflict resolution

- Often, restrictions in time and budget will make it impossible for certain employees to achieve all possibly defined training goals, at least within the desired timeframe. To resolve such conflicts, training objectives and subsequently training curricula need to be prioritised. To prioritize training activities we need to address the following questions:
    - Is this training legally required for standard operations?
    - Is this training legally required for relevant emergency situations on the UTS?
    - Is this training directly relevant for life-saving in UTS emergency situations?
    - Is this training relevant to create buffer capacities for UTS emergency situations?
    - Is this training relevant for improving the efficiency of standard UTS operations?
    - Is this group of staff that will be trained more critical to deal with UTS emergencies?
    - Is this training material optimal to deal with UTS training and does it reflect actual needs covering possible threats in the UTS?
    - Is the training plan, methodology and time/location frame according to the training objectives and supports the UTS aims of training (feedback)?

8. Available time and time pressure

- Planning training milestones should integrate degrees of flexibility to cope with planning UTS training quality requirements.
- Schedule trainings according to predicted demands: For example perform metro hub trial at times the metro do not operate (night or early morning hours)

9. Circadian rhythm and stress

- Perform trainings during regular working hours unless the training requires a specific setting and infrastructure that is highly used from the general public and should not be communicated to them (terrorism attack at metro station trial should be examined at late night hours when the metro is closed) Trainings should always avoid an excess of workload for both trainers and trainees. It is important not to press trainers and trainees but develop training programs that aim to transfer the maximum level of knowledge to participants without stressing them. Exceptions may occur when testing events that need more time to respond and restore the UTS to previous conditions, but also in such cases should be examined in phases the training program.

10. Team collaboration quality

- Provide training on the principles of collaborative actions to all UTS strategic management actors (transport authorities, infrastructure managements, UTS decision making representatives etc) .
- Provide training on collaborative UTS crisis management to all crisis management teams (monitoring UTS safety and security staff, traffic police, UTS decision makers etc.).
- Provide team development interventions to recently formed teams based on the role in the UTS and examine different collaboration schemes reactions and performances (i.e. metro driver with hub responsible dealing with a fatal event in the metro lines, and for the same event management trial- test hub responsible and terminal security interaction).
- Provide trainings that increase awareness and understanding of vulnerabilities and respective mitigation strategies (i.e. an event cause destruction to the ramps, reduced mobility elevators and similar accessible paths in a hub and 100 reduced mobility persons are trapped there). When on-the-job training is applied and experienced trainers are supposed to act as trainers, the training effectiveness should be evaluated by another, independent trainer.

11. Quality and support of the organization

- The UTS should support training actions and prioritize training activities. Moreover, transport experts or employees higher in UTS hierarchy could undertake the role to monitor training activities and organize the groups of trainers.
- To achieve a high quality of training the following techniques could be followed:
    - Role-playing (i.e. bus driver takes the role of the Public Transport authority decision maker and proposed a strategy for an event).
    - Scenario-based training (i.e. bridge collapse and traffic simulation in the central of London).
    - Training for role improvisation (i.e. security alert system collapse and event situation in hub).

5.1.4.4 Interdependencies recommendation:

- Monitor Safety and Security is related with training security staff to properly interact in UTS events
- Defining procedures include the training procedures, limitations, guidance and standards that should be followed
- Perform risk assessment takes feedback from the training activities to assess risks in the UTS
- Coordinate Service delivery regarding training staff requirements
- Regulate domain and operation for the training procedures regulation and training operation
- Coordinate emergency actions to develop the training material
- Define procedures for training (locations, time, involved UTS stakeholders etc.)

5.1.4.5 Limitations

- The usefulness of training as a measure to increase UTS resilience should not be limited to the training for specifically known and anticipated risks and to the training of meta-competences (such as team-work, participative leadership, team-based problem solving, etc.). Training on aspects such as the overall knowledge and understanding of UTS operations or the flow of traffic/transit information, can be useful towards enhanced urban transport resilience. However, the management, implementation and assessment of such training initiatives may be challenging. In some cases, implementing cross-sector/department exchange of knowledge and expertise can benefit this purpose.
- The use of a guideline-based training approach has its limitations with respect to the training of target groups that are not identified as a finite number of known individuals, such as transit travellers, drivers or other stakeholders.

5.1.4.6 Examples

- Driver training in driving simulators and in vehicles without passengers for beginner drivers of trains.

5.1.5 Coordinate Service delivery

5.1.5.1 Background facts

The function aims at coordinating service delivery during ordinary /normal operation, as well as during and after incidents/disruptions of normal service.

The function aims at coordinating transport service delivery during ordinary /normal operation, as well as during and after incidents/disruptions of normal service. Coordination of transport service delivery before a disruption, concerns business as usual and standard communication and operation procedures should be used. Coordination of transport service delivery during or after an incident/event requires the implementation of emergency rules and procedures as well as wider communication and coordination with first responders. Post – event coordination of service delivery should focus on implementing alternative scenarios according to emergency plans and procedures and risk assessment based on the strategic transport plan.

The coordination of urban transport (UT) service delivery involves all aspects of providing urban transport service and all relevant stakeholders. In particular, aspects to be considered may include:

- Public transport service with Operation control Center (OCC)
- Transport infrastructure (road network infrastructure, shared rail/road infrastructure, transport hubs)
- Traffic Management Center (TMC)
- Paratransit management
- Accessibility management (parking/park&ride/kiss&ride, pedestrians, cycling)
- Integrated smart ticketing & telematics
- Information to the public (language-independent or multilingual, through different sensorial channels)
- Timetable coordination (dynamic/schedule based)

5.1.5.2 General recommendations

An overall supervising authority responsible for the coordination of transport service delivery should be established. Specific transport service providers should follow compatible operation, maintenance and emergency procedures. Safekeeping and cross-labeling of incident inventories should be given priority. Immediate communication and information of management staff for all potentially severe incidents subject to immediate risk or other system weaknesses relevant to health and safety needs.

Access links to transport infrastructure for service provision should be planned, defined and communicated by overall supervising authority to service providers. Alternative access routes should be planned and communicated to transport service providers in cases of service disruptions.

User generated feedback on service effectiveness is also important in updating the coordination of transport service delivery.

Specific recommendations depend on the Operation Plans of urban transport providers as well as on the mobility patterns (transport demand) in the area under consideration.

5.1.5.3 Common Conditions recommendations

1. **Availability of resources**

Humans (labour) – skills/competence

- Consult with transport service providers and the general public (transport surveys), for operation requirements, including required skills and competence of staff.

Budget:

- Provide adequate budget for the service delivery in the Strategic Transport Plan. To perform the function, adequate budget should be provided per transport provider. Transport service demand impacts appropriate budget allocation.

Technical equipment:

- State of the art technical equipment, components of transport infrastructure (mainly road and rail) as well as vehicles and transport applications of ICT infrastructure (e.g. Variable Message Sign panels, Operation Control Centers, Traffic Management, integrated smart ticketing) should be used, including a resilient internet network covering all areas of service delivery.

Data& Algorithm:

- Prepare maintenance reports, emergency response status reports
- Prepare maintenance status reports for transport infrastructure, vehicles and equipment at predefined time periods.
- Emergency Status reports required to perform the function following an incident /disruption of transport service.

2. **Training and experience**

- Staff should be adequately trained to implement relevant rules and procedures (e.g. operating, communications procedures, safety and security procedures). Staff should be periodically tested for adequate training and knowledge of routine and emergency rules and procedures to catch up updated operating procedures. Staff should also be trained for transport applications of ICT infrastructure.

3. **Quality of communication**

- Clearly define all potential communication channels among stakeholders(VMS, information signs, maps), provide emergency communication plan
- Use standardized communication tools, protocols and languages

4. **HumanComputer Interaction and operational support**

- Provide operational support for use of ITS, training procedures and suitable software to assist responsible personnel.

5. **Availability of procedures and plans**

- Ensure that clear operation plans and emergency procedures are available
- A responsibility matrix, operating, safety and emergency rules and procedures as well as trained staff are preconditions of the said function. Preventive and failure-driven maintenance of transport infrastructure is essential precondition of the function too.

6. **Conditions of work**

- Ensure best possible conditions of work, considering air quality and lighting conditions for metro service staff as well as drivers work in urban road traffic conditions.

7. **Number of goals and conflict resolution**

- Establish conflict resolution procedures in case of different orders by ordinary upper level staff and emergency staff

8. **Available time and time pressure**

- Ensure a degree of flexibility when planning milestones and deadlines to cope with quality requirements (e.g. considering itineraries, time of first and last buses close to metro stations should be close to time of first and last trains to achieve timetabled transfers in marginal times.).

9. **Circadian rhythm and stress**

- Ensure compatible nightshifts for (especially maintenance) staff of various transport service operators
- Train driver recruitment procedures should include psychometric tests

***10.* Team collaboration quality**

- Take into account team collaboration competences when recruiting personnel
- HR management of transport providers should assess the strength of a potential employee to hold colleagues together, to gather/report information to colleagues and 3rd persons, to trust and respect his/her team and to coordinate/integrate with others.
- Establish mutual performance monitoring procedures.
- Team performance at each transport unit level is an essential KPI over and above individual performance metrics.

***11.* Quality and support of the organization**

- Establish clear decision making process and alignment of responsibility with accountability
- Perform regular audits to check the need to update operating procedures following specified time periods
- Perform audits to check the need to update operating procedures following disruptions of transport service

5.1.5.4 Interdependencies recommendations

- Apply emergency exercises and emergency communication plans to coordinate transport emergencies effectively.
- Use maintenance procedures for physical /cyber infrastructure that take into account transport service peaks, to adjust to more critical availability needs.

5.1.5.5 Limitations

- Possible budget constraints or inadequate legal framework may impose limitations to coordination of transport service delivery.

5.1.5.6 Examples

USA Department of Transportation (DOT)

- USA Department of Transportation (DOT) and its partner agencies, have juggled the roles of funder, owner, operator, guider, and regulator of the Nation's transportation infrastructure to coordinate UTS service delivery and build resilience in the transportation system.

Transport Scotland and Scottish Environment Protection Agency (SEPA) coordinates service delivery to deal with Flood Risk Management

- As Local Flood Risk Management Plans are developed, Transport Scotland will aim to provide information on how trunk road drainage assets might impact on Potentially Vulnerable Areas (PVAs), as well as understand how flooding in the PVAs might impact on trunk road operations. This will be augmented by our Disruption Risk Management process which will improve understanding of known flooding locations, and deliver mitigation plans and improvement programmes.

5.1.6 Manage awareness & user behavior

5.1.6.1 Background facts

This guideline is directed to UTS infrastructures that are used by passengers or other persons that are not related to the infrastructure through an employment status in the UTS organization that manages the infrastructure itself or by another organization professionally related to it.

In order to anticipate, detect, or recover from an adverse event, such as a service disruption, the collaboration of the end users or the public may liberate important resources. Therefore, an ex-ante designed strategy for managing user awareness and user behaviour can lead to a higher organizational efficiency in terms of how resilience is achieved.

Managing user awareness and user behaviour may include short-term and long-term actions. Ad-hoc-communication is the tactical information immediately given to the users, such as information about delays or evacuation routes via signs and P.A. system. Long-term actions may include the provision of general information through smartphone applications and internet platforms, printed posters with instructions for emergency responses (wheelchair exit movements from stations, alternative routes etc), organized events to aware and inform UTS stakeholders, trainings for children organized at schools and the elderly organized at open care centres for the elderly, and similar means of communication that are not meant to produce immediate effects.

Manage awareness and user behaviour in the Urban Transport System refers to the level of awareness of different stakeholder categories involved in the UTS (managers, drivers, station staff, decision makers, travellers etc.) adequate to support safe and secure behaviours in cases of UTS corruptions and emergencies. Therefore it includes a list of elements like:

- Signalling, awareness, stakeholder communication, training, etc.
- Surveys – communicating outcomes
- Training (material, emergency simulation,
- Dissemination channels (media, leaflets)
- Clear communication of guidance in case of emergency (signing, alternative sensory channels for providing information, info on alternative modes/routes, multilingualism or language independent info)
- Software apps
- Education of special groups (kids, elderly, disabled etc)

Safety & emergency awareness of the general public in the view of severe disruptive events in the UTS is of great importance. Public communications for keeping safety procedures by posting information and graphics in vehicles & hubs and public education of schooling population in matters of safety & emergency are nesecities.

In case of emergencies, guidance for affected travellers is secured through signage, public address system of the transport provider and VMS panels (indicating alternative modes/routes) in road arterials. Special attention should be given to alternative sensory channels for visual & hearing impairments along with instructions for handling wheelchairs during emergencies.

To aware travellers in order to adopt resilient mobility behaviour the following means of awareness could be used:

- TV and radio advertising and information for UTS resilience and proper behaviour of travellers.
- Software apps for mass alerts and bulk SMS that may instruct people on the move in cases of emergencies
- Station/ terminal/ road advertising

- Training material and training findings (from training staff) to be used in campaigns for the general public awareness for UTS resilience etc.

The reduction of the perceived public risk influences positively peoples' cognitive & affective judgment of risks and effectuates panic prevention. Awareness campaigns aim at developing enhanced confidence to the transport system.

5.1.6.2 General recommendations

Develop engaged communities with active participation of community members with responsibilities and awareness regarding their travel behavior along with common knowledge about disaster risks in the UTS, factors that lead to disasters and actions that should be taken individually and collectively to reduce exposure and vulnerability to hazards.

All communications to the users or the public should be based on a work plan that contains a justification and the objective of a message, the media and channels to use, the expected results and a timeline for delivering the message.

Governmental support and the support of private or public organizations should be sought to implement long-term actions such as campaigns or educational programs for raising public awareness about citizen safety and disaster risk reduction. Anniversaries of past disastrous events are recommended for the implementation of campaigns, along with events to raise awareness.

Public awareness campaigns are recommended, if:

- A new type of adverse event has been added to the risk analysis and the cooperation of the public is required to reduce the risk or increase buffer capacities.
- It has become clear that the general public is unaware of the risks related to a certain type of event and/or safety advice from the organization has not been followed by the public.

Plans and procedures for ad-hoc communications need to be aligned with mitigation strategies for anticipated events or disruptions.

Depending on the objectives of certain communications, partnering with public bodies is recommended in the following cases:

- Schools or other public educational institutions should become involved in increasing public awareness.
- Design the communication strategy around the addressability concept (4R - right people at the right time in the right place through the right channel).
- Work with partners to deliver a joined up service (exhibitions and advice provision) to the community.
- At individual user request, provide 1:1 advice on "how to"; (e.g. contacting local authorities and other bodies as well as provide advice on how to protect themselves and their property against future events)
- Establish a people centered early warnings system to empower individuals and communities threatened by hazards to act in sufficient time and in an appropriate manner to reduce the possibility of personal injury, loss of life and damage to property and the environment.
- Establish a cooperation of privately owned infrastructure operators and public bodies across sectors and borders, as well as with local communities as citizens organizations, business, academy, NGO, local and regional government, in order to enable a multi-dimensional response to problems and needs.
- Communication systems should be community-centered rather than agency-centered, thus tailored to meet the needs of every group in every vulnerable community.
- Consider the use of social marketing and evidence-based approach.

5.1.6.3 Common Conditions recommendations

1. Availability of resources

Humans (labour) – skills/competence

- The task of managing long-term campaigns on awareness and user behaviour should be performed by experts in public relations or marketing and the responsible for UTS service delivery and mitigation of disruptions should be included when defining such campaigns.
- Consult with transport service providers and relevant stakeholders, safety and security trainers, transport professionals, for operation requirements, including required skills and competence of them.
- The task of managing ad-hoc situation awareness and user behaviour should be performed by specifically trained staff. Training should include contents on travel behaviour in emergency situations and evacuation behaviour of large groups of people.

Budget

- Provide adequate budget for proper signalling, educational campaigns, TV spots, training material including educational material for transport safety and security, promotional material for environmental friendly user behaviour adaptation, campaigns, response guidance material, development of software apps for mass alerts and bulk SMS able to instruct people on the move, salaries of staff responsible for the training and development of the previous.
- Budget planning should account for the required communication UTS infrastructure, as well as for the planning of the procedure itself. Certain channels, such as social media, need constant attention to be maintained functional and thus require adequate budget availability.

Technical equipment

- State of the art technical equipment (pcs, simulators etc.), components of transport infrastructure (mainly road and rail) as well as technologies for alerts (applications) should be used, including a resilient educational and awareness internet network covering all areas of service delivery.

Data & Algorithm

Collect and exploit statistical data to tune and better:

- evaluate mode/route choices and shifts.
- collect feedback of the training/awareness campaigns/ lessons learnt.
- understand risks perception and evaluation from users.
- estimate social media usage for trips made and UTS related information exchange among travellers.
- know the carpooling- car sharing usage.
- know peak hour traffic and transit assignments (before and after campaigns correlations).
- estimate ticket purchase rates/ station flows.

2. Training and experience

- Assess the level of awareness after informing travellers for the consequences of their selected travel options.
- Assess the level of communication among travellers and decision makers/ UTS employees and/or authorities.
- Train UTS responsible staff for safety and security issues in resilience management of UTS.

3. Quality of communication

- Selection of proper communication channels/ test messages/ evaluate feedback from communication/ assess the quality level of communication in correlation with users behavioral changes and level of awareness, accessibility, inclusiveness and interoperability of communication for all. Define different levels of quality of communication based on user clustering/level of understanding and mean of communication (sms, application, tv spot, printed material etc.)

4. Human Computer Interaction and operational support

- Applications provided to the users should undergo usability testing to ensure their helpfulness during emergency situations .Therefore we need to develop smart apps to aware for UTS risks, alerts and communicating facts (from lessons learnt by similar UTS resilience management efforts to manage awareness and user behaviour in order to eliminate risks). Moreover, the communication methods need to be selected based on their scalability and sustainability. Recommended actions include:
    - Support interaction through social media accounts of users and promote relevant material (connect them to travel together/ share experiences/ interact)
    - Develop a user platform to include all the above and let citizens interact and be tested in trial scenarios of UTS disasters
    - Use computers/apps and ICT infrastructure to inform for the evacuation route planning in cases of emergencies along with reduced mobility people guidance

5. Availability of procedures and plans

- Develop procedures and plans to guide communication activities. (i.e. VMS messages, rerouting), promotional activities (i.e. UTS awareness TV/radio spots for safe and secured movements), sharing information and data collection strategies. A strategy for long-term communications, such as campaigns for safe movements in a transit station in cases of UTS events or procedures to follow for reduced mobility persons, should be created.
- The procedure for delivering ad-hoc messages should be defined, including general standards for the communication and specific messages/communication actions for predefined situations. This includes the use of channels and precise phrasing in order to be accessible by all kind of travellers.

6. Conditions of work

- Responsible for ad-hoc communications need to be continuously provided with status information or orders from the coordinators of UTS service delivery or mitigation.

7. Number of goals and conflict resolution

- Conflict resolution procedures need to be established in case of different orders by ordinary upper level staff, emergency staff and staff responsible for reduced mobility persons. Moreover, there should be individual/ personalized communication on evacuation procedures providing specific to traveller needs information for travellers with special needs. Communications should specifically aid vulnerable groups, for example by naming accessible exit routes in the case of fire in a transit hub.

8. Available time and time pressure

- Ensure a degree of flexibility when planning milestones and deadlines to cope with quality requirements
- Prioritize actions and movements (safety first, reduced mobility persons and young children first).
- In emergency situations, communications related to safety issues should always be prioritized and be accessible by all travellers (with attention to reduced mobility and special needs ones). Campaigns that encounter time pressure, i.e due to metro station corruption, should rely on social media strategies and news agencies to deliver relevant key messages and real- time information to travellers.

9. Circadian rhythm and stress

- NA

10. Team collaboration quality

- For managing awareness and user behaviour it is important to have a high quality collaboration among public UTS authorities, TMC and road operators in order to act in a collaborative framework of user awareness (VMS information strategies, safe routes prioritizing etc.).

11. Quality and support of the organization

- UTS authorities and key decision maker actors should achieve a high quality of communication and support common targeted decisions for UTS resilience.

5.1.6.4 Interdependencies Recommendations

Manage awareness and user behavior should be connected with:
- Monitoring user generated feedback, giving the impact of awareness and behavioral changes towards resilient movements
- Collecting event information, providing input from travelers behaviors in cases of UTS emergencies
- Coordinating service deliver, Monitor operations, Manage ICT resources and Use of the service to frame the awareness process and user behavior strategies and standards in accordance with the UTS resilience plan
- Monitorng Safety and Security as part oft he monitoring plan and process
- Coordinaitng emergency actions as travellers should be awared and and able to behave properly in cases of emergenies
- Monitoring Resource availability, to develop awaireness campaigns.

5.1.6.5 Limitations

- UTS awareness campaigns and communications effects are not guaranteed. The UTS staff responsible for managing awareness and user behaviour should always be prepared to face undesired user behaviours and deal with these.

5.1.6.6 Examples

ATTIKO Metro Athens
- Partnering between a local metro company and the local government to promote alternative routes in case of flooding.
- Planning of evacuation routes from a metro station for different user groups, including vulnerable users such as wheelchair users or persons with diminished eyesight.

5.1.7 Develop/update procedures

5.1.7.1 Background facts

The purpose of Standard Operating Procedures (SOP) in Urban Transportation Systems (UTS) is to ensure smooth transportation links at both city and regional level generally and especially within emergency context, where quick and safe movement of material and humans are a priority. It should coordinate the use of transportation resources to support the needs of emergency support forces requiring transport capacity to perform their emergency response, recovery and assistance missions.

Therefore, the final scope of this function in case of UTS is to assist in the coordination of vehicles, equipment, and the transportation facilities necessary for support of short and long term response and recovery operations in case of emergency.

5.1.7.2 General recommendations

To contribute to the resilience of the UTS, some general considerations should be taken into account when developing/ updating procedures:

1. Identify the goals and objectives for the emergency response procedures by defining what exactly the addressed emergency response team should do (e.g. evacuation of disaster area through public transport and government vehicles, limit the access to the disaster area, cleaning and reparation of access routes).
2. Review hazard or threat scenarios identified during the risk assessment phase for the addressed UTS.
3. Assess the availability and capabilities of resources for incident stabilization (e.g. evacuation of disaster area through public transport and government vehicles, limit the access to the disaster area, cleaning and reparation of access routes) including people, systems and equipment available within the addressed organisation and from external sources (public emergency services).
4. Confront with public emergency services (e.g. first defence, fire, police and emergency medical services) to determine their response time at city level, knowledge of the addressed urban area and its potential hazards and their capabilities to stabilize an emergency at the addressed urban area.
5. Determine if there are any regulations (e.g. LTZ accesses, one-way routes) pertaining to emergency procedures at the addressed facility; address the management of existing regulations in the plan.
6. Define protective actions for life safety (evacuation, closure of access to the disaster area, communication through all available means: VMS, web portal, mobile APPs, ecc. & control through all available means: UTC, LTZ, etc.).
7. Develop hazard and threat-specific emergency procedures using guidance from existing material and by using experience derived from former events.
8. Coordinate emergency planning with public emergency services to stabilize incidents involving the hazards at the addressed urban area.
9. Train personnel so they can fulfil their roles and responsibilities.
10. Facilitate exercises to practice the operational procedures defined in the emergency response plan.

5.1.7.3 Common conditions recommendations

1. Availability of resources

Humans (labour) – skills/competence

- The operational procedures should be defined by specialized personnel within the responsible mobility agency in collaboration to public emergency responders (civil defence, police, etc.).
- The procedures should also identify the emergency response team if not identified elsewhere.

Budget:

- Budget planning should account for the required time in order to permit the knowledge and testing of the operational procedures.

Data & Algorithm:

- Analyse statistical data and build assessment and predictive models.
- Use official and standardized formats to describe the emergency response procedures and test them where applicable by running demonstrations in the addressed urban area.
- The operational procedures should be defined in compliance to existing traffic regulations (LTZ, preferential lanes, way of routes).

2. Training and experience

- The operational procedures should be subject of training and feedback should be collected during training phase from the involved responders.

3. Quality of communication

- Test the different communication channels (VMS, mobile APPs, web-based information, media) and tools in order to guarantee their proper use for warning users to take protective actions and provide them with information related to the operational procedures. The communications capabilities also enable members of the emergency response team to communicate with each other and with users.
- Estimates of traffic capabilities, routes available for use, and route closures will be made available to state government for public information, through all available means, real time.

4. Human Computer Interaction and operational support

- The interfaces of the Mobility Supervisor should allow monitoring the whole involved urban area in terms of real time data. The Mobility Supervisor should also allow the operator to simulate the impact of the disaster on the road network. The HMI should also permit the interaction with the Traffic Strategy Actuators for the field implementation of the mitigation strategies.

5. Availability of procedures and plans

- This includes the availability of communication channels and precise clear phrasing within the operational procedures.

6. Conditions of work

- N/A

7. Number of goals and conflict resolution

- The operational procedures should have a well-defined target in relation to the addressed urban area and personnel
- The operational procedures should provide specific information for special categories of users (e.g. special categories of users should be addressed when describing SOP: impaired people, elder, children, ecc.)

8. Available time and time pressure

- The SOP for the emergency management in the UTS should be specific, clear and succinct.

9. Circadian rhythm and stress

- N/A

10. Team collaboration quality

- Roles should be clearly identified both within the responsible mobility agency and among mobility related organizations and responder organizations when defining procedures in order to enable high quality team collaboration.

11. Quality and support of the organization

- The organization should support the financial aspects in relation to operational procedures definition, training and testing.

5.1.7.4 Interdependencies recommendations

Risk assessment

- Risk assessment provides the factual basis for activities proposed in the strategy portion of a hazard mitigation plan. An effective risk assessment informs proposed actions by focusing attention and resources on the greatest risks. The four basic components of a risk assessment are: 1) hazard identification, 2) profiling of hazard events, 3) inventory of assets, and 4) estimation of potential human and economic losses based on the exposure and vulnerability of people, buildings, and infrastructure.
- The risk assessment should provide the basis for procedures development and should follow a standard (e.g. OSHAS); nevertheless in case of missing or incomplete risk-assessment the process of developing procedures should overcome to this in Step 2. The process should be also continuously updated and self-learning.

Operation plan

- The Operational Plan does present highly detailed information specifically to direct people to perform the day-to-day tasks required in the running the organisation. Organisation management and staff should frequently refer to the operational plan in carrying out their everyday work in order to ensure the desired level of service of the transportation network for all transportation modes.
- Procedural documents, the SOP, describe how to accomplish specific activities needed to finish a task or achieve a goal or objective. Put simply, Operational Plans describe the “what” and SOP describe the “how.” The SOP should grow naturally out of the responsibilities identified and described in the Operational plans.

Safety regulation

- All defined procedures should follow standard guidelines in relation to existing safety and health regulations (e.g., OSHAS 18001)

5.1.7.5 Limitations

- Limitations in relation to SOP might be related to their complexity and non-applicability due to the damage of infrastructure itself.

5.1.7.6 Examples

- Transportation has a vital role in Disaster Management as it can minimize the time span of all the Emergency Support Functions. PEN INDIA TECHNOCRATS has developed the SOP for ESF

'TRANSPORTATION' by integrating the role of Primary & Support agencies with reference & context of HPC Report, statutory documents & Guidelines of Disaster Management Cell – UPAAM & exploring the subject with their experience. The aim & objective are to have least Response Time in case of emergencies involving from a transportation point of view.

5.1.8 Manage human resources

5.1.8.1 Background facts

In the frame of UTS, managing human resources is a function that regards every organisation involved in providing transport service, managing and regulating urban traffic (private and public), providing support and emergency services in critical scenarios, as well as offering other services, such as dissemination and update of related information.

Strategic workforce planning should address three critical needs:

(1) aligning an organization's human capital program with its current and emerging mission and programmatic goals;

(2) adopting long-term strategies for acquiring, developing, and retaining competencies and expertise to achieve programmatic goals;

(3) previewing the continuous update of all actors' competencies, skills and risk awareness, according to technological changes in the Transport sector, such as the ones related to the implementation of different ITS with the aim of promoting the transport efficiency, safety and security together with a clear and effective protection of the environment.

HR function develops effective human capital management strategies to ensure the organization is able to recruit, select, develop, train, and manage a high-quality, productive workforce in accordance with merit system principles. This function includes:

- developing human resources and human capital strategies and plans;
- establishing human resources policy and practices;
- managing current and future workforce competencies;
- developing workforce and succession plans;
- managing the human resources budget;
- providing human resources and human capital consultative support;
- measuring and improving human resources performance;
- determining, implementing, monitoring, reviewing and evaluating human resource management strategies, policies and plans to meet business needs;
- advising and assisting other managers in applying sound recruitment and selection practices, as well as appropriate induction, training and development programs;
- developing and implementing performance management systems to plan, appraise and improve individual and team performance;
- representing the organisation in negotiations with unions and employees to determine remuneration and other conditions of employment;
- developing and implementing occupational health and safety programs and equal employment opportunity programs, and ensuring compliance with related statutory requirements;
- overseeing the application of redundancy and other employee retrenchment policies;
- monitoring employment costs and productivity levels;
- training and advising other managers in personnel and workplace relations matters.

Anyhow there are several drawbacks that may increase the function variability up to an undesired level, such as:

- Personnel
    - Different ranks
    - Different experience levels

  - Different skills and competencies
- No standard approaches for HRM systems
- The lack of data
- Non-harmonized processes
- Classification problems
- Insufficient synchronization
- Skill mismatch
- Lack of common language based on occupational areas
- An organization that supports HCM provides employees with clearly defined and consistently communicated performance expectations. Managers are responsible for rating, rewarding and holding employees accountable for achieving specific business goals, creating innovation and supporting continuous improvement.
- Users and their great variety introduce a source of variability, which together with the transport dynamics, increases complexity and uncertainty.
- The presence of users in critical scenarios requires special training and promptness of emergency actors.

5.1.8.2 General recommendation

Human resource availability needs to be secured for both daily activities and during emergency. A dedicated buffer capacity (e.g. stand-by staff) should be defined in advance and tailored according to emergency scenarios.
A Human Resource Management system/Human Capital Management System should be implemented.
The skills and expertise that staff develops over years in performing highly complex processes, constitute a critical operational asset. The retirement, dismissal, leave or absence of specialised staff should be anticipated and accounted for, namely by provided a sufficient overlap period with replacement staff to support suitable on-job training.
The 10 human capital components that a UTS should develop are:

1. Organizational design
2. Leadership
3. Culture
4. Engagement & awareness
5. Learning & adapting
6. System thinking
7. Safety and Security behaviour
8. People analytics
9. Workforce management
10. HR Manager skills

5.1.8.3 Common Conditions recommendations

1. Availability of resources

HR Management should guarantee

- Historic and updated performance data and its analysis in view of current operational conditions and the demands these may impose.

Human Resources Management System/Human Capital Management ICT system (HRMS/HCM)

- Use an auditable real-time HRMS/HCM system to maintain employee status, role information and system for collecting and analysing hiring data. In the back office, HCM is either a component of an enterprise resource planning (ERP) system or a separate suite that is typically integrated with the ERP. HCM is a software tool for both employee records and talent management processes. The records

component provides managers with the information they need to make decisions that are based on data. Talent management can include dedicated modules for recruitment, performance management, learning, and compensation management, and other applications related to attracting, developing and retaining employees.
- HRMS/HCM software streamlines and automates many of the day-to-day record-keeping processes and provides a framework for HR staff to manage benefits administration and payroll, map out succession planning and document such things as personnel actions and compliance with industry and/or government regulations. While now nearly synonymous with HRMS, HCM systems usually go beyond
- HRMS/HCM should contain information about knowledge, skills and abilities (KSAs), interests General Work Activities, (GWAs) and work context.

Financial plan
- Recruitment activities should be driven by the financial plan. According to this it is recommended to gather labour market intelligence coherently and consistently in order to quantify the skill requirements and its market value.

2. Training and experience
- As the development of employees and the continuous improvement in corporate performance are strictly interrelated, the organization’s main objective is to increase the value of internal human resources through targeted programs. Training and knowledge management, in fact, guarantee continuous improvement by developing cultural competencies, reinforcing the organization identity and spreading its values.
- Compensation and Benefits management skill: Being able to keep compensation and benefit packages attractive over time is essential to retaining top talent.
- Recruitment and Hiring skill: A complementary set of decision-making skills, avoid biases skill and strong interpersonal skills are necessary skills for an effective hiring manager.
- Performance/Employee Evaluation skill: Developing a successful and meaningful performance evaluation process takes time and innovation. Human resource managers who actively develop programs that engage the employee in an on-going professional development process help building a dynamic workforce. In order to frame performance evaluations positively, human resource managers need to develop versatile communication skills.
- Training and Staff Development skill: In the role of a training and staff development leader, human resource managers have an opportunity to develop a wide range of important skills, particularly in what concerns the relevant selection criteria and the identification of training needs, as well as leadership.
- Adaptation and flexibility skill; HR managers must be well prepared to respond to rapidly changing workforce dynamics. With three generations in the modern workplace, managers need to be equipped with sound knowledge as well as a wide repertoire of skills to address the four top competency areas in human resources environments across all industries. Building effective communication skills, organizing complex corporate policies, preparing employee programs, and demonstrating creative problem-solving and conflict resolution ability, are among the top skills needed to be successful in a human resource management position.

3. Quality of communication
- Encouraging internal communication: To keep employees constantly informed of the organization activities and business development, a wide range of corporate communication means are in place (intranet, internal corporate magazines, etc.). Moreover, in order to promote an open and transparent organisational culture, the organisation should encourage continuous dialogue between managers and employees both informally, using an approach of listening, and through structured feedback meetings, primarily focussing on individual performance and professional growth.

4. Human Computer Interaction and operational support

- Integrate HRM System with IT Physical Security Access control system to ensure real time employees' access management (e.g. terminated employees are consistently denied access, throughout the organisation).

5. Availability of procedures and plans

- Adopt a Consistent Skill and Competencies Categorisation and Experience Levels – The aim is to develop a table-based structure on occupational areas, such as Administration, Intelligence, Operations, Logistics, etc. that categorise the manpower skills and associated competencies required. The Technical Team must use standardized Occupational Area Codes as the starting point to develop this catalogue.
- Catalogue of Current HRM Models, Methods, and Methodologies: The technical team should develop a catalogue that delineates the various models with their associated methods and methodologies that are currently used in their HRM. The group shall be responsible for categorising models, methods and methodologies.
- Minimize downside to employees for participation, such as demotion, loss of employment or privacy.
- Include coordinated policy to appropriately scale employee access during high-risk periods, minimizing risk of sabotage.
- Use (available/CERT) research findings to develop a process and a set of policies focused to protect assets and operations while dealing with a potential hostile insider.

6. Conditions of work

- HR management, having in mind health and safety concerns regarding every employee, has the responsibility of defining working conditions in terms of tasks, workstations, work schedules, shift work, workloads and every individual or collective protection against heavy work and/or risky conditions.
- Establish an all-party consent statute regarding free use of internet and any technological tools (e.g. email, Skype, etc.), particularly in what concerns critical matters regarding security issues and knowledge protection.

7. Number of goals and conflict resolution

- Motivational approach – involvement of human resources through inducements and contribution strategy. Inducements are desired aspects of participation. For instance, inducements of working for a company are a suitable salary along with insurance options. Contribution on the other hand has a negative utility form the HR perspective, but is the requirements for participation. Inducements and contributions of a position in a system, should be contracted each other since human resource may not adhere to contribution.
- Ensuring equal opportunities Career opportunity and career progression are managed without discrimination while respecting and enhancing diversity. Considering skills as an asset to be developed and shared, organizations should be committed in helping people adapt in real time to change in an increasingly complex world.
- Attention to the Work/Life Balance - In order to promote respect for all employees as individuals, organization should promote care and attention to employees by supporting them in achieving a sustainable work/life balance.

8 Available time and time pressure

- HR are the most effective means of coping with operational variability and the time pressure that often results from such variability. This should be taken into account so that working conditions should be designed in such a way that impacts of variability and time pressure are minimised and do not compromise inherent human adaptive capacities. However, it should be highlighted that time pressure represents a source of stress to employees, favouring the occurrence of errors and hasty decisions that compromise safety and security.

9 Circadian rhythm and stress

- As circadian rhythm asynchrony has important effects in performance and lead to decrements in vigilance, HR should preview job schedules, as well as individual rest and sleeping times that favour the desire performance.
- Research has shown that the direct effects of various stressors (including fatigue) can be modulated by individual differences and psychological processes (i.e., motivation, effort, etc.), which favour the adaptation process. This requires from HR management a good leadership encouraging employees and favouring their risk perception, decision-making and performance.
- High workload and time pressure result in an increase in subjective stress level being both sources of fatigue, as well as errors and hasty reactions. Thus, HR should manage job allocation ensuring acceptable workloads and thus, creating conditions for the best performance.
- Other factors of stress and burnout threats caused by internal human relationship (e.g. mobbing) and external factors (e.g. family status, mourning) should be managed taking into account both psychological and physiological health.
- All employees should be assigned with an active role in contributing to their own development and the success of the organisation or system. In order to minimise the risk of work-related stress, HR management should:
    - Ensure good communication with colleagues and their manager;
    - Support colleagues by providing appropriate information and by sharing knowledge and resources where appropriate;
    - Engage in discussion about their performance and act on feedback;
    - Raise issues of concern at an early stage and seek constructive solutions;
    - Make use of the support and training resources available;
    - Ensure that bullying and harassment is not tolerated;
      Comply with organization employment policies and policies on health, safety and security;
    - Seek appropriate advice and support at an early stage if difficulties arise.

10. Team collaboration quality

In order to ensure a good collaboration within each team, HRM should:

- Define HRM polices to be integrated with business strategies.
- Develop HRM policies in coordination with internal legal, security and human resources team managers and, where applicable, with the resource manager for job specific policies.
- Build a cross-departmental insider threat approach and response team, to include: IT, Physical Security, Legal, and Human Resources.
- Coordinate employee hiring, screening, and termination policies with legal team and asset owners or risk managers to ensure legal team understanding of the potential costs of insider threats.
- Coordinate legal perspective with asset owners and risk managers to develop clear understanding of insider threat consequences and costs.

11. Quality and support of the organization

Ensuring a good support from the organisation is an important condition for the best performance and requires to:

- Establish a strong Employee Assistance Program to help employees identify themselves and peers for assistance during high-risk periods of difficulty.
- Develop documents to establish accountability, e.g., employee’s annual ethics certification, confidentiality agreements, supplier security requirements for contracts.

- Focus on Talent Management and Succession Planning: Talent Management is a key lever in achieving the organisation's talent development goals and releasing the potential of people. Therefore, attracting, retaining and developing leaders which can face future challenges, thus giving priority to the development of internal resources, is crucial to solid succession planning. A consistent, global approach that encourages cross-functional and cross-sector mobility (even across geographies) allows capitalisation of the talent management process which constitutes an essential competitive advantage. This process ensures that the leadership pipeline is continuously fed at all levels of the organization.

5.1.8.4 Interdependencies recommendations

Emergency HR request

- Preparing for emergencies involves evaluating risks, determining the legal and regulatory players, and the role of unions, vendors, and contractors, especially on a multi-employer site. Moreover, the cooperation with safety, engineering, risk management and operations to both address contributing factors and to implement best practices is recommended.
- Establishing an institutionalised connection with emergency responders in order to create reliable communication channels. Such collaboration includes the participation in the investigation and root cause analysis, the contribution to define training requirements, etc.
- Managing pay and benefits for employees engaged in emergency respond and extra time work requested by the emergency.
- Creating and maintaining up to date an emergency plan for mobilizing the right human resources in due time. In particular, it is necessary to establish a reliable engagement process with different level of employee readiness.

Operation HR plan

- Involve top management employees and other stakeholders in developing, communicating, and implementing the strategic workforce plan.
- Determine the critical skills and competencies that will be needed to achieve current and future programmatic results;
- Develop strategies that are tailored to address gaps in number, deployment, and alignment of human capital approaches, for enabling and sustaining the contributions of all critical skills and competencies.

5.1.8.5 Limitations

- Limitations depend on the skills of the UTS related staff, budget and interconnections with monitoring staff and training.

5.1.8.6 Examples

Quito, Ecuador establishing a municipal risk management system with the appropriate human, technical and financial resources and capacities.

- Quito city in Ecuador established a municipal risk management system by carrying out policies in an integrated manner to security, addressing situational risks, road safety and risks to natural and technological hazards. More information at: http://www.quito.gov.ec

5.1.9 Manage ICT resources

5.1.9.1 Background facts

Urban transportation systems have been some of the most active areas of ICT deployment which has proven to play a crucial role for the efficient management and optimization of urban transport operation especially in case of emergency or disaster. Technological advances in telecommunications and information technology, coupled with ultramodern/state-of-the-art microchip, RFID (Radio Frequency Identification), and inexpensive intelligent beacon sensing technologies, have enhanced the technical capabilities that enable the implementation of intelligent transportation systems (ITS). Although ITS may refer to all modes of transport, EU Directive 2010/40/EU (7 July 2010) defines ITS as systems in which information and communication technologies are applied in the field of road transport, including infrastructure, vehicles and users, and in traffic management and mobility management, as well as for interfaces with other modes of transport.

Intelligent Transportation Systems (ITS) are widely recognized as an efficient and effective way to ease traffic congestion in many large cities by controlling traffic to realize the optimal use of existing road capacity. Intelligent Transportation Systems (ITS) are actually advanced applications which aim to provide innovative services related to different modes of transport and traffic management and enable various users to be better informed and make safer, more coordinated, and 'smarter' use of transport networks. Sensing systems for intelligent transportation comprise vehicle-based and infrastructure-based networked systems. Advanced applications may deal with: inductive loop detection, video vehicle detection, Bluetooth detection, audio detection, information fusion from multiple traffic sensing modalities etc. Some example systems include the following:

- Emergency vehicle notification systems
- Collision avoidance systems
- Cooperative systems in road traffic
- Traffic detection systems
- Traffic monitoring systems
- Video surveillance systems

Intelligent transport systems vary in technologies applied, from basic management systems (such as car navigation, traffic signal control systems, container management systems, variable message signs, automatic number plate recognition or speed cameras) to monitor applications (such as security CCTV systems), and to more advanced applications that integrate live data and feedback from a number of other sources (such as parking guidance and information systems, weather information, bridge deicing systems). The new embedded system platforms allow for more sophisticated software applications to be implemented, including model-based process control, artificial intelligence, and ubiquitous computing. Additionally, predictive techniques are being developed to allow advanced modelling and comparison with historical baseline data.

Variable or Changeable Message Signs are playing increasingly important role in the attempts to improve highway safety, operations and use of existing facilities. VMS are traffic control devices which are used for traffic warning, regulation, routing and management, and are intended to affect the behavior of drivers by providing real-time or predicted information. Examples of such information include: travel times between known destinations, traffic congestion, construction notices, special event notice and motorist instructions, maintenance operations schedule, pending sever weather announcement, incident notification. In urban areas, VMS are used within parking guidance and information systems to guide drivers to available car parking spaces. They may also ask vehicles to take alternative routes, limit travel speed, warn of duration and location of the incidents or just inform of the traffic conditions. Most manufacturers produce VMS which comply with the National Transportation Communications for Intelligent Transportation System Protocol (NTCIP), which allows the them to be integrated with an intelligent transportation system. The NTCIP is a family of standards designed to achieve interoperability and interchangeability between computers and electronic traffic control equipment from different manufacturers. VMS should also comply with the corresponding established national and international standards.

5.1.9.2 General recommendation

- Deliver and maintain a well-established plan dealing with all the possible difficulties and taking into account all ICT resources needs in UTS
- Develop effective ways to maintain information and communication systems among transport system managers, staff and users under normal and extreme conditions.
- Address urban transportation needs through innovative applications of broadband, mobility and cloud services, such as:
  - Smart vehicles and infrastructure (e.g. vehicles and roadways that communicate with one another through networks leading to safer and more efficient travel and transportation, driverless vehicles)
  - Transportation services
  - Multimodal transportation (making it possible for individual travelers to optimize their journey through the city across multiple modes of public and private transportation)
  - Redefined city spaces (reshaping city spaces, reducing distinctions between work/shopping/living areas, and transforming the city itself into a service)
- Utilize ICT for transport management practices
  - Adopt Intelligent Transportation Systems, such as electronic fare and road user charging systems, transport control centers, and real-time user information, when applicable.
  - Provide access to public transit system information, including service changes, schedules and maps.
  - Provide alerts for outages, including mobile devices.
  - Develop online or mobile device payment access for public transportation, tolls, parking and metro congestion management systems.
- Disasters such as hurricanes, fires and risks of explosions or toxic chemical releases sometimes require major evacuations. Such events require effective planning, communications and management, activities that are important at any time, but become even more critical during major emergencies.
- Smart city projects need to leverage IoT Technologies and data to facilitate and support real-time Urban Transport Information systems.

Traffic lights, traffic control sensors and video-surveillance, vehicle management systems and communication channels need to be in deep integration to allow both resilience and risk management.

5.1.9.3 Common Conditions recommendations

1. Availability of resources

Supply resources:

- A variety of traffic monitoring and surveillance systems should be in place in order to provide real-time information on special events, thus improving route selection, reducing travel time, mitigating the severity and duration of incidents and improving the performance of the transportation network.
- Travel time and speed data should be available for vehicles travelling along streets, highways, motorways (freeways), and other transport routes. Methods used to obtain the raw data may include:
  - Triangulation method
  - Vehicle re-identification
  - GPS based methods
  - Smartphone-based rich monitoring
- A message displayed on a panel in order to be complete should include:

    - a problem statement indicating incident, roadwork, stalled vehicle etc.
    - a location statement indicating where the incident is located
    - an effect statement indicating lane closure, delay, etc. and
    - an action statement giving suggestions about what to do.
- Develop ways to prioritize transport system resources when necessary. For example, design systems to allow emergency, service and freight vehicles priority over general traffic.
- Design critical components of the transportation system to be fail-safe, self-correcting, repairable, redundant and autonomous. For example, where possible, use roundabouts instead of traffic signals, since they function without electricity.
- Encourage efficient use of resources, including energy conservation.
- Distribute emergency evacuation information to at-risk populations and all officials, including instructions on pickup locations and routing guidance. This information should be distributed regularly, not just during major emergencies.
- For the provision of passenger information (static or real time) consider:
    - Data availability: Information can only be provided where it is available, and collecting information can be resource intensive. Also, there may be difficulties in one organization (say an operator) allowing other organizations to access its information.
    - Data accuracy: Collecting information is error-prone, particularly when it is passed between systems manually. Also, prediction algorithms are not perfect, and real-time announcements may be in error for this reason.
    - Getting information to the passenger: A variety of dissemination mechanisms may be used, but it is not always easy to ensure that the correct information reaches the passenger when it is most needed. Apart from the obvious economic considerations, information overload must be avoided.
    - Latency or Response time: Information provision must react quickly to a passenger request or a real-world update. For example, there is little point in announcing a service three minutes after it has departed.

2. Training and experience
- Staff cross-training to perform critical management and repair services.
- Training of technical experts in order to be able to manage, update, and repair in time the ICT resources during an emergency.
- Regular test exercises for the technical experts.
- Educating and creating awareness in the population so that they may respond with the appropriate action.

3. Quality of communication
- Ensure quality communication through ICT with residents and travelers under emergency conditions in order to avoid panic movements and actions.
- Consider the use of VANETs (Vehicular Ad hoc Networks) as a key component of ITS for the spontaneous creation of a wireless network for data exchange.
- Ensure information sharing (TV, mobile TV, radio, data broadcasting, internet etc.).
- Revise regularly technical standards for important communications.

4. Human Computer Interaction and operational support.
- The system should be able to identify and contact vulnerable people, provide individualized directions for their care and evacuation, and establish a chain of responsibility for caregivers
- User-friendly platform for the technical experts and the travelers/passengers.

- Operational platform which will ensure the communication of travelers/passengers and rescuers in emergencies.

5. Availability of procedures and plans

- A plan for an efficient transportation system needs to be prepared, human resources need to be developed and organizations strengthened for proper infrastructure planning and maintenance.
- Institutional arrangements should be made to enable transportation operators to sustainably manage their infrastructure assets.
- Maintain contingency plans to allocate fuel and other resources in emergencies.
- Revise technical standards on measures for countering congestion
- Transport Planning for Disaster Management
    - Evacuation Route Design on Road Networks
        - Existing Network Design for Evacuation
        - Communication Network Design
        - Public Transportation Network Design
        - Social Organization Network Design
        - Multi Agent Transport Simulation
        - Assessment of Vulnerability and Criticality
    - Information Provision Strategy for Dispersion
        - Alternative shortest path provision
        - Space Syntax Technique (to find alternative shortest path)
        - Dynamic Shortest Path Calculation
        - Short-term Travel Time Prediction
    - Furniture Layout Design on Transit Stations
        - Pedestrian Movement Modeling
        - Different Layout Design for the Station Furniture
        - Pedestrian Simulation on Designs
        - Evaluation of Design

6. Conditions of work

- Friendly working environment
- ICT infrastructure should be accessible for all

7. Number of goals and conflict resolution

- The ICT management plan should set goals and objectives for the UTS that are Specific, Measurable, Assignable Realistic, and Time-related (S.M.A.R.T).
- The roles and responsibilities of each team member should be clearly defined and not overlapped in order to avoid conflicts.
- The number and scale of tasks/responsibilities assigned to each person should be reasonable (and not excessive) based on the ICT management plan and the corresponding timetable.
- Specific rules/principles should be defined in conjunction with a hierarchical working structure in order to address possible conflicts.

8. Available time and time pressure

- Prioritize evacuations based on factors such as geographic location (evacuate the highest risk areas first), and individual need and ability.
- Planning milestones and deadlines should integrate degrees of flexibility to cope with planning quality requirements

- Timely disaster warning to mitigate negative impacts. Such warnings must be unambiguous, communicate the risks succinctly and provide necessary guidance
- In emergencies the importance of the ICT support is of vital significance especially in the first 72 hours referred as "Golden 72 Hours". Moreover, during this period any damages in the communication infrastructure have to be repaired.

9. Circadian rhythm and stress

- A plan should be defined for managing the risk of operators fatigue and the disruption of the circadian rhythm in safety-sensitive businesses (e.g. a Fatigue Risk Management System (FRMS) in order to reduce the possibility of critical human errors.
- The management of ICT resources should be such that it reduces sources of stress for ICT operators.
- In case of critical operations carried out by only one person a second person should be in stand-by.
- Staff should be adequately trained to manage stress and act efficiently under pressure avoiding panic.
- ICT resources should include functions to be executed in an automatic manner with threat and risk alerts prior to events in order to avail a safety response time. Automated emergency response alerts should be activated when necessary.

10. Team collaboration quality

- All involved stakeholders (transport authorities, traffic police, police and station security agencies and staff, ICT staff, transport operator managers, hub and terminal managers etc.) should collaborate effectively.
- Adhere to the facets of teamwork quality (communication, coordination, balance of member contributions, mutual support, effort, and cohesion).
- Utilize suitable team collaboration tools to ensure effectiveness.
- Establish tools/methods for evaluating often team collaboration quality (e.g. Col-MM).
- Continuously train the team to retain the quality of the team’s collaboration in high level.

11 Quality and support of the organization

- Improve the efficiency of government operations
- Perform external and internal audits to ensure the safety/adequacy of ICT resources.
- Perform proper testing and vulnerability assessment activities need to be scheduled periodically, depending on the variability of the ICT asset.

5.1.9.4 Interdependencies recommendations

- In order to monitor the operation of the UTS, the necessary ICT equipment and services have to be set/installed, including sensing infrastructure, emergency vehicle notification systems, collision avoidance systems, traffic detection and monitoring systems, video surveillance systems etc.
- The definition of the procedures has to be performed considering the requirements of the ICT infrastructure.
- The coordination of emergency actions is based on the quality and the readiness of the ICT resources.
- Supply resources availability should be monitored in order to ensure ICT proper operation. In case a problem is detected immediate action should be taken based on the backup plan in order to reduce any negative consequences in urban transport.
- User generated feedback should be considered in a timely manner in order to ensure proper and efficient UTS operation.

5.1.9.5 Limitations

- Myopic preference for a low-cost ITS option without a clear long-term strategy may limit the scope for future system expansion and compatibility with other traffic systems.
- ICT cannot eliminate possible economic loss and damage to UTS property in case of a disastrous event but it can mitigate its negative impacts.
- Lack of adequate financial support.
- Limitations set by transportation channels.
- Limitations set by governments, legislation, cyber security regulations and international transportation standards.

5.1.9.6 Examples

- eCall – An Emergency vehicle notification system: eCall is a European initiative intended to bring rapid assistance to motorists involved in a collision anywhere in the European Union. The in-vehicle eCall is generated either manually by the vehicle occupants or automatically via activation of in-vehicle sensors after an accident.
- Intelligent disaster management system based on cloud-enabled vehicular networks proposed by Alazawi et al.:Alazawi et al. propose an intelligent disaster management system which is able to gather information from multiple sources and locations, including from the point of incident, and is able to make effective strategies and decisions, as well as to propagate the information to vehicles and other nodes in real-time.
- MATSim - Multi-Agent Transport Simulation: MATSim is an open-source framework to implement large-scale agent-based transport simulations.

5.1.10 Maintain UTS physical/cyber infrastructures

5.1.10.1 Background facts

UTS infrastructures are critical for any city or metropolitan or regional area. Such infrastructures need to be maintained and managed in order to guarantee a safe service level during regular operation and, moreover, in order to be able to adapt them in case of emergency.

UTS are deeply interconnected with – and are part of - the city CIs.

The need for maintenance stems from several causes: security reasons, when a malfunction or failure may endanger the safety of persons; importance of maintaining the CI service; requirement to maintain in good conditions certain parts of the CI. Despite technological advancements and the generalization of leanness principles, it is still possible to grossly divide maintenance in ordinary and extraordinary.

Ordinary maintenance for UTS is mainly related to the need to make the different subsystems well interoperable and well monitored during regular operation.

Extraordinary maintenance for UTS – adapted to the resilience concept – can be related to the capability to adapt and configure the existing assets in order to ensure a “best-effort” operation of the urban transport infrastructure for the safeguard of population and evacuation procedures, during emergencies.

This guideline analyses the possible aspects and issues that may affect the Physical and Cyber UTS infrastructure functionality.

5.1.10.2 General Recommendations

This guideline reminds best practices and references for coordinating the maintenance service to keep UTS subsystems, equipment, hardware assets, ICT and other related infrastructure facilities (e.g. smart city assets for mobility, energy, telecommunications) in operation, and operating efficiently and safely.

Physical infrastructures of UTS can be divided into these main areas:

- Sensors/hardware positioned on the ground: surveillance and traffic monitoring video cameras, sensors, telematics gates controlling entrance/exits to/from specific areas/roads
- On-board hardware: personal devices of workers used as moving sensors, on-board control units, hardware necessary to make the vehicle work and connect to the transport control centre
- Hardware of the Transport Control Centre
- Transport vehicles
- Enabling ground infrastructures (e.g. tram line pathway).
- Cyber infrastructures of UTS are mainly related to software used to configure, control, manage and tune the different hardware assets and the services related to the UTS physical hardware infrastructures.

These may include:

- Automatic Vehicle Management systems
- Communication networks
- Traffic monitoring tools
- Traffic management and configuration tools
- Digital communication channels and displays on-board and on public spaces (roads, bridges, water canals).

Each of the above assets should be properly maintained with suitable contracts where service-level agreements will determine time of intervention, recovery time, and service and business continuity depending on the relevance of the asset and on the risk assessment performed on the UTS.

5.1.10.3 Common Conditions recommendations

1. Availability of resources

Humans (labour) – skills/competence

- Each UTS infrastructure can be seen as a complex system: accumulation of competence about each system is as important as knowledge of components and regulations.
- A continuous exchange of information between maintenance personnel and the other infrastructure's stakeholders, including the management, should be put in place in order to increase the level of awareness on the real status of the infrastructure.
- UTS assets are usually composed of two main types of co-existing assets:
    - Legacy and non-standard hardware or systems (such as obsolete on-board control systems on the vehicle).
    - New and more recent sensors and monitoring assets and hardware making it possible to control operation and produce new services to users of the transport system.

  Skills on both the asset types are very difficult to be maintained and managed simultaneously, because traditional transport authorities have skills that are historically based on the old "analog" assets, while recent companies producing new services such as IoT technologies for transport management are not skilled on traditional transport asset maintenance.

Budget

- Adequate financial resources are needed for regular maintenance and there must be reserves for extraordinary interventions. Maintenance costs must be considered an essential, unavoidable part of the budget.
- A trade-off between maintaining obsolete assets and updating those assets with a replacement must be done periodically, in association with the strategy definitions of the Organization.

Data & Algorithm

- UTS is managed, controlled and used through data exchange processes.
- Typically, existing UTS assets are "legacy" and "vendor-locked-in" which on the data side is translated into the existence of many "black-box" whose data are not easily accessible by other system.
- Therefore, high integration costs are common when dealing with obsolete transport management systems. However, when activating new contracts, it is mandatory to introduce new requirements to have standardized access to structured data.
- UTS management algorithms are implemented into the business logic of the different management systems.
- In order to set up higher level resilience strategies the Intelligence Transport System should accept Machine 2 machine controls from other system, for example to activate other configurations managing degraded conditions.

2. Training and experience

- The increasing importance given by public authorities to quality and safety, while meeting sustainability targets, has upgraded the attention paid to effective maintenance and asset management, which is considered critical by all stakeholders.
- Efficient maintenance management training enhances the capacity of human capital to contribute towards the enterprise strategic goal of rationalizing asset usage and increase the safety.

- More efficient training can be achieved through on-the-job training (OJT), even with the help of augmented reality (AR) tools, to improve training rhythm and reduce training costs.
- In particular, within UTS, it is usual to have maintenance personnel on the field with uncomfortable operation spaces, hard access to data and technical data of the asset, in which case the use of mobile and portable technologies can help having more effective maintenance operation. These new tools require adequate trained personnel.

3. Quality of communication

- Guarantee a structured and validated flow of information among maintenance personnel, decision makers and citizens (the final users of the infrastructure) aiming at increasing the awareness level of the real status of the infrastructure.
- Guarantee the accuracy and understandability of the communication through standardized communication tools, protocols and languages.

4. Human Computer Interaction and operational support.

- Utilization of maintenance software tools for real time and offline data analysis and maintenance focused intervention plans.
- Utilization of software tools implementing standardized and local maintenance procedures and practices permitting operative personnel and infrastructure managers to take right decisions.

5. Availability of procedures and plans

- Develop a strategy and plan for UTS infrastructure maintenance, and ensure that such plans are really shared and widely known among maintainers themselves, but also among stakeholders, controllers, experts, and even the general public, in transparency.

6. Conditions of work

- Wide, shared, agreed awareness of security and sustainability issues need to be adapted to conditions of work for maintenance of UTS assets.
- Most dangerous working conditions are those referred to maintenance of hardware and physical UTS infrastructures, while software operations are usually less critical on this aspect.
- When possible, it would be preferable to let maintenance employees' work on the UTS physical asset within their company quarters, thus allowing for better and more controlled working conditions.
- If on-the-field work is required, proper attention must be paid to security working conditions and avoiding stressful situations, for instance by documenting in advance the possible dangerous conditions.

7. Number of goals and conflict resolution

- Roles and duties of the different actors maintaining a complex physical or cyber infrastructure need to be defined and documented in order to reduce conflicts during intervention upon failure or regular ordinary maintenance operations.
- The efforts and the timing during the emergency should be reduced by being able to early detect the anomaly generating the crisis.
- The amount of data collected during standard operation to be used during the emergency should increase.

8. Available time and time pressure

- UTS maintenance personnel shall be able to help people dedicated to emergency management in a very short-time.
- Standard maintenance activity shall be carried out during normal infrastructure's operation.
- Workers need to be trained to perform rapidly during normal maintenance operation, in order to be able to solve rapidly failures during emergencies.

- An updated and continuous learning process on the maintenance guidelines related to the UTS assets will help the execution of maintenance activities during emergency in short time.

9. Circadian rhythm and stress

- To ensure that physical and cyber transport infrastructures are properly managed and well-maintained, it is important also to allow workers proper time shifts. As a matter of fact, the stress and the excess of working hours can lead to human errors in following written procedures for the infrastructure maintenance.
- More than one person should be trained to maintain each specific urban transport subsystem, in order to avoid excessive pressure and stress over the same employee.

10. Team collaboration quality

- High quality of human relations is required, in particular among technical personnel of critical infrastructure, infrastructure managers and emergency stakeholders.
- UTS assets are a typical field where multi-vendor sub-systems co-exist, therefore a proper collaboration and communication strategy need to be implemented among the different stakeholders of the maintenance of the specific asset.

11. Quality and support of the organization

- Clear decision making process and alignment of responsibility with accountability should be put in all the UTS maintenance chain.
- Maintenance organization shall be characterized by task assignments, work-flow, reporting relationships, and communication channels that link together the work of the different individuals and groups participating to the UTS maintenance.
- Any structure of the organization must allocate tasks through a division of labor and facilitate the coordination of the performance results. There is not one optimal structure that meets the needs of all circumstances. Organization structures dedicated to maintenance should be viewed as dynamic entities that continuously evolve to respond to changes in technology, processes and environment.

5.1.10.4 Interdependencies

The current guidelines are linked to many other critical functions related to the UTS resilience:

- Strategic planning and financial budget planning is an important input to the Maintenance of Cyber and Physical UTS infrastructures.
- Such a function is related and propedeutic to the service delivery, and to the monitoring of operations and ICT subsystems.
- Human resources management and training is a critical success factor for an effective maintenance of UTS subsystems.

5.1.10.5 Limitations

- Complexity of the Physical/Cyber Infrastructure leads to parts or subsystems not properly maintained, which becomes then vulnerable in cases of failures or emergencies.
- Many of the current technologies are lacking consolidated standards and reference maintenance procedures; this can lead to vulnerabilities.
- Strength of environmental disasters may overcome the limits of tolerance to UTS failure of the asset, even if maintained.
- Communication failures among the many and heterogeneous UTS actors of the physical and cyber infrastructure maintenance may lead to cases where the single part or subsystem is well-maintained, but the system as a whole is not.

- Lack of dedicated human resources often forces the same person maintaining multiple systems, thus causing stress and error-prone activities.
- Difficulty to scale the UTS monitoring system to city level
- Difficulty to share diagnostic information between heterogeneous urban transport systems
- Difficulty to share information between systems managed by different entities/ transport authorities

5.1.10.6 Examples

Kuala Lumpur's Stormwater Management and Road Tunnel (SMART)

- Substantial investments were spent to develop Kuala Lumpur's Stormwater Management and Road Tunnel (SMART) and on maintaining flood retention ponds and main drains; for maintenance and cleansing of rivers and main drains; and for river cleansing and beautification, from both the Federal Government and City Hall. For more information about the SMART tunnel, consult pages 6-7 of: Natural Hazards, UnNatural Disasters: The Economics of Effective Prevention (World Bank- United Nations, GFDRR, 2010). http://tinyurl.com/7aalwlj

5.2 MONITOR

5.2.1 Monitor Urban Transport Safety and Security

5.2.1.1. Background facts

Safety and security issues of transport operations and service delivery include attention to maintenance problems, accidents, (non) recurrent traffic congestion, extreme weather conditions, as well as unexpected events. ICT equipment is essential in monitoring all aspects of the urban transport system and triggering and communicating safety and security alerts. Traffic Management Centers, Operation Control Centers adequately staffed and equipped, interactions and communication channels with Police, Traffic Police and Data Protection Authorities are important to perform the function.

A conceptual distinction can be made between 'safety' and 'security', whereby the former refers to accidents and diseases, while the latter refers to acts of violence. Therefore, in the UTS case safety refers to manners and actions that ensure safe movements and eliminate traffic accidents or other mobility related accidents, while security deals with the feeling of safety people have while moving (terrorism attacks, thieves at bus stops etc.). Therefore, monitoring safety and security in the UTS system is a necessity in terms of resilience management and sustainable movements.

At the same time, while the measures and competences to manage safety are necessary, they are insufficient to manage all the risks and realities of violence, which carry additional complexities that occur in transport hubs and terminals along with transit stops and at red signal stops. In cases of emergencies these violence attitudes tend to increase making the conditions worst. Competence and measures to reduce the risks and impacts of violence can include most safety risks, but are likely to overlook some others. In short, there is considerable complementarity and overlap between both areas, but they are not identical.

Monitoring is an enterprise-wide activity that the UTS uses to "take the pulse" of its day-to-day operations and, in particular, its operational resilience management processes. Therefore, UTS authorities need to collect data related to unsecure conditions, reported violent behaviours at transport infrastructure spots and map the most secure places/routes and terminals in order to prioritize secure movements in cases of emergencies.

The same data collection is needed for safe movements (roads and paths well maintained and visible etc.). All these data are input to the proper UTS monitoring system in order to be able to provide safe and secure guidance in emergency conditions. Monitoring also provides valuable information about operating conditions that could indicate the need to activate traffic police/ station security or other transport body real time involvement.

All these data enable measuring process effectiveness across resilience capabilities of the UTS. For example, through monitoring, the public transport organization that operates in the urban scale, can determine whether its resilience goals, regarding security activities taken (i.e. cameras at stops) are being met and which transit stops are secure for travellers.

5.2.1.2. General Recommendations

In order to perform an effective monitoring of safety and security, the Urban Transport System must implement transport infrastructures and processes that support and enable the monitoring needs (CCTV cameras at stations and stops and office with security staff to report and react in cases needed). This implies that this system collects, organizes, records, and makes available the necessary information in a manner that is timely and accurate and that ensures data confidentiality, integrity, and availability. Moreover these data must be reliable and be communicated directly to response bodies (security staff, police, traffic police etc.).

5.2.1.3. Common Conditions recommendations

1. Availability of resources

- The relevant resources refer to safety and security personnel (adequate number of security staff, staff that monitors real time safety and security conditions etc.), equipment (CCTV cameras at stations, stops, across the road, informative screens to aware people to pay attention for their safety and security, equipment for the monitoring centre-including alert systems etc.) budget (to buy, replace and/or maintain security equipment, to maintain road safety infrastructure, for safety and security personnel salaries etc.), processes (for safety and security facilities, safety instructions and priorities, pinning “blind spots”, mapping mobility related accidents and violence disturbing movements etc.) and material (printed guidance instructions for safety and security at stops, hubs, terminals, multimedia videos with security instructions, safety materials for road infrastructure, data collected, stored and their format – videos/log files/ reports etc.).

2. Training and experience

The main activities that the staff would be required to perform regarding the monitoring safety and security process are:

- operating, monitoring, and configuring monitoring systems components
- timely respond to alerts and communicate events to security response bodies (traffic police, station security personnel, police etc.)
- supporting stakeholders in understanding and interpreting monitoring data
- securing data collection and analysis from monitoring system components
- data linkage in cases of UTS security or safety alerts- for example link the geographical data with the data from previous traffic accidents in the spot of the event and the potential risks along with the level of safety conditions and monitoring
- apply safety and security regulations in everyday practice
- filter data and develop security and safety alerts for end users (communicate the safety and security risks to travellers in order to aware them and prepare them to respond properly and safely in cases of emergencies)

3. Quality of communication

- The communication of the monitoring data must follow quality standards regarding accuracy, validity, security and timeliness of data.
- As mentioned in D3.5, monitoring data can expose the organization’s weaknesses and therefore must be protected from unauthorized, inappropriate access where it is stored or collected, and in transmission to users and stakeholders. In addition, the timeliness of the collected data is paramount to providing an appropriate response to events, incidents, and threats and other actions the organization may take for improving its safety and security operations. Moreover, as this process includes also monitoring of people, personal data should be carefully treated, according to existing standards and regulations. The issues of cyber security should be treated according to existing recommendations.
- Moreover, the quality of communicating safety and security issues to the general public should be properly selected in order to avoid panic movements and actions. It is important to keep the users perceived level of safety and security in a tolerance level where they are able to continue their movements without feeling threatened in a way that leads to panic reactions.

4. Human Computer Interaction and operational support.

- This part has mostly to do with the personnel responsible for handling the monitoring equipment, that need to be properly skilled and specialised (through adequate training and previous experience) to handle safety and security data, analyse and combine them if needed to understand and communicate information and alerts.

5. Availability of procedures and plans

- The procedures and plans for safety and security monitoring should be clearly defined in the Safety and Security Urban Transport Monitoring plan and should comply with the monitoring requirements as defined by the needs of the addressed stakeholders. Each involved party should be aware of their responsibilities and recommended actions in normal routine or in case of an emergency. The goal of establishing specific procedures is that the performance of the task is realised in a well-organised and effective manner, so as to provide timely and accurate information of the safety and security status of transport infrastructure and general public movements. Such processes may involve the collection, storage and generally the management of data, as well as monitoring operation procedures (controls, reports, etc.). The procedures should be prioritized in order to secure travellers, with specific instructions for kids, the elderly, reduced mobility persons along with transport infrastructure prioritizing protection guidance.

6. Conditions of work

- The conditions of work are crucial for the monitoring safety and security operation considering that a precondition is to work in a safe environment with no disturbances from external conditions in order to be able to observe and immediately recognize and response to alerts. It is important to follow clearly specified responsibilities for all involved parties/staff in order to activate the alert system and operate efficiently in case of emergency.

7. Number of goals and conflict resolution

The goals set are also defined by the requirements of the monitoring plan. Some indicative ones for the UTS are:

- monitoring access to a transport hub
- personnel identification (hub, drivers etc.)
- number of tickets validated at each transit stop
- CCTV videos monitoring data
- counters for boarding/alighting travellers at stops
- complaints office data from hub travellers regarding thieves, violent behaviours, unsafe conditions in the station and/or transport mode operating
- identify the risks involved prior to starting work activities and ensure they are undertaken in a way which minimises the risks, from risky road reports, traffic police data, statistics, threats
- maintain work areas as safe and as free from hazards as possible during work activities;
- ensure equipment and materials are used in a correct, safe manner which is consistent with current legal and organisational requirements and store them safely and securely when not in use;
- put into effect, without delay, the appropriate safety procedures in an emergency- activate real time communication with cooperative bodies (police, traffic police, station security)
- ensure the level of the quality of the data collected – cross check if applicable with evidence of events-reports from security bodies etc.
- provide safety and security information to travellers- time responsive and with alternative paths to follow, along with appropriate information (means and form) covering different travellers needs
- develop event-driven campaigns and ensure stronger dynamic public resilience with a higher rate of travel demand recovery after a catastrophic event.

8. Available time and time pressure

- The required tasks should be executed in an automatic manner so that they would not require additional time from the employees and in order employees to be protected as well if needed.

- During an event disrupting operations, guidance to the affected travellers has to be given. In the post-event period the focus is on restoring operations, raising awareness of the population and influencing traveller behaviour.

9. Circadian rhythm and stress

- A plan should be defined for managing the risk of employee fatigue and the disruption of the circadian rhythm in safety-sensitive businesses (e.g. a Fatigue Risk Management System (FRMS)) in order to reduce the possibility of critical human errors. Moreover, staff should be adequately trained to manage stress and act efficiently under pressure avoiding panic.
- Safety and Security monitoring tasks should be executed in an automatic manner with threat and risk alerts prior to events in order to avail a safety response time. Still when the risk is unknown the automated emergency response alert should be activated.

10. Team collaboration quality

- When monitoring urban transport safety and security the involved parties' collaboration quality is a very critical action that reflects to the response of emergencies. The highest quality of communications is a precondition to properly alert and inform travellers and be able to respond and remain safe and secured. This reflects both to travellers and UTS infrastructure. Within the UTS monitoring plan, responsibilities and authorities should be assigned for the performance of the whole process and its specific tasks.
- Team collaboration is needed for:
    - defining roles and responsibilities in the process plan, including roles responsible for collecting, recording, distributing, and ensuring the confidentiality, integrity and availability of monitoring data and for
    - including process tasks and responsibility for these tasks in specific job description.
- The stakeholders involved usually are:
    - transport authorities,
    - traffic police, police and station security agencies and staff
    - transport operator managers, hub and terminal managers
    - information technology staff,
    - external entities, such as security companies that operate or have under their responsibility the monitoring of a transport infrastructure

11. Quality and support of the organization

- The role of the UTS in this case is to provide the safety and security program/plan/ guidance and effectively apply it. This is usually decomposed in the following:
    - Establish and Maintain a UTS Monitoring Program
        - Establish a UTS Monitoring Program
        - Identify Stakeholders and external actors/ influences
        - Establish Monitoring Requirements/ Preconditions and Methods
        - Analyse and Prioritize Monitoring requirements and respond actions
    - Perform Monitoring
        - Develop/ replace/restore and/or Maintain UTS Infrastructure
        - Establish UTS Collection Standards and Guidelines
        - Collect and Record Information and data
        - Assess data collected, validate, analyse, combine and prioritize data (time-related communication and response)
        - Distribute/ communicate Information

5.2.1.4. Interdependencies

- The risk assessment report would define the procedures that should be of special focus for safety and security monitoring for the UTS, as the ones of higher risk and thus needing closer attention and preventive measures.
- The Use of the Service controls UTS Safety and Security
- Emergency actions coordination should be in close cooperation with monitoring UTS safety and security, as they should consulted in defining the emergency response plan and timing along with safety and security critical event detection.
- Operations monitoring should be in close cooperation with safety and security monitoring as the overall monitoring actions for safety and security control within the transport system
  - The collection of event information is closely related with safety and security monitoring as these event information data are are used to assess and monitor safety and security in the UTS.

5.2.1.5. Limitations

- In case there are no resources or competencies to perform UTS safety and security monitoring, this task may be assigned to an external entity. In this case additional provisions for data security should be made and possible a MoU between the UTS organisation and the external operator should define the details of how the collected data should be managed and exploited. This would require developing and implementing contractual instruments (including service level agreements) with external entities to establish responsibility and authority for performing process tasks on outsourced functions including process tasks in measuring performance of external entities against contractual instruments

5.2.1.6. Examples

Transportation safety video surveillance

- The benefits of transportation video surveillance are:
  - Helps prevent crime and deter criminals
  - Prevents vandalism
  - Creates safer environment for passengers
  - Holds employees accountable for their responsibilities
  - Allows for remote viewing off-site from a smartphone or tablet
  - Reduces liability in cases of passenger injuries

5.2.2 Monitor Operations

5.2.2.1. Background facts

In Urban Transportation Systems (UTS), monitoring operations contribute towards a better execution in decision making and mobility actions in the controlled urban area. Responsibility for monitoring, i.e. the collection of the figures, calculation of desired Key Performance Indicators (KPIs) and for comparison of output with target, lies at different levels of supervision. It is important that even junior supervisory staff is aware of the targets and can take corrective action if there is under-achievement, without having to wait for more senior staff to react. Reporting and summarising is done at different hierarchical levels too, but detailed analysis is the responsibility of more senior levels. Monitoring of operational progress should be given the same emphasis, or priority, as applied to other operational activities and would permit the real time intervention on actuation strategies as a result of a real time evaluation of the applied measures.

5.2.2.2. General Recommendations

Monitoring operational performance can be executed with different timeframe according to purpose:

- Periodic Monitoring: Periodic monitoring involves making comparisons between achievements and strategic targets at the end of specified time periods, for example, monthly, three-monthly or longer intervals by analysing KPIs calculated on statistic basis. It is useful for the definition of strategic mobility plans.
- Continuous Monitoring: Useful at Tactical level, Continuous monitoring is applied frequently to specified KPIs which enable information on plan implementation to be collected often, such as at weekly intervals. Continuous monitoring provides the mobility manager with the means of applying close control over operations enabling frequent comparisons to be made between planned programmes and inputs of resources with actual achievements and inputs.
- Real time Monitoring: Needed at operational level, real time monitoring is needed for system components whose working dynamics can evolve suddenly and the cascade effects can be propagated with unpredictable effects; real time monitoring of the KPIs during operations can evaluate the impact created by the operation itself.

As information gathering and control demands increase, the reliability, capacity and protocol limitations of existing communications infrastructure is constraining organizations' ability to meet performance, cost and security objectives. One of the primary means by which organizations have chosen to improve their capabilities is to begin migrating applications from proprietary protocols to IP because it is more economical and scales better

5.2.2.3. Common Conditions Recommendations

1. Availability of resources

Humans (labour) – skills/competence

- Human resource availability needs to be secured for both daily activities and during emergency within the responsible mobility agency in case of UTS. A dedicated buffer capacity (e.g., stand-by staff) should be defined in advance and tailored according to emergency scenarios.
- Monitor capability in case of UTS can tightly depend to specific technical and not technical skills (e.g. leadership, problem solving, traffic engineering), knowledge, competencies. In order to control the possible function variability it is necessary to mitigate such dependencies defining a Human Resource

Replacement Plan where missing human resources are immediately replaced with others (properly trained in advance) that are currently assigned to different tasks/activities/roles.

ICT infrastructure

- Most of actuators in case of UTS are based on ICT systems. Therefore, monitoring of the ICT infrastructure should:
    - Have high performance
    - Be redundant
    - Be reliable
    - Have a graceful degradation
    - Not create a significant impact on the system under monitoring.
- Failure of the monitored system should not cause a failure in the monitoring system. Simple redundancy and automatic fail-over is particularly important for monitoring systems, as it is important to "monitor the monitoring," or ensure that an inoperative monitoring system doesn't generate false positives.
- In order to guarantee the operation monitoring and event detection is necessary to set up a proper ICT infrastructure able to collect information for the CI. Operational monitoring should be enabled for all controlled equipment.
- Collecting these data presents its own set of technological problems and general purpose monitoring tools require a great deal of customization and configuration for most uses. At the same time, most specialized monitoring tools only collect certain types of data and must integrate into general purpose systems. In order to support the operation monitoring function properly in the UTS environment is necessary to ensure different models that operate in a layered architecture. The recommended structure includes following components:
    - Knowledge Management Systems (KMS): operators use these systems to query the knowledge base in an easy-to-use and familiar format. KMS automate the capture of structured and unstructured information generated by the operations, the mobility users and the road network to manage unstructured high volume stream of data (Big Data) generated by heterogeneous resources as required.
    - Application Layer encompasses state-of-the-art, integrated algorithms and models that automate CI resilience assessment quantification.
    - Resilinece Management Support System extracts knowledge from the data and translates such knowledge into a meaningful mobility dashboard for supporting decisions and consequently actuation of road network management strategies.
    - Computer Aided Dispatch: CAD systems are an essential component of public safety operations. The CAD user's operating environment is characterized by real-time information processing. CAD systems provide deployment and tracking of resources for efficient responses to events. CAD should be designed to process standardised messages as CAP.CAD should include an escalation strategy. It's not enough to simply send alerts: needed to ensure that someone acknowledges the alert and handles the recovery. Since people have "real lives," and aren't always on call, it should be possible to send alert to someone on the front lines, and if they cannot respond, pass that alert onto someone else. Moreover, it's possible to turn on alerts for many different metrics, but this has the effect of "spamming" administrators, and decreasing the relative (perceived) importance of any given alert. Finally messaging system should be compatible through all available channels in the UTS (VMS, mobileAPPs, e-mail, ecc.)
    - Mobile: Mobile data applications are used for the on-scene aspect of public safety operations. They are designed to provide messaging, state query functionality and display CAD information in the field.

Data management and privacy

- Define where and how the data collected and examined will be stored and maintained.
- Define who will have access to the data and which actions are allowed.
- Define how the confidentiality and privacy of the data will be maintained. The level of
- Define how personally identifiable data will be handled. The
- Use of standard to document data sources.
- Define a data quality profile for each data source and a method for quality assessment addressing the following dimensions: Relevance (Fitness), completeness, consistency, accuracy, timeliness, integrity, accessibility and clarity, comparability, and coherence.
- Integrate and fuse data through an holistic driven semantic approach

Monitoring method

- Active monitoring: Monitoring systems that collect data by directly interacting with the monitored systems. Administrators must consider the impact (i.e. cost) of the monitoring and weigh this with the value of the test itself.
- Passive monitoring: Monitoring systems that collect data by reading data already generated by the monitored system. The system collects this data from logs/"traps" or from messages sent by the monitored system to a passive data collection agent. The log data is an example of passive monitoring. Passive monitoring is significantly less resource intensive for the monitored system than other methods.

2. Training and experience

- Increase Risk perception: Dedicated training activates should be organized for the staff in order to gain the desired risk perception level and manage to appropriately interpret the KPIs shown on the mobility dashboard. Risk perception of the staff directly affects the capacity of recognising potential issues, classifying them according to the internal risk procedures and forwarding the information to the right functions at the right time.
- Manage internal Knowledge transfer: This involves managing the internal transfer of knowledge and experience among employees involved in the monitoring activities. Managers, safety specialists, designers, engineers often have inadequate access and exposure to operational filed experts and operational environment. To understand and improve work, mutual access and interaction at vertical and horizontal level should be ensured.
- Train employees in view of system thinking, problem solving and naturalistic decision making. In fact, a critical characteristic of a complex system is its under-specification. This means that existing procedures might not be applicable to an unexpected scenario. Thus the skill of problem solving and situation contextualisation needs to be acquired through adequate training, for the employees to be able to cope with unexpected issues.

3. Quality of communication

- Support efficient shareholders and (internal and external) stakeholders/experts coordination and cooperation.
- Guarantee the accuracy and understandability of the communication through standardized communication tools, protocols and languages.
- Secure data understandability.
- Provide early warnings triggered by defined thresholds in relation to desired KPIs.
- Report continuously operational performance for UTS infrastructure maintenance.

4. Human Computer Interaction and operational support

- Equipment should be designed in accordance with key ergonomics standards including EN614 Parts 1 and 2.

- Control rooms should be designed in accordance with key ergonomics standards and best practices (e.g. EN11064, EEMUA 191 and EEMUA 201, High Velocity Human Factor).
- Staff should be involved in the design process. This should include different types of users including operatives, maintenance and systems support personnel.
- Monitoring interfaces for UTS should be usable in both normal and emergency situation. The CHI design and evaluation needs to be conflict free, independent and stakeholder and situation oriented.
- Information messages should be standardized (e.g. Common Alert Protocol-CAP).

5. Availability of procedures and plans

- Defining clear Standard Operational Procedures (SOP) that recognize distributed decision making requirements.
- Enabling procedure and plans accessibility and wide dissemination within the organization. All kinds of communication channels should be used like email, intranet, leaflets, etc.

6. Conditions of work

- Establish a “Safety culture” means the value and priority replaced on safety across all levels within an organisation. It refers to the extent to which individuals commit to their personal safety (independence) and to safeguarding others (interdependence). It is necessary to go beyond the classical
- Approach based of the fear of repercussion and consequences (or reward conformity) towards the true commitment to safety and adaptation as an internal organization value.
- Leverage the role of context and culture in order to socially influence the right behaviours. In fact social influences have the propensity to change an employee’s thoughts, beliefs and values, which in turn, can shape their behaviour. An example of social influence is the organisational culture of a workplace and the style of leadership that governs it.
- Just culture signifies the growing recognition of the need to establish clear mutual understanding between staff, management, regulators, law enforcement and the judiciary. This helps to avoid unnecessary interference, while building trust, cooperation and understanding in the relevance of the respective activities and responsibilities.

7. Number of goals and conflict resolution

- Adopt a minimum performance for UTS operation. Define a set of desired KPIs that enable monitoring of both field equipment and the conditions of the road network (e.g. Level of Service) when applying mobility actuation strategies.

8. Available time and time pressure

- Understand demand over time. It is important to understand the types and frequency of mobility demand over time, whether one is looking at ordinary routine work, or a particular event. Identify the various sources of demand and consider the stability and predictability of each.
- Separate value and failure demand. Where there is failure demand in a system, this should be addressed as a priority as it often involves reworking and runs counter to the system’s purpose.
- Look at how the system responds. When the system does not allow demand to be met properly, this will result in more pressure. It should be considered how the system adjusts and adapts to demand, for understanding the trade-offs used to cope. Field experts should be consulted and signals that may indicate trouble should be seek.

9. Circadian rhythm and stress

- Managing fatigue and workload as hazard: Fatigue refers to the issues that arise from excessive working time or poorly designed shift patterns. It is generally considered to be a decline in mental and/or physical performance that results from prolonged exertion, sleep loss and/or disruption of the internal clock. It is also related to workload, as workers are more easily fatigued if their work is machine-paced, complex or monotonous. Compliance with the Working Time Regulations alone is insufficient to manage the risks of fatigue. Measures to manage fatigue are:

- Ensure that workload assessment considers visual inputs (e.g. scanning display screens, looking out of windscreens, CCTV), auditory inputs (telephones, radios, alarms), cognitive activities (analysis of inputs, decision making) and psychomotor skills (physical actions, such as controlling a process using a mouse, keyboard, or buttons and levers).
- Consider not just the number of personnel, but how they are being utilised.
- Set clear roles and responsibilities, ensuing that staff are clear on their priorities. This will help to ensure that even when workload is high, staff is able to focus on key activities.
- Some tasks may be re-allocated from humans to machines/computers, or vice-versa; considering human performance, safety, maintainability, personnel requirements, etc.
- Develop a policy that specifically addresses and sets limits on working hours, overtime and shift-swapping, and which guards against fatigue.

10. Team collaboration quality

- Consider the information flow: Field experts of all kinds, (including system actors, designers, influencers and decision makers) need effective ways to raise issues of concern, including problems and opportunities for improvement and need feedback on these issues.
- Ensure collaboration within the responsible mobility agency and also among the responsible mobility agency with public emergency services.

11. Quality and support of the organization

- Active monitoring - By “active monitoring” we are referring to all those checking activities, formal and informal, carried out by line managers which lie at the heart of effective management. Active monitoring involves checking that all these components, people, equipment and systems, continue to work as intended. What distinguishes it is the recognition that the topics which are actively monitored must include those barriers or controls needed to prevent a major accident. This needs to include preventive barriers as well as those barriers which are intended to mitigate the consequences of the event if it materialises. In particular an effective active monitoring program will ensure that the staff are:
    - doing what they should be doing and checking what they should be checking;
    - reporting what should be reported and to the right people;
    - taking appropriate action on the information provided particularly to remedy
    - identified deficiencies in risk control systems.

5.2.2.4. Interdependencies recommendations

- Monitoring function is strictly connected with the emergency coordination function.
    - Moving from the single-ended monitoring of the past to the integration of multi-monitoring and central control systems, evolving from “monitoring without control” into smart, integrated systems. Simple data acquisition is inadequate for current circumstances, and systems must be enabled with decision support tools and also with strategy actuators modules.
    - Need of control, sensor networks, fault diagnosis and computational intelligence tools for handling in real-time highly complex data generated at different geographical locations in different formats.

5.2.2.5. Limitations

- Improving the effectiveness monitoring and early warning UTS systems does not lead always to reduced risk for disaster-prone communities — early warning does little good unless it is followed by (early) action.

5.2.2.6. Examples

Emergency Operations Center of the Makati City, Philippines

- The Makati Command, Control and Communication (Makati C3) center was developed to serve as the city's Emergency Operations Center dealing with monitoring, coordination, and integration of services and resources during disasters and emergencies with an active role in risk-sensitive land use planning and community-based disaster risk reduction. Read more at http://tinyurl.com/7su6wtw

5.2.3 Monitor Resource availability

5.2.3.1 Background facts

In the face of inevitable resource limitations, every organisation strives to maximise operational efficiency. Across all industry sectors, access to diverse and variable resource needs relies on increasingly tight system couplings that must be developed and sustained amongst supply chain stakeholders. The high complexity and dynamics that emerges from such system interdependencies require a continuous ability to monitor the flow of multiple critical resources, aiming to develop updated and thorough support to the planning of operations and the subsequent allocation of resources. This may be particularly relevant when faced with the need to adjust (planning and resource allocation) to changes in the operational environment.

Understanding that a sociotechnical system and its functioning goes much beyond the description of human, technological and organisational resources and their interdependencies, it is essential to consider:

- The way in which such interdependencies support the provision of critical resources;
- The types and degrees of variability to which these are submitted in the face of pressures emanating from a system's operational environment.

Therefore, monitoring resources availability implies that operational variability of the system must be considered and managed in order to ensure the system functioning.

The sources of operational variability, as well as the mechanisms that may potentially propagate it and impact on system performance must be identified.

The resources and system capacities required to manage and cope with operational variability must also be taken into account.

5.2.3.2 General recommendations

Following these research statements, some general recommendations for practice are stated in the following (to be used if relevant):

- Work organisation and task allocation ensuring acceptable workload and work schedules.
- Manage working times and shifts, in order to ensure the individual's arousal and prompt reaction in critical situations.
- Providing training in accordance to job needs and users' requests with the appropriate frequency.
- Favouring the development of competences and expertise with experience in order to ease the formation of compensation behaviour with increasing age.
- Selection of trainers according to their status, expertise and communication qualities.
- The contents and quality of communication must be clear and easily understood by all users.
- The design of Human Computer Interaction must comply with usability requests.
- Public infrastructure must be totally accessible without any physical barrier to the access and use of the facility by any individual.
- The displayed information within and outside any public infrastructure must be totally accessible to users providing alternative sensorial channels for the information display.
- The implementation of a Safety Culture project in the organisation should start by the creation of a mental model of Safety allowing for risk and safety perception. This requires a good leadership, the involvement of all employees in the process, the identification of personal responsibility, the definition of

risk management principles, the development of an activity-based safety system, the development of methods and tools for risk analysis, and the required training.

- As a team leader has an important role in the management of human resources, his/her selection must be based on defined and relevant criteria, particularly leadership and communication characteristics.
- As acting under time pressure is recognized to degrade human performance across a variety of cognitive domains, operators who must act in critical situations must be specially trained to improve their decision making ability towards the appropriate action to be performed in due time.
- Due to the risks of a circadian rhythm desynchrony, which lead to decrements in vigilance and has negative effects in performance, the definition of job schedules, as well as individual rest and sleeping times, must comply with related European or International standards and regulations.

5.2.3.3 Common Conditions recommendations

1. Availability of resources

Humans (labour) – skills/competence

- Highly trained and skilled personnel.
- Provision of conditions for the development of competencies with experience.
- Technical and organisational conditions ensuring acceptable workload, managing fatigue and stress in order to anticipate negative effects on job performance, controlling workability across ageing, and promoting health, arousal and preparedness towards prompt reactions in emergency situations.

Budget:

- Ensure the required budget for the system functioning and emergency situations.
- Preview the needs for external operations and the related budget.
- Preview specific budget for Training.

Data & Algorithm:

- Use of historic and updated data bases on human, technological and organisational resources and their isolated and combined influences on the system functioning.
- Use of agreed concepts and definitions.
- Monitor the access to data and services resources continuously and activate alarms and tickets when those are not accessible; keep track of all dysfunctions.
- Define service level agreements with those operators and services that have to provide data and services.

2. Training and experience

- Continuous and updated training over time in order to maintain and improve relevant skills and expertise of the staff.
- Ensure training for emergency situations in relation to the use of all resources.
- Selection of trainers according to their status, expertise and communication qualities.

3. Quality of communication

- Ensure the contents and quality of communication.
- Ensure the required communication assets.
- Adopt the use of communication tools, protocols and languages.

4. Human Computer Interaction and operational support

- Technological equipment and tools should comply with ergonomic standards and recommendations, such as:

  - They should allow for easy, comfortable and secure interactions and successful human-machine dialogues, thus requiring appropriate design of interfaces and the definition of contents according to the targeted mission.
  - They should be located in an adequate environment complying with ergonomics standards and recommendations regarding screen reflexions that lead to mental and visual fatigue.
  - The duration of exposure when working with technological equipment must be regulated following ergonomics standards and recommendations.
  - Working schedules and shifts should respect biological needs for rest and sleep in order to ensure the necessary performance of every operator.
  - Usability requests on the design of Human Computer Interaction should be fulfilled.

5. Availability of procedures and plans

- Planning of infrastructures previewing physical and informational accessibility needs and requirements within the infrastructure and surroundings.
- Planning process that recognizes distributed decision making requirements (as opposed to a centralised decision making).
- Planning previewing conditions for emergency response based on naturalistic decision making, which means the way people use their experience and knowledge to make decisions in real-world settings, including dynamic and continuously changing conditions, real-time reactions to these changes, ill-defined tasks, time pressure, and significant personal consequences for mistakes. This requires experienced decision makers.

6. Conditions of work

- A Safety Culture project in the organisation should be implemented as it is the basis for a perfect coupling of all system resources towards the system resilience.
- Working conditions (technical and organisational) should respect the mode of human functioning and the individual limits for a continuous job performance. Passive fatigue of drivers and operators working in control rooms leads to drowsiness and, in consequence, reduces the individual ability to monitor a system, anticipate any disturbance and react promptly in an emergency situation being the direct cause of many accidents. The performance of a fatigued or drowsed driver or operator is similar to a performance under the effect of alcohol.
- An understanding of human performance, and particularly the human error, should also be integrated in the Safety Culture project as a basis for safety management.
- Anticipation ability should be promoted by means of increasing competencies and using job-related experience and knowledge.

7. Number of goals and conflict resolution

- Planning teams should be built taking into account the scale and timeline of the plan.
- The choice of team leaders should be based on leadership profile, communication qualities, and the ability to create a healthy clime based on trust and respect.
- A good team leadership is required to avoid and eventually manage conflicts without creating additional risks to the system.

8. Available time and time pressure

- Planning milestones and deadlines should integrate degrees of flexibility to cope with planning quality requirements.
- Acting under time pressure is recognized to degrade human performance across a variety of cognitive domains (judgment and decision making; visual search behaviour, vigilance and attentional processes; situation awareness; memory recall strategies; concession making and integrative agreements; and subject's self-ratings of performance).

- In emergency situations, time pressure is a common reality that operators must be trained to deal with in order to avoid negative interference on decision making.
- As time pressure increases workload, particularly in situations of concurrent tasks or task switching, operators must be trained for reducing the interference of those conditions on the tasks performance and ensuring the performance of the required actions in due time.
- It must be understood that time pressure could decrease human performance and lead to errors if operators are not prepared for acting under those circumstances.
- Time pressure is the underlying stressor that determines operator performance, error production, and judgments of workload.

9. Circadian rhythm and stress

- Circadian rhythm asynchrony has important effects in performance, which are related to decrements in vigilance. This statement has implications on job schedules, individual rest and sleeping times and sleep quality as contributing factors to the desired performance.
- Research has shown that the direct effects of various stressors (including fatigue) can be modulated by individual differences and psychological processes (i.e., motivation, effort, etc.).
- The "trinity of stress" is referred as consisting of input features (environmental stressors), adaptation features (cognitive appraisal), and output features (changes in bodily functions and ultimately performance efficiency).
- Stress has been defined as the interaction between three elements: perceived demand, perceived ability to cope, and the perception of the importance of being able to cope with the demand. Unlike many previous definitions of stress, this formulation distinctly incorporates the transactional process believed to be central to current cognitive appraisal theories. These reciprocal influences have direct implications for personnel selection, choice of team leaders and training.
- Fatigue and stress effects on decision making and task performance are difficult to separate. After measuring levels of arousal and anxiety during different stages in a continuous and prolonged task, it has been found that the expectation of the end of the shift resulted in a release in tension (although no performance decrements were noted). These findings should be taken into consideration for training.
- High workload results in an increase in subjective stress level and, objectively, in gradual, not sudden, decrements in recognition memory accuracy and reaction time. Acceptable workload should be targeted.

10. Team collaboration quality

- The quality of team collaboration is a critical issue in emergency scenarios, which require:
    - Adherence to the principles of collaborative planning through the development of mutual benefit relations.
    - Information flow and continuous update.
    - Autonomy, flexibility and accurate control under a good leadership.

11. Quality and support of the organization

- From each organisation, the following is required:
    - Clear decision making process and alignment of responsibility with accountability.
    - Check, report, decide and act.

5.2.3.1. Interdependencies recommendations

- Monitoring resources generates information on resource allocation and the understanding of their flows. This constitutes one of the fundamental tools for planning activities, both as a primary input and as indicators for the potential need of planning revision or reassessment.
- ICT constitutes a fundamental resource for all operational and managerial activities. The failure of ICT services may critically compromise the operation continuity. The monitoring of these services should

provide the ability to anticipate potential disruptions and the deployment of contingency resources (adaptive capacities). The same concerns exist for energy supply requiring as well anticipation and preview of contingency resources.

- Keep updated information on the status and supply of critical resources constitutes a fundamental resource for the anticipation of potential needs for operational adjustments.
- In case the ICT infrastructure needed to support the resource monitoring fails, a dedicated communication and periodic reporting channel should be established with the suppliers. Reporting data about the resource consumed should be provided "on demand" and on pre-determined period.
- A specific protocol and procedures to promptly inform about resource delivery failure and the related causes should be defined in advance between the CI and its suppliers. Such procedures should be included in the emergency plan of the parties.

5.2.3.2. Limitations

- Limitations occur, based on difficulties with:
    - updating the information on resources use.
    - assessing the situation and mobilising the appropriate resources.
    - unavailability of technological assets resulting from breakdown or lack of energy.
    - insufficient personnel and/or low human performance due to fatigue, inappropriate workload or sleep deprivation.
    - poor communication

5.2.3.3. Examples

Funding Resilient Infrastructure in New Jersey: Attitudes Following a Natural Disaster
(Robert B. Noland, Ph.D., Marc D. Weiner, Ph.D., and Michael R. Greenberg, Ph.D., Mineta National Transit Research Consortium, College of Business, San José State University, San José, CA 95192-0219. Sponsored by U.S. Department of Transportation).

- This research examines public attitudes toward revenue sources that can be dedicated to protecting vulnerable areas, most notably the transportation linkages on which the state depends. A statewide survey was conducted to gather data approximately four months following Superstorm Sandy, the costliest natural disaster in the state's history. The authors' objective was to sample public attitudes while the impacts of the disaster were still fresh. They found little support for temporary tax increases to improve resiliency, with the most positive support for taxing visitors (i.e., a hotel and recreational tax) and for a 30-year bond measure (i.e., taxing the future). This observation seemingly contradicts broad support for investing in new infrastructure, as well as maintaining and protecting existing infrastructure. Multivariate analysis to understand the underlying attitudes toward raising revenue found that more left-leaning or communitarian attitudes are associated with more support for gasoline, income, or sales taxes devoted to mitigating vulnerability. Those who supported investment in transit and protecting infrastructure also were more likely to support these taxes. There was no parallel finding of factors associated with taxing visitors or issuing bonds.

Disaster Resilience: A National Imperative NRC 2012. TRB.

- This report confronts the topic of how to increase the USA's resilience to disasters through a vision of the characteristics of a resilient nation in the year 2030. The characteristics describe a more resilient nation in which
    - Every individual and community in the nation has access to the risk and vulnerability information they need to make their communities more resilient.

- All levels of government, communities, and the private sector have designed resilience strategies and operation plans based on this information.
- Proactive investments and policy decisions have reduced loss of lives, costs, and socioeconomic impacts of future disasters.
- Community coalitions are widely organized, recognized, and supported to provide essential services before and after disasters occur.
- Recovery after disasters is rapid and the per capita federal cost of responding to disasters has been declining for a decade.
- Nationwide, the public is universally safer, healthier, and better educated.

5.2.4 Monitor user generated feedback

5.2.4.1. Background facts

A disruptive event affecting a critical infrastructure can significantly impact the social opinion, at different levels, depending on the “effect” induced by the event (e.g. the impact on the opinion of citizens is different if a disruptive event generates a reduction in the quality of service rather than causalities).

The widespread of mobile technologies – in particular smartphones – and social networks (e.g. Twitter, Facebook, Instagram, etc.) has enabled an every-time and every-where collaborative and active participation of citizens who are free to generate and share information and opinions about any event occurring in their daily lives. With respect to UTS, social networks/media are largely used by citizens, in particular commuters, to share updated information about inefficiencies, delays and other events (such as, sudden traffic jams, unexpected strikes, etc.). This allows for having a large set of “human/social” sensors in different locations within the cities, even moving, reporting useful information both during the emergency/event than after that.

Indeed, in case the communication network is not affected by the disruptive event, social/human sensing is crucial in order to infer useful information which cannot be otherwise acquired, for instance acquire information about the entity of the effect of the event in an area which is not monitored through ICT systems. In this case, the human/social sensor is crucial to support the emergency management and identify impacts on the UTS that could affect the effectiveness of the rescue and emergency management teams.

On the other hand, after an event, the social/human sensing becomes crucial to analyze the social opinion and facilitate both recovery to the normal situation and system adaptation. For instance, human/sensing can be adopted to infer the perceived level of security and safety of the citizens after a terrorist attack on the UTS, as well as to identify possible criticalities, reported by the users, which represent barriers to the acceptance/usage of a specific service. Furthermore, the information shared by commuters may support a more effective, efficient and socially-accepted planning of the services, optimizing resource allocation to support investments in actions to reduce risks and improve overall resilience of the UTS (adapt phase).

5.2.4.2. General Recommendations

A bottom-up engagement of travelers in urban transport resilience may be provided through crowd sensing of social web media (‘travelers as moving sensors’). Content analysis and text mining request adequate software tools. Structured real-time information about road traffic density/LoS/speed or public transport ridership may be derived through ICT technologies (road sensors, smart card ticketing readers). Big data mining modules, able to visualize the extracted aggregate information are then needed. A combined analysis of smart devices’ geolocation data (crawling detection) and tweet contents (cause of crawling) may provide a remote picture of transport incidents.

Stated choice surveys may derive the value of perceived risk and the WTA risks in local transportation contexts. The dynamic behavioural resilience of the traveling population is then assessed.

5.2.4.3. Common Conditions Recommendations

1. Availability of resources

Humans (labor) – skills/competence

- Personnel in charge to monitor and manage communication channels have to be trained in order to use simple social media monitoring and social network data analysis tools. The aim is to detect and infer useful information, “hidden” in the user generated contents, in order to define suitable communication material for supporting a more rapid recovery to the normality of the UTS usage.
- Stakeholders involved in the emergency management have to be able to access to social/human sensing data as any other data source (ICT monitoring and control systems), in order to have a more

complete view of the scene and, in case, involve citizens to improve the effectiveness of operations/actions.

Budget
- Costs for accessing, implementation and update of social/human sensing data have to be considered.

Data & Algorithm
- Data which can be crawled from the web and the social networks.
- Collect data from blogs and App that may be dedicated to collect feedbacks in terms of comments, scores, images on the services and specific geolocazied elements as bus stop, rack, red light, plates, underpass, bridges, etc.
- Software tools for analyzing – online and batch – the crawled data:
  - Time-series and trend analysis
  - Natural Language Processing and Text Mining
  - Sentiment and opinion mining
  - Statistics and Data Mining

2. Training and experience
- Training on social media monitoring and opinion/sentiment analysis tools
- (Social) communication skills
- Basic expertise in statistics and Data Mining

3. Quality of communication
- Communication material aimed at supporting a quick recovery to normal usage of the UTS
- Diffusion of the communication material on the different channels, in particular social networks and media, in order to reach any user (commuters, tourist, citizen in general) independently on his/her preferred media/channel and to reduce/avoid any possible “digital divide”.

4. Human Computer Interaction and operational support
- Access to social/human sensing data and analysis software supporting the operators during the emergency management in UTS.
- Access to social/human sensing data and analysis software supporting the personnel in charge for communication to achieve the recovery to normal level of usage of the UTS quickly as well as to support the definition of adaptations to the overall system/service.

5. Availability of procedures and plans
- Procedures related to the communication to the public have to be frequently revised/updated in order to take into account the most used/preferred social media channels over time (they might change according to the availability of new apps, new social networks, new channels and devices).

6. Conditions of work
- Guarantee privacy and security of the public data crawled from the web and social networks – according to the internal and local policies.

7. Number of goals and conflict resolution
- Reducing efforts during the emergency management while increasing its effectiveness, by exploiting data and information from social/human sensing.
- Increasing the amount of data and information available during the management of the emergency, integrating social sensing to data coming from monitoring and control systems as well as other external official sources.
- Reducing time to recovery to the normal condition

8. Available time and time pressure

- Personnel must be trained and put under exercises in order to be sufficiently skilled in extracting useful information from human sensing.
- Access and examine data in very short time through easy friendly visualization
- Prompt and quick action and timely monitoring for prevention

9. Circadian rhythm and stress

- N.A.

10. Team collaboration quality

- Adherence to the principles of collaborative planning through the development of mutual benefit relations, during the management of the emergency and the recovery and adaptation

11. Quality and support of the organization

- Alignment of responsibility for communication actions

5.2.4.4. Interdependencies recommendations

- Analysis of user generated data crawled from web and social media has to be correlated with official data coming from ICT based systems for monitoring and control the UTS service and its level of usage.
- Communication mechanisms and channels used to monitor usage behaviour and increase user awareness are relevant sources of information to monitor user feedbacks.
- User generated data crawled from web and social media can be used as further source of information (social/human sensing) to improve effectiveness and efficiency of the UTS service delivery and, more important, to support a quick recovery to the normality by addressing the feedbacks generated and shared by the users (both commuters and tourists) and citizens in general.
- User generated data crawled from web and social media can be used as further source of information (social/human sensing) to improve effectiveness of emergency actions, in particular in order to retrieve useful information in areas not covered – temporary or permanently – by ICT based monitoring and control systems.
- Data generated by users/citizens has to be analysed and processed to extract, collect and monitor relevant information about an event.
- Communication mechanisms and channels can be refined and improved to infer, characterize an possibly predict UTS usage behaviour as well as increase user awareness and implement transportation demand side management strategies.

5.2.4.5. Limitations

- Trustworthiness of the sources: data generated by citizens contrary to official data sources (such as ICT based monitoring and control systems) cannot be completely considered “trustworthy”. Data analysis can allow for the estimation of trustworthiness of the sources in order to minimize – but not exclude – misleading information. In cases that feedback is collected by social media accounts, the validity of information and time of posting is also a matter of limitations.

5.2.4.6. Examples

Commute London case- twitter train travellers generated feedback monitoring

- Commute London taking account of the human impact of delays on the London railway gives transport rail operators the opportunity to shape their recovery and resilience plans around the needs of users. Taking feedback from users, based on social media twitter accounts of travellers in real-time, provides advise to rail passengers and staff of problems likely to impact their services before, during and after the official sources have reported an incident.
  For more information: http://commutelondon.com/resources/TwitterTrainsofThought2015.pdf

5.3 RESPOND

5.3.1 Coordinate emergency actions in UTS

5.3.1.1. Background facts

Urban transport systems are a very critical infrastructure in every moment of a community life. During both ordinary stresses and extraordinary emergency conditions there must elasticity and readiness to either shutdown the systems or redirect the traffic. These two options must be considered as theoretical extremes, while in reality UTS shutdown or UTS reconfiguration to move people away from the crisis, will be both present in a pragmatic (and not rarely dramatic) mix of answer to emergency.

Their “operational functional status” can be significantly different according to the gravity of the emergency event.

There must be some specific events that affect the whole mobility system in the city, thus requiring very minimal transport capabilities, only limited to the evacuation of people needing assistance, or to the entrance of medical assistance or civil protection into the affected area.

In other cases, such as a local flash flood, only a part of the city is affected and a re-routing of mobility need to be configured in UTS management tools.

In any case, a resilient city need to properly address the coordination of emergency actions in UTS, by implementing suitable preliminary actions and by putting the different actors in condition to operate rapidly and efficiently during emergency.

During emergency conditions, UTS functionality must be guaranteed even as a “best effort” service level, i.e., the minimum availability which is capable to evacuate population or to re-direct traffic flows out of the affected area.

5.3.1.2. General Recommendations

To this extent, the coordination of UTS emergency actions includes:

- Re-assignment of traffic according to emergency context
- Re-routing & timetables rearrangement of Public Transport
- Cooperation with other first responders/law enforcement such as local police and civil protection
- Coordination of on-the-field activities to manage road signs to advertise traffic changes
- Complementarity of mobility modes in case of service level loss, in accordance with service level agreement
- Communication of the current mobility conditions to citizens and stakeholders of the proper contents in the proper channels
- Decision on system operation until emergency is closed

5.3.1.3. Common Conditions recommendations

1. Availability of resources

Humans (labour) – skills/competence

- In order to rapidly address the necessary issues during emergency, members of the emergency coordination staff should include people who profoundly know the UTS, and its users, along with their territory, counting on their own personal experience as inhabitants, pedestrians, drivers, and commuters.
- In addition to scientific, technical, legal and procedural education, there shall be exercises, simulations and case studies, as a preparation to cope with UTS re-adaptation during emergencies. Such

simulations and trials must be conducted on a regular basis in order to improve ordinary stress and extraordinary emergency awareness, but in particular there must be emphasis on the human factor.

- Emergency actors must know each other in person, having clear, fair communication, and having established a relevant human empathy among them, before the emergency begins.
- The members of the emergency response team should be periodically collected and informed together, in order to facilitate their communication and relationship.
- In all the phases of a crisis response, a strong communication and information plan must be implemented, involving all the main actors of the neighbourhood.
- A proper personal knowledge and empathy among the emergency coordination team members dealing with UTS and those dealing with IT, communication, and local police, need to be established and maintained in regular conditions, since those profiles need to be very rapidly interoperating during emergency.
- Specific skills of employees capable of working and acting on obsolete “analog” UTS subsystems need to be maintained in the organization, in order to be able to manage subsystems in very extreme conditions where digital and modern transport asset are no longer operating.

Budget:

- Financial reserves to be accessed in case of UTS emergency should exist. A proper financial planning devoted to resilience and crisis management must be included in the overall budget definition process, with special focus on UTS obsolete and up-to-date technologies, which require different attentions and considerations.
- A proper insurance system should exist in parallel to the crisis management budget, to be used in order to cover the costs and risks, which the Organization is not able to cover with its own financial resources.

Data & Algorithm:

- Crisis Management team should have immediate access all the relevant data organized in a way (for example as a dashboard) for direct understanding the current conditions of the city mobility: contextual data, strategic infrastructures, telecommunication networks, road graph status, traffic sensors data, people flows, should all be accessible to the emergency coordination team in charge of guaranteeing operations of the UTS infrastructure.
- These data should be possibly available and accessible even without networking and power supply infrastructures, through local copies, data backup, business-continuity and emergency recover solutions.
- Algorithms for strategies have to be available and operative even in the lack of internet connection communicating in other means with devices and operators. All the devices and operators in the hierarchical control architecture have to provide a minimum level of operative-ness in the case of strong degradation of data flow.

2. Training and experience

- Due to the UTS operations complexity, specific project management, coordination and human relations skills are necessary in the Crisis Management team.
- When new tools (such as new digital communication channels) are introduced within the operational procedures (e.g., the usage of WhatsApp or Telegram to communicate with people), a specific training program must be put in practice within the crisis management team.
- Training must be ensured also for those UTS subsystems requiring very particular and specific skills, such as obsolete and analog subsystems, old legacy assets

3. Quality of communication

- Given the complexity of the crisis scenario, where multiple actors react in the same time in the same territory, communication is a critical factor to be properly managed and addressed.
- UTS Emergency procedures need to specify who is in charge of communicating what to whom, when, and on which channels regarding mobility conditions in the city. Decisions must be rapidly delivered to

the person/entity in charge of communication and multiple and redundant channels need to be activated, with a unique source of the information itself.
- Semantics of the communication is crucial to avoid misunderstanding and to activate the needed actors at the right moment. Time and effort must be dedicated during the planning phase in order to ensure that the same terms are well understood and agreed by the different actors of the crisis response process.

4. Human Computer Interaction and operational support
- The opportunities of new digital media and tools need to be leveraged in order to maximize the effectiveness of the emergency actions. Not only social media and common messaging tools, but also game-based training and augmented reality applications can be used to collect possible requirements from stakeholders, and to train on best practices of crisis management.
- Regarding the software adopted within the emergency coordination centre, user interfaces should be periodically revised and analysed, in order to ensure that information is provided instantly in a clear and simple way to the specific decision-maker. Multiple login should be avoided in order to save time to access information, promoting single sign-on across the different information systems.
- UTS management systems are usually very complex and specific of the single type of UTS infrastructure. To this extent, particular care must be paid to the switch from general dashboards to specific UTS management tools, in order to avoid confusion and interpretation errors in the emergency control room

5. Availability of procedures and plans
- Preparedness implies planning and it must be carried at all the organizational levels. Coordination of emergency actions is responsible for setting up, maintaining and updating general, localized, specific plans for each kind of risk, based on risk identification, analysis, evaluation and reduction.
- Approved and updated procedures and plans need to be properly published and made accessible to the different actors. Meetings with the emergency coordination team need to be periodically (at least twice per year) organized, and be used to disseminate and promote knowledge of the approved procedures.
- Public utilities in charge of managing the different city transport systems need to be forced to produce and share easy-to-understand procedures explaining the behaviour of their UTS in case of emergency: which functionalities can be guaranteed under which conditions and event gravity, and which inter-relations with other transport systems need to be particularly taken into account during emergency.

6. Conditions of work
- UTS emergency response and management actors need to be endowed with proper tools, instruments, and skills to behave correctly and effectively, according to the approved procedures.
- Proper personnel shift and timetable scheduling need to be organized in the planning phase, by reducing as much as possible stressing conditions, and by rotating personnel as possible given the emergency conditions.
- The organization need to provide workers of proper insurance guarantees covering the risks associated to their activity.

7. Number of goals and conflict resolution
- Operational emergency procedures need to include the expected goals of each emergency response process (e.g. to restore viability under a flooded road underpass)
- After crisis solutions a proper assessment need to be implemented to check the occurred conflicts (e.g. actor X thought that actor Y would have solved issue Z, actor Y thought it was a duty of actor X).
- Occurred conflicts need to be addressed, solved and reported in the following operational procedure update.

8. Available time and time pressure
- Simulation and training programs need to address the time pressure issue, workers need to be trained to react with prompt actions, and decision makers need to be trained to solve issues in due time.
- Risk assessment and critical system functions need to take into account the time after which the damage and impact of an unavailable resource is going to worsen (e.g., after 6 hours of power supply downtime, hospital or local bus authority AVM temporary power supply system is going down)

9. Circadian rhythm and stress

- There must be specific psychological training of the personnel involved in the emergency response to cope with stress. In particular, UTS personnel must be ready to act individually, in potential loneliness, or in the necessity of leading other people to deal responsibly.
- Working shifts may take into account wake/sleeping rhythm and manage shifts according to the severity of the event and to the availability of human resources

10. Team collaboration quality

- Training courses may include team working and group-working, thus improving relationship and group empathy among the emergency coordination team members.
- Specific training programs for work under very stressful situation need to be implemented at least once per year.

11. Quality and Support of the organization

- The UTS emergency organization needs to annually check the human resources, technological tools and equipment requirements from the emergency coordination team.
- Periodical meeting occasions need to be scheduled by the organization in order to show the emergency coordination team to the rest of the organization, thus promoting communication flows across the vertical departments and the emergency coordination team.

5.3.1.4. Interdependencies

- The coordination of UTS during emergency is executed under critical circumstances, where decisions may imply hard consequences on lives or on city basic transport and mobility services.
- Therefore, some decisions may be affected or polarized by strategic and top management requirements.
- Emergency coordination and the consequent actions on UTS configuration need to be performed in very strict scheduling therefore a short time to reaction – together with the complexity of actions on the transport systems, may limit the capability to act effectively.
- In order to avoid such a risk, a deep knowledge of the city transport systems and of the possible consequences of each action need to be assured in the emergency coordination team.

5.3.1.5. Limitations

- Poor security culture and awareness in travellers and UTS staff.
- Limited resources and spare time for training of UTS staff.
- Extremely dynamic processes with high volumes of vehicles and travellers to be managed during crisis.
- Communication gaps among the different UTS actors.

5.3.1.6. Examples

Albay Province, Philippines Risk Reduction case

- The Albay provincial government in the Philippines established a permanent disaster risk management dealing with the high risk of typhoons, floods, landslides and earthquakes. This case is a great example of urban planning and UTS disaster prevention, preparedness and response that have been well coordinated. Read more at http://www.unisdr.org/we/inform/publications/13627 (page 48) and http://tinyurl.com/ck6btnb.

5.3.2 Restore/Repair operations

5.3.2.1. Background facts

Disaster impacts comprise physical and social impacts, in particular with respect to UTS. Physical impacts can concern infrastructure as well as services and procedures. A limited disaster could not have a significant impact on physical infrastructure (e.g. a temporary interruption of a connection between to stations due to technical difficulties) but can heavily impact the level of service and the quality perceived by the users (e.g. a delay during the peak hours when commuters are moving to go to work).

Damage to infrastructures can cause direct service and procedures problem. However, restoring infrastructures is not every time enough to repair correctly services and procedures linked to them. Furthermore is necessary to act quickly to restore services and procedures to avoid more social impacts including psychosocial, economic, and political implications.

With respect to UTS, in case of an adverse event, the mobilization of stand-by O&M personnel, activation of a staff recall system or a HR replacement plan, are actions possibly needed. Spare vehicles or a retraction of alternative modal carriers based on SLAs may retain transport capacities.

IT resources such as telematics or a computer-aided dispatch of vehicles and drivers enable the recovery of scheduled services.

There are a lot of different cases that can block or damage UTS services and directly influence community procedures. These can be catalogued in different scales:

- localized impacts (e.g. local traffic stop due big incidents)
- diffused impacts (e.g. traffic and public transport congestion due meteorological events; railway network block due to derailments);
- total impacts (e.g. dramatic events like 1966 Florence flood or 2009 L'Aquila earthquake affecting most of the urban CIs, not only UTS);

Despite infrastructures are normally handled by the public authorities, services and procedures are almost always outsourced to private or semi-private companies, such as for urban transport. They are responsible for the continuity of services, to their implementation and of all communications to the citizens and institutions. Institutions instead care infrastructures from which the services are dependent. Relations between the two entities are normally controlled by contracts signed previously. In these contracts normally are foreseen the procedures and recovery times in case of service problems or disruption.

5.3.2.2. General recommendations

Goal of the function is the restoration of routine UTS activities that were disrupted at a differing scale. The function encompasses activities planned before disruption (such as a Disruption Recovery Plan) and those improvised after a large-impact unforeseeable incident.

The function must have availability of sufficient resources at least for short-term recovery at an acceptable level. It aims restoring urban transport services to their initial level.

The restoration of modal services enables cross-modal network operations of the transport system as a whole.

5.3.2.3. Common Conditions recommendations

1. Availability of resources

Humans (labour) – skills/competence

- Members of Restore and Repair operations should be people who profoundly know the relation between the UTS and the overall urban environment, including the other urban CIs, in relation to the essential functional priorities (technical and procedural) for which they are in charge. Their working vision should be based on an integrated operational approach, which encompasses a set of actions useful to recover people's daily activities, public and sensitive data mobility and goods transport, but also to obtain a life-line system for rescuing people and economic values and for repairing and restoring all the interconnected systems – internal as well external (e.g. other interconnected urban CIs) – when they are disrupted. In relation to this dual aspect people involved in the function should maintain their skill and competences at a high level by means of recurrent trainings in the field of smart cities, smart mobility/transportation, urban planning and urban resilience activities. Such acquired expertise must be shared with the territorial management authorities in order to maximize the effectiveness of the possible restore and repair activities, to optimize the intervention times within the local planning rules and to ensure continuity between the emergency phase and the ordinary management phase.

Budget

- In case of critical situations that turn into emergencies financial reserves should budgeted for store and repair. The allocation of support funds should be budgeted in relation to the current status of the UTS and relative risks. The portfolio should also have a wide margin of use because of the variability of each possible event in terms of typology, level of criticalities and extension. In this perspective funds must be designated both by the involved private/semi-private companies and the public entities in relation to their responsibilities.

Data & Algorithm

- Use of standard documentation for data and algorithms.
- Use of recognized project management concepts.
- Use of standardized models and protocols.
- Production of quantitative measures in order to manage the required action plans.
- Use of Historic data in relation to short- to long-term responses (natural and anthropic) of the urban context to possible and actual critical scenarios.
- Acknowledge existing legal acquis, local conditions and regulatory regimes.
- To locate the exact relationship between infrastructures and services/procedures is a sensitive issue, but it can provide major advantages in terms of resilience. This relationship must be properly applied to simulation models when restore and repair aspects are tested and validated. Models are used to prepare backup services and redundant procedures that can avoid problems due localized disaster impacts, mitigate and absorb problems due diffused disaster impacts. The same model can also identify stressful situations that must be avoided in order not to become fatal in case of disaster.

2. Training and experience

- Social and territorial data analysis, network examination and software simulation by good practice experts
- Management and coordination skills to collect the contingent information and to project restoration activities
- Expertise in financial and environmental management, procurement and technical issues in design, construction and maintenance

3. Quality of communication

- Guarantee a complete and clear share of knowledge, data and aims among all the actors and from actors to the final users (active interaction) at all the main steps of the implemented actions
- Guarantee the accuracy and understandability of the communication through standardized communication tools, protocols and languages

4. Human Computer Interaction and operational support

- Utilization of software tools to analyse data and project focused intervention plans.
- Utilization of social networks to collect data and information about the opinion of users (both commuters and tourists) and citizens with respect to the recovery actions

- Utilization of software tools to analyse the impact of the operational strategies which could be applied to the disrupted system, also supporting the evaluation socio-economic cost-benefit.
- In normal situation or in case of emergency, the monitoring of the services/procedures is directly connected to the monitoring of infrastructures, with all the temporal, qualitative and quantitative connected considerations. However, services and procedures also have a great social impact. To monitor and to be able to interpret feedbacks from media and social network becomes important. Evaluate the psychological impact that the lack of a service has on the population is difficult and not temporally immediate. But being able to understand what services and how quality are perceived as belonging to a normal situation is a key point to focus energies.

5. Availability of procedures and plans

- Open Planning process to effectively outline the structural and not-structural list of actions
- Strategic financial and operational plans according to possible scenarios to be repaired
- Procedure for fast availability of all the necessary resources

6. Conditions of work

- Determination (in advance) of specific legislation to ensure that personnel may bear responsibility, also under an effective insurance system
- knowledge and awareness about priorities for recovery after the emergency in order to disseminate prop erly funds, material and human resources
- Capacity to facilitate the cooperation among the different stakeholders during the debriefing activities and all the steps of the field operations

7. Number of goals and conflict resolution

- Tang ible structural and not structural measures to restore the ordinary and fully operational condition that were disrupted by disaster impacts.
- the operating units should be organized taking into account the scale of the problem and timeline of the plan
- Quantitative and qualitative measures about the expected impact of the applied working methodologies
- Define the activities that must be planned before and in provision of a disaster impact and those that must be improvised only after disaster impact.

8. Available time and time pressure

- Immediate response needed in order to restore basic services as soon as possible
- Function must be planned to act in short-term recovery and long-term reconstruction based on the importance of the service/procedure
- Restore_timing_plan: depending on how crucial the operation is for the whole system operation, the pre-event recovery plan should define time-critical restoration activities. In a (chrono) logical order, transport demand recovery follows service restoration.
- A continuous (daily) monitoring of the transport operations recovery is advised.

9. Circadian rhythm and stress

- Restore quickly service/procedures the lack of which can stress ordinary life
- Identify what services and how quality are perceived as belonging to a normal situation

10. Team collaboration quality

- Adherence to the principles of collaborative planning
- Collaboration and cooperation between institutions and private companies that operates on services/procedures

11. Quality and support of the organization

- Clear decision making process and alignment of responsibility
- Alignment of decisions with defined priorities
- Having clear what type of services and procedure must be repaired before others

5.3.2.4. Interdependencies recommendations

- This function must be activated by and with the supervision of the Coordinate Service delivery function, receiving by it plans and coordination with other procedures. It would be appropriate to not start this function before critical emergency is finished. A transport infrastructure in good order is a precondition of the transport service restoration.
- To operate correctly this function need for appropriate funding and an accurate strategic plan.
- This function must provide the highest possible feedback to Coordinate Service delivery function so that it can coordinate the activities. This can be performed by direct communication or by monitoring continuously the repair operations. This function must also communicate with Manage awareness & usage behaviour function so it can be awareness about status of services and procedures.
- It's strongly recommended that this function coordinate itself with Restore/repair physical infrastructure function. In particular is necessary share operation plans and carefully coordinate restore timing plans. Also human resources can be optimized to repair/restore both infrastructures and services/procedures. Obviously is necessary that a service must be restored after the infrastructures it depends are restored and checked. Capacitated trained personnel with work experience must be involved. Furthermore, clear roles and responsibilities of the field & management personnel have to be assigned in advance, along with responsible body for permission to start operations.
- To increase resilience it is also important, after the activities, that all data regarding the restoring operation became available to those who deal to collect information about the disaster event.
- During the repair operations must be kept taken into account the current laws and standards about safety risk. It’s strongly recommended to restore the community services and procedures to its previous condition avoiding reproducing their previous hazard vulnerability.
- The pre-event recovery plan prioritizes transport services (links & nodes) to be restored. In the transport industry, a typical target for the said function is 90% operability in the short-/mid- term. KPI metrics for service restoration is the time needed up to 90% operability. KPI metrics for demand recovery is a static resilience indicator measuring the transport demand covered by alternate carriage capacity as percentage of the transport demand reduction due to the disruption.

5.3.2.5. Limitations

- Possible limited financial resources
- Possible contracts limitations between institutions and private companies
- Possible resistance to allocate more money to avoid hazard vulnerability in future
- Possible lack of infrastructures where to place alternative services and procedures

5.3.2.6. Examples

National Response Framework (NRF) - USA

- This is a guide to how the U.S. Nation conducts all-hazards response. It is built upon scalable, flexible, and adaptable coordinating structures to align key roles and responsibilities across the Nation, linking all levels of government, nongovernmental organizations, and the private sector. It is intended to capture specific authorities and best practices for managing incidents that range from the serious but purely local, to large-scale terrorist attacks or catastrophic natural disasters. http://www.fema.gov/pdf/emergency/nrf/nrf-core.pdf (Mar. 24, 2016)

National Disaster Recovery Framework (NDRF) - USA

- It describes the concepts and principles that promote effective Federal recovery assistance in U.S. It identifies scalable, flexible and adaptable coordinating structures to align key roles and responsibilities. It links local, State, Tribal and Federal governments, the private sector and nongovernmental and community organizations that play vital roles in recovery. The NDRF captures resources, capabilities and best practices for recovering from a disaster (localized or at large scale).

5.4 LEARN

5.4.1 Provide adaptation & improvement insights

5.4.1.1. Background facts

The complexity of interconnected systems, such as critical infrastructures, requires a deep analysis of the possible responses to events. Furthermore, the highly dynamic behaviour – associated with the operations during and after the event, as well as the occurrence of "new" types of event – makes more difficult to model "a-priori" the possible response. This is even more relevant where citizens are deeply involved, such as in using urban transportation services.

According to these considerations, the need to learn, directly from data, becomes crucial. Ex-post analysis, taking into account the nature and features of the event, the operations performed (and their timing), as well as the comparison with good practices, will permit to identify criticalities/vulnerabilities and, subsequently, define corrective actions to improve the adaptation of the system to similar events.

With respect to UTS, the "response" of people to an event (commuters who well known the urban transportation network as well as tourists who might do not know it very well) is a phenomenon characterized by a certain level of chaos, depending on concurrent/antagonist individual behaviours, current level of demand and supply, provisioning of right information at right time in order to reduce time needed to come back to a stable condition.

Data availability is therefore important for improving the capabilities to infer and model the behaviour of the UTS and simulate the expected impact of alternative corrective actions, even with respect to other types of events.

One relevant "unstructured" data source is related to social media and the contents generated by users – in particular people involved by the event as well as citizens in general. These sources of information allow for monitoring and characterizing the response of people to different events occurring at different time.

5.4.1.2. General recommendations

Both ordinary stresses and emergency situations need to be analysed. The most intrinsic robustness of a transport system comes from continuous listening to the public, both the commuters and the occasional visitors.

The former learn and adapt the system inefficiencies, and can provide suggestions for long term amelioration. The latter provides immediate feedback, and because they don't know the system, they may suggest fast, short term amelioration, in communications, signaling, ticketing, availability and quality of comforts.

After having listened to the people, conducted exercises, and eventually after that real emergency have been resolved, it should be enacted continuous debriefing, circulate the results for review and provide summaries to information exchanges. Feedback must be shared with other transport systems withing the reach, in order to enforce the diffusion of good practices.

When considering the relevant adaptation options, the following should also be considered:

- by when it will be necessary to take action and why,
- what level of adaptation will be required, and
- the consequences of over- as well as under- adaptation, in order to decide on the level of adaptation required.

- Establish an internal System Thinking perspective focusing on an holistic rather than a reductionist view of the organization
- Learning and Adaptation objectives should incorporate the total human beings with all the persons' intellectual and spiritual assets.
- Consider the Environmental Impact Assessment (EIA) as an appropriate instrument to mainstream adaptation, helping to improve the climate resilience of infrastructure. The Environmental Impact Assessment (EIA) is a procedural and systematic tool that is in principle well suited to incorporate considerations of climate change impacts and adaptation within existing modalities for project design, approval, and implementation. The EIA Directive requires that environmental impact assessments shall identify, describe and assess the direct and indirect effects of a project on the human beings, fauna and flora, soil, water, air, climate, the landscape, material assets and cultural heritage and the interactions between these factors
- While adaptation challenges differ from sector to sector, the ongoing adaptation process also includes several common elements across the sector. Adapting infrastructure to a changing climate needs to be considered in two ways:
    a) when **constructing new infrastructure**, climate resilience can be ensured by locating, designing and operating an asset with the current and future climate in mind. This is particularly important in the case of large infrastructure which usually has a lifespan of at least 20 years and, therefore, investment decisions influence future generations' wellbeing,

    b) existing infrastructure can be made more climate-resilient by retrofitting and/or ensuring that maintenance regimes incorporate resilience to the impacts of climate change over an asset's lifetime.

- Achieve sector and location specific climate resilience, there is a need for a thorough and coherent assessment of local climate impacts – based on historical records, but also including projections on future climatic conditions.
- Promote the creation and participation to a Trusted Information Sharing Network as a forum in which the owners and operators of critical infrastructure work together and share information on threats and vulnerabilities and develop strategies and solutions to mitigate risk.
- Define a Critical Infrastructure Program for Modelling and Analysis (CIPMA), a computer-based capability which uses a vast array of real data and information from a range of sources (internal and external) to model and simulate the behaviour and dependency relationships of critical infrastructure systems.

CIPMA uses an all hazards approach to undertake computer modelling to determine the consequences of different disasters and threats (human and natural) to critical infrastructure. Owners and operators of critical infrastructure can use this information to prevent, prepare for, respond to or recover from a natural or human-caused hazard.

5.4.1.3. Common Conditions recommendations

1. Availability of resources

Humans (labour) – skills/competence
Several stakeholders have to be involved in the debriefing activities:

- Technical/methodological experts for implementing and analyzing the "what-if" simulation scenarios with respect to current and adapted UTS.
- Experts in communication to translate simulation findings into proposals for the management.
- All the actors involved in the emergency coordination and management should provide information about performed actions, features of the event and the environment, behaviour of the people involved in the event and their response.
- Experts who can provide updated knowledge about good practice and support ex-post comparison and analysis.

- UTS users involved in the event, commuters and tourists as well as citizens are directly affected by the event (e.g. by its propagation).

Budget

- Adaptation might require relevant investment. To secure such investment, the role of insurance of financial reserves to be accessed for setting the de-briefing activity up is crucial.

Data & Algorithm

- All the data acquired through monitoring systems
- All the data related to other historical events
- All the information collected and reported from actors involved in the event
- Good practices
- Network modelling and simulation algorithms
- Data Mining algorithms
- What-if simulation algorithms

2. Training and experience

- Data analysis, network analysis and software simulation to analyse and evaluate UTS and possible adaptations
- Management and coordination skills to collect and share information, manage the debriefing and support analysis and discussion
- Good practice experts

3. Quality of communication

- Guarantee a complete and clear share of knowledge, data and information among the different actors
- Guarantee the understanding of the possible advantages and impacts produced by the discovered insights and provided adaptation actions.

4. Human Computer Interaction and operational support

- Utilization of software tools to analyse data.
- Utilization of social networks to collect data and information about the opinion and sentiment of citizens/people with respect to the event, the emergency management and the recovery actions.
- Utilization of software tools to model rules of the system – even "new" ones, discovered through the ex-post analysis of the event.
- Utilization of software tools to simulate "what-if" scenarios in the interconnected system and obtain (synthetic) data.
- Utilization of software tools to analyse the impact of adaptation strategies which could be applied to the system, also supporting the evaluation socio-economic cost-benefit.

5. Availability of procedures and plans

- Planning process to effectively implement the proposed adaptations: working groups' management and economic/financial analysis for priorizing adaptation actions

6. Conditions of work

- The cooperation among the different stakeholders during the debriefing activities, the analysis and the definition of insights and adaptations should be facilitated. Cooperation is related to sharing of data, information and evaluation at every level and multi-domain: social, economic, technological, infrastructural and service.

7. Number of goals and conflict resolution

- Quantitative and qualitative measures about the expected impact of the application of the defined adaptations (e.g. reduction of risk with respect to similar past events as well as events occurred in different geographical areas).

8. Available time and time pressure

- Medium/long term goals related to the reduction of risk and possible impacts of disruptive events, even if analysis should be performed in the very short-time after the event in order to guarantee the collection and analysis of data and information which are not stored into ICT systems.
- Adaptations can be related to different levels and domains, thus different times can be required to implement adaptation actions, even according to budgetary constraints

9. Circadian rhythm and stress
- N.A.

10. Team collaboration quality
- Collaboration and cooperation are crucial for accurately address the analysis of data and information, the definition of adaptations and the evaluation of their potential impact.

11. Quality and support of the organization
- Clear decision making process and alignment of responsibility
- Planning operations to implement adaptation of the overall system, according to budgetary constraints
- Procedures improved to effectively prevent and mitigate events, according to collected data, information and results from what-if simulation
- Overall targets: increasing knowledge about the impact of events, reducing vulnerabilities of the system, improving effectiveness of the response
- The collected knowledge improves the resilience of the overall system and may also be shared in order to support resilience improvements also to other critical infrastructures

5.4.1.4. Interdependencies recommendations

- An effective adaptation can be only identified taking into account relevant data about the event and possible budgetary constraints.
- The current status of the cyber physical infrastructure associated to the UTS as well as the usage behaviour have also to be known in order to define the most suitable adaptation actions. Usage in particular should be analysed according to local specificities and with respect to different "modalities" (e.g. commuters or tourists) at different time scales (e.g. period of the year, days of the week, hours of the day)
- Finally, all the information related to the service provision has to be deeply evaluated in order to estimate the possible variations of the service associated to the adaptation actions and improvement insights identified.

5.4.1.5. Limitations

- Costs for the "optimal" adaptations could be too high, making difficult their implementation – priorization of actions can facilitate the implementation of the most critical adaptations
- Unavailability / late availability of data

5.4.1.6. Examples

Responding to climate impacts: railways between Copenhagen and Ringsted (DK)
- Increased precipitation and increased water flow in watercourses can affect the new railway line between Copenhagen and Ringsted. In connection with the project on expanding the track capacity between Copenhagen and Ringsted on Zealand, the Public Transport Authority, which has analysed the track capacity, has carried out a climate change impact assessment for the project. The goal of the impact assessment is to investigate a future rail track's robustness to climate change over a 100-year operating period. The assessment shows that especially increased precipitation and increased water flow in watercourses can impact on railway constructions, whilst other factors such as increasing temperatures, rising sea levels and rising groundwater will not have a significant impact. Of particular importance is an expected 20% increase in the intensity of rainfall in heavy downpours in the year 2100. In areas where watercourse crosses the track, under a bridge or tunnel, climate changes mean there is a risk that water cannot flow quickly enough and thereby build up and Risk eroding the railway construction. Therefore a new track between Copenhagen and Ringsted will have a 30 per cent greater

capacity for water flow than the norm that is used at present. The Public Transport Authority assesses that the recommendations for adaptation to climate change are robust in relation to the variations in the expected climate changes.

5.4.2 Collect event information

5.4.2.1. Background facts

When a disruptive event affects UTS, it generates “effects” at different layers which could be monitored – and hopefully controlled during the emergency management – through ICT systems or information reported by operators and citizens.

The collection of information and data related to disruptive events are therefore crucial in order to enable the definition of good practices, the contribution to guidelines definition/update, the identification and evaluation of actions supporting a quick recovery to normality as well as adaptations to increase the overall resilience of the UTS to disruptive events.

As any other organization, a company managing UTS works with three classes of knowledge: *tacit knowledge*, rule-based knowledge, and background knowledge. Tacit knowledge consists of the hands-on skills, special know-how, heuristics, intuitions, and the like that people develop as they immerse in the flow of their work activities; *rule-based knowledge* is explicit knowledge that is used to match actions to situations by invoking appropriate rules; *background knowledge* is part of the organizational culture and is communicated through oral and verbal texts such as stories, metaphors, analogies, visions, and mission statements. Thus a dedicated information/knowledge management is necessary.

The basic goal of information management is to harness the information resources and information capabilities of the organization in order to enable the organization to learn and adapt to its changing environment.

Different ICT systems and platforms are generally used to constantly monitor the current condition and the quality of service of the UTS, both at cyber and physical level, and support the evaluation of possible risks. Other ICT solutions are then employed during the emergency management, often requiring a high level of integration/interoperability with monitoring and control systems generally used during the normal operations. Moreover, in many cases, the solutions adopted during the emergency management also require integration/interoperability with monitoring and control systems of other critical infrastructures – interconnected to the UTS – as well as across the different stakeholders involved in the operations.
All these ICT based systems, platforms and solutions usually allow to collect and store in-home data (usually structured) which can be stored in order to be analysed – ex-post – to better understand the features of the event, its impact and the effectiveness of the current guidelines and good practices.

However, a huge amount of external information is usually lost, even if it could be extremely relevant to deeply understand, model and analyse the event and evaluate the current resilience capabilities of the UTS. In effect, any event is characterized by a multi-domain and multi-level nature, involving not only ICT systems and operators but also citizens, as users of the UTS or people in the city affected, in some sense, by the impacts generated – and propagated – by disruption of UTS.
This is even more relevant for UTS, where both commuters, citizens in general and tourists are users of the urban transport service, representing to different modalities of response to a disruption (i.e., contrary to tourists, both commuters and citizens have a better knowledge about the overall transportation network of the city and it is easier, for them, to “adapt” their mobility choices to mitigate the impact of the event on their daily life activities).
People involved in the event can for sure provide a lot of information which can complete the data and information collected through ICT systems and reported by the operators, respectively. It is important to highlight that in some cases the “human/social sensing” could be the only solution to collected information (e.g. about a specific area not covered by monitoring systems and not yet reached by the emergency management operators).

The critical issue associated to this function is related to the modifications which may occur over time and affecting ICT systems used at every level: to monitor and control the UTS, to coordinate, monitor and support the operations during the emergency management, to collect and store relevant information reported by the users of the transport service – or citizens in general – usually defined as “user generated contents”.

5.4.2.2. General Recommendations

- Establish a organzialtional knowledge base to record ongoing operation data
- Identify organizational information needs. The identification of information needs should be sufficiently rich and complete in representing and elaborating users' real needs. Since information use usually takes place in the context of a task or problem situation, particular information needs will have to be elicited from individuals. Unveiling information needs is a complex, fuzzy communication process. Most people find it difficult to express their information needs to their own satisfaction. Personal information needs have to be understood by placing them in the real-world context in which the person experiences the need, and to the ways in which the person will use the information to make sense of the environment and so take action.
- Information acquisition seeks to balance two opposing demands. On the one hand, the organization's information needs are wide-ranging, reflecting the breadth and diversity of its concerns about changes and events in the external environment. On the other hand, human attention and cognitive capacity is limited so that the organization is necessarily selective about the messages it examines. The first corollary is therefore that the range of sources used to monitor the environment should be sufficiently numerous and varied as to reflect the span and sweep of the organization's interests. While this suggests that the organization would activate the available human, textual and online sources; in order to avoid information saturation, this information variety must be controlled and managed. A powerful way of managing information variety is to involve as many persons as possible in the organization in the gathering of information, effectively creating an organization wide information collection network.
- Human sources are among the most valued by people at all levels of the organization: human sources filter and summarize information, highlight the most salient elements, interpret ambiguous aspects, and in general provide richer, more satisfying communication about an issue. Information acquisition planning should therefore include the creation and coordination of a distributed network for information collection.
- The adaptive organization needs to be able to find the specific information that best answer a query, and to collate information that describes the current state and recent history of the organization. Well integrated archival policies and records management systems will enable the organization to create and preserve its corporate memory and learn from its history.
- The system should capture hard and soft information, support multiple user views of the data, link together items that are functionally or logically related, permit users to harvest the knowledge that is buried in these resources, and so on. Because the same information can be relevant to a range of different problem situations, it becomes necessary to represent and index the unstructured information by several methods. The development of automated indexing systems makes it increasingly feasible to adopt a user-centered approach to indexing, over and above document-oriented indexing that represents the document's content

5.4.2.3. Common Conditions recommendations

1. Availability of resources

Humans (labour) – skills/competence

- At the heart of the organization are four groups of experts who need to work together as teams of knowledge partners: the domain experts; the information experts; and the information technology experts:
    - Domain experts are individuals in the organization who are personally engaged in the act of creating and using knowledge;
    - Information experts are the individuals in the organization who have the skills, training and know-how to organize knowledge into systems and structures that facilitate the productive use of information and knowledge resources;

- The information technology experts are the individuals in the organization who have the specialized expertise to fashion the information infrastructure of the organization. The information technology experts include the system analysts, system designers, software engineers, programmers, data administrators, network managers, and other specialists who develop computer-based information systems and networks.

- Skill and competences involved in this function are really different and multi-domain. Personnel of the UTS, who is in charge to internally cooperate to the emergency management, has to be trained in order to effectively support emergency management operators and guarantee cooperation and information sharing even beyond the current integration/interoperability of the ICT systems and solutions.
- Furthermore, psychologists as well as human and social science experts should cooperate to support users of the UTS, in particular frequent users such as commuters, and citizens involved in the event in reporting information which could be useful in order to comprehensively understand the nature and characteristics of the event and the effectiveness of the overall response performed.
- Finally, technological competences and skills are strictly required to allow the storage of all the data and information collected in a multi-domain and multi-level knowledge base which can be then used for supporting an ex-post analysis based on both historical and updated data and information. Technological competences and skills are also required in order to assure – hopefully improve – the level of integration/interoperability between different ICT systems, even along their own evolution.

Budget
- Financial reserves to be accessed for acquiring new ICT systems as well as to update those currently used with the aim to improve data and information collection, storage, integration and sharing.

Data & Algorithm
- Data coming from all the ICT systems used to monitor and control the UTS (also during the emergency management), regarding the trends of values to be monitored from the city and the decision and actions taken from the intelligent transport systems and other control rooms.
- Data coming from all the ICT systems used by the emergency management operators.
- Data/information collected through “social/human sensors” during the emergency (mainly users affected by the event).
- Data/information collected through “social/human sensors” after the emergency (both users involved in the event and citizens in general).
- Data warehousing and Big Data management (both structured and unstructured data).
- Data/Information Fusion.
- Data registered from the cameras have to be saved and not left on the system that typically performed periodic overwriting.

2. Training and experience
- Technological skills to store and integrate data from different sources and in different formats (Big Data, Information/Data Fusion, Data Warehousing).
- Psychology and human/social science skills to retrieve relevant and trustworthy information about the event from users/citizens involved in the event.
- Cooperation skills to support and facilitate the collection and sharing of relevant information.

3. Quality of communication
- Guarantee communication channels which may work as a backup in case of emergency in order to ensure data/information sharing among different systems and stakeholders during the emergency management.
- Guarantee the correct communication with the users/citizens involved in the event – by involving psychology and social/human science experts – to collect useful and right information in order to improve understanding about the event and the current resilience capabilities of the system.
- Communication with other interconnected CIs

4. Human Computer Interaction and operational support

- Several human-computer interactions during the emergency management, according to the different ICT systems used and the cooperation among operators
- Data/information input and storage to enable retrieval, visualization, correlation and analysis after the event

5. Availability of procedures and plans
- It is important to have already defined, and in case updated, procedures and plans regarding the cooperation between critical infrastructure and other emergency operators, in particular with respect the data and information sharing/integration goals

6. Conditions of work
- Provide legislation to ensure the cooperation among different stakeholders and storage of shared data/information into a comprehensive knowledge base

7. Number of goals and conflict resolution
- A detailed report of the data and information collected and stored regarding the event
- A detailed report of the updated (new) data and information into the knowledge base
- Increasing the level of knowledge related to events, their specific impacts and the relations with the overall “environment” (features of the CI, number and types of interconnected Cis, procedures, ICT systems involved, actions, etc.)

8. Available time and time pressure
- Personnel must be trained: hands-on training sessions should be performed
- Technical personnel must be trained to support and keep up-to-date the procedure for data and information integration/fusion
- Timeliness of data

9. Circadian rhythm and stress
- There must be specific psychological skills to support the collection f information from users/citizens that could be under stress due to the event.

10. Team collaboration quality
- High quality is required, in particular among technical personnel of critical infrastructure and emergency stakeholders
- Involvement of psychology and social/human science experts as to take into account characteristic of both event and critical infrastructure in order to acquire useful information from what users/citizens report

11. Quality and support of the organization
- Clear plan for cooperation and information sharing with other relevant stakeholders (emergency management operators and human/social science experts

5.4.2.4. Interdependencies recommendations

- Interdependencies are related to the different data sources, in particular internal, which have to be considered in order to increase the level of knowledge about events, features of the UTS and possible impacts. Data are related to different actors and technological systems involved during all the phases of the prepare-absorb-recover-adapt process.
- In order to maximise the internal data availability, a dedicated procedures, wide information as well as a specific ICT infrastructure should be put in place to favourite data transfer from different functions.

5.4.2.5. Limitations

- Post-event stress could make difficult to collect reliable and consistent information about the event from involved citizens/users

5.4.2.6. Examples

Virtual Detection Zone in smart phone, with CCTV, and Twitter as part of an Integrated ITS"

(B. Hardjono, A. Wibisono, A. Nurhadiyatna, I.Sina and W. Jatmiko "Virtual Detection Zone in smart phone, with CCTV, and Twitter as part of an Integrated ITS", International Journal On Smart Sensing And Intelligent Systems Vol. 6, No. 5, 2013)

- **-** In this proposed integrated Intelligent Transport System, GPS enabled smart phones, and video cameras are used as traffic sensors, while Twitter is used as verifier. They are attractive because they are non-intrusive, and consequently more practical and cheaper to implement. The novel Virtual Detection Zone (VDZ) method has been able to map match by using pre-determined check points. VDZ speed accuracy ranges from 93.4 to 99.9% in higher speeds and it only needs one longitude and latitude coordinate, to form a detection aware zone. Also by using ANFIS we show that a more accurate traffic condition can be obtained using three sources of data.

6 CROSS SECTOR INTERDEPENDENCIES

Due to the complex nature of UTS and its critical position in the overall social and economic system, there are numerous interdependencies with other sectors, even within the system itself.

UTS is actually composed of a number of sub-systems which operate independently but highly interconnected. Each transport mode for instance can be considered as a different sub-system, to which all system-related ERMG guidelines also apply, even in a smaller scale than for the whole UTS. Thus, all these sub-systems should cooperate for the optimal operation of the overall UTS.

Apart from these “internal” interdependencies, UTS is actually interacting with almost any other critical system. From energy and communications, to health facilities and any kind of industry (including dangerous materials), dependencies and interdependencies to the UTS are strong and critical for the operation of all these systems and for establishing a resilient environment.

The complexity and multitude of existing links to other systems and sectors, makes it virtually impossible to simply describe them in full detail and with all possible interactions. Thus, several methodologies and implementation examples of modelling the interconnection of transportation systems have been developed and can be found in the literature, like (Pengcheng& Srinivas, 2011), (Gomes, 1990), (Dugundji & Walker, 2014). This type of models (here only indicative examples given) can represent the interconnections of a given UTS with other critical (and not only) systems. Of course, these are case-specific and vary according to the characteristics of the system under consideration.

Following the generic guidelines provided in D3.5, concerning cross-sector interdependencies, for the case of UTS the following can be recommended:

- Understanding and addressing risks

In the case of UTS this implies risks deriving from dependencies and interdependencies both between sub-systems of the UTS, like, for instance, shared/interacted infrastructure between different modes and between the UTS and other sectors, like energy (transportation of fuels, energy supply for the UTS, etc.), communications (communication infrastructure interacting with transportation systems, communication services used by the UTS for its operation, etc.), health (access to health facilities, transportation of patients, etc.), dangerous materials industry (transportation of dangerous materials, especially through critical infrastructure components, like tunnels, etc.)

- Data management

An issue of utmost significance is the management of data between different systems and sectors. Data can be of different and of various types and contents, affecting at the same time one or multiple functions of each system. The use of a centralised tool at local or even at European level (like CIWIN) is absolutely necessary for the effective and smooth data distribution, fusion, storage and analysis.

- Managing cascading effects

The more the interdependencies the greater the risk of cascading effects. Thus, in the case of UTS this is an issue that should be closely looked into, through strong cooperation between systems and sectors for the in-depth analysis of the possibility of such events at different levels (in terms of localisation and magnitude). For example, there should be clear understanding and pre-decided response and mitigation actions for the case of a multi-vehicle crush in an urban highway during a severe downpour, which will definitely result in road closure, with all kinds of implications that this may infer, in order to result in the least possible disruption to the UTS and, consecutively, the overall local activities operation.

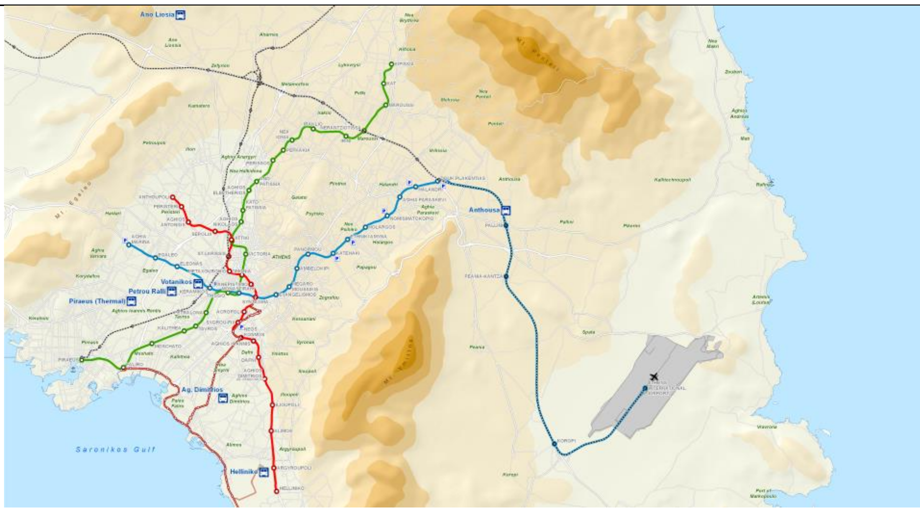
In whole, managing interdependencies between the UTS and other sectors require overall monitoring structures, which, depending on the magnitude and significance of the urban environment in question, shall be established at local, regional, national or even EU level. Such structures should be in charge for analysing existing interdependencies, ensuring the resilient operation of all systems under the given circumstances, while guaranteeing the preparedness for response in the case of disruption occurring to any of the linked systems. It is also important to establish clear communication channels between the affected organisations, through several media (online tools, workshops, etc.) to ensure understanding and cooperation at all levels of involved stakeholders.

7 RESOLUTE PRELIMINARY OPERATIONAL SCENARIOS

The final goal of RESOLUTE is to adapt and adopt the identified concepts and methods from the defined guidelines for their operationalization and evaluation when addressing Critical Infrastructure (CI) of the Urban Transport System (UTS) by following the recommendations defined in this deliverable. This will be done through the implementation of the RESOLUTE Collaborative Resilience Assessment and Management Support System (CRAMSS), which aims to adopt a highly synergic approach towards the definition of a resilience model for the next-generation of collaborative emergency services and decision making process and through the verification/ update of all organizational processes that find themselves in the ERMG. The operationalization and validation of the guidelines is within the objectives of WP4, 5 and 6.

This section offers two practical examples of how ERMG can be reflected in reality, by presenting two use-case scenarios emerged from RESOLUTE pilot sites. For each of them, all functions in the four categories (Anticipate/ Monitor/ Respond/ Learn) and relative recommendations have been addressed, along with the description of their on-site application and by indicating, for lacking situations, possible improvements that could be implemented following the RESOLUTE approach.

7.1 Metro Bomb Attack Scenario

Use Case Scenario	Metro Bomb Attack
Overview	The use case scenario in Athens will examine a disruption of metro service due to a bomb attack and will evaluate and improve the metro system's resilience. In terms of static resilience, in the short term there will be planning strategies to absorb attack consequences and increase emergency preparedness for the reactive phase. Alternative transport service will be provided through bus bridging from lines stabled at depots close to metro stations. In terms of dynamic resilience, a stated preference survey will be undertaken to assess the willingness to accept the perceived risk to use the metro service in the post-attack period.
Area	 A map of the greater Athens area, showing the metro network including the metro link to the airport, as well as the locations of seven thermal bus depots.

	• Athens area has a population of 3,827,624 inhabitants (2011) • The use-case area comprises the municipality of Athens as well as fifteen other municipalities currently served by the metro network in Attica region, including the municipalities served by the metro link to the airport. The metro network provides a radial service to these municipalities.
Actors	Attiko Metro's Managing Director is the Critical Infrastructure manager involved in the Athens use case. Supporting agencies and first responders are the General Secretariat for Civil Protection (CP) and its Operational Centre 199 SEKYPS, Region of Attica CP, Police (GADA), EMAK Rescue Team, EKAB first aid and hospitals. The final users are PT riders and road travellers.
Triggers	In the use case in Athens, control points that trigger the emergency situation is the state of the "nodes" and "links" of the metro network, that is, the metro stations and tunnels where a severe incident may take place.
Goals	The targets for two sub-case scenarios are: > sub-case (1): to restore the service in the short-term, providing alternatives such as bus bridging of closed stations retracting spare buses from proximal depots and scheduled bus lines (if not already running parallel services), achieving modal substitution of disrupted Metro service > sub-case (2): to restore metro ridership to its initial level (pre-event) as soon as possible.
Preconditions	a) An essential precondition for the bus bridging scenario is that there is a guarantee that the service provided by the metro which is temporarily disrupted will be provided by alternative transport modes (buses). This means that such an agreement between the metro operator and the bus operator in Athens, called a Service Level Agreement (SLA), should be in place. Model runs will specify the specs of this SLA. b) In order to achieve maximisation of the switch from fearful to just worried metro passengers, an essential precondition is the knowledge of the population's WTA perceived risks.
Critical infrastructures	The metro network infrastructure involved in the use case scenario in Athens has the following characteristics: Fleet of (6 wagons/train x 66 trains =) 396 vehicles Train-kms travelled: 5.6 millions p.a. Network of 36 route-kms / 36 stations In addition, traction power substations are also involved.
Risks on service disruptions and alternatives	Either the "nodes"(stations) or "links" (tunnels) of the metro infrastructure might become inaccessible and disrupted due to a consequential bomb attack. Alternative service that should be provided includes service by alternative modes (buses) close to metro stations.
Data elements	• Static historic data (e.g. ridership and traffic figures). • Real-time data (telematics, smart card transactions).
Data flows	• Daily ridership: 770,000 pax • Peak hour traffic : 93,500 pax per hour O-Ds and station- to- station passenger flows (from transport model runs and/or gating transactions)
(Current) Systems	Describe the systems involved in emergency mitigation process at the moment Attiko Metro's safety-related systems include i.a. • Automatic Train Protection (ATP) and Supervision (ATS) • Operation Control Centre (OCC) • Closed Circuit Television (CCTV) • Fire Detection and Fire Fighting • Safety, Security, Access Control and Intrusion Detection Systems • Tunnel Ventilation • Public Address System • Intercom System • Radio-Telecommunication (TETRA)

	Emergency rules and procedures include i.a. • OCC response to incidents • Fire fighting • Train evacuation in tunnel • Bomb threat • Controlled smoke channelling with ventilators • Station evacuation • High-impact incidents) • Bomb blast – gas attack The existing systems can be improved by a service level agreement between the bus service and the metro operator to provide adequate level of service in case of a disruption of metro service. In addition, currently there is no knowledge of user behaviour in case of a severe metro service disruption due to ,
Evolution of the mitigation systems within RESOLUTE	The expected upgrade on current systems after RESOLUTE project includes i.a.: 1) Service Level Agreement realisation (1st sub-case) → resilient UTS supply This SLA will increase the resilience of the UTS, providing adequate level of service and shortening the necessary time period for bus bridging, in the case of disruption of metro operation. 2) Communication Plan to alleviate fear from metro attacks and maximise switch of population from fearful to simply worried (2nd sub-case) → resilient travelling population

ERMG operationalization			
ANTICIPATE	**Function**	**Already existing (+)/ Possible improvements through RESOLUTE approach (-)**	**Description of the application of the Guidelines**
	Develop Strategic Plan	+	The General Secretariat for Civil Protection/GSCP (under the Ministry of Interiors) and the Region of Attica CP Unit have developed Strategic Plans for Catastrophic Events
	Manage financial affairs	+	Financial reserves within state fiscus have been assigned to the GSCP for catastrophic eventualities
	Perform Risk Assessment	-	RESOLUTE identifies (beyond existing Operating Plan) risk consequences of attacks as well as vulnerabilities of the metro system in Athens
	Training staff	+	Operations & Maintenance staff providing metro services in Athens have been trained to apply emergency procedures and participated to station- as well train-related drills.
	Coordinate Service delivery	+	The coordination of metro service under normal or degraded mode is assigned to the Operations Control Centre/OCC at the central interchange station SYNTAGMA.
	Manage awareness & user behaviour	-	A very central contribution of RESOLUTE is the assessment of users' resilience in terms of traveller behaviour after a metro attack. A use (sub)case will assess the WTA attack

			risks by the Athenian population. Ways of reducing perceived public risk or increasing the trustworthiness of the UTS will be demonstrated. Communication spots, mass alerts & bulk SMS raising public awareness are parts of the advanced strategy. A novel dynamic process KPI for user resilience is to be developed.
	Develop/update procedures	-	Operating and routine safety rules & procedures serve prevention & avoidance functions during metro service provision. Emergency rules & procedures serve response & abatement functions in case of severe incidents. Athens metro updates on a regular basis such procedures. ERMG UTS Guidelines will contribute in this respect.
	Manage human resources	+	Potential metro drivers are licensed only after psychometric tests. Working regulations are elaborated by competent external source. Labour legislation of course applies. Continuous training is an essential HR activity. A HCM module is part of the ERP system. Grading and compensation system are interlinked.
	Manage ICT resources	+	ICT resources include i.a. ATP/ATO functionalities, TETRA communications, telematics, public address systems and smart ticketing gates are in place.
	Maintain physical/cyber infrastructure	+	Maintenance rules, procedures and instructions apply. Preventive metro maintenance activities are scheduled according to vendor prescriptions. Engineering (night) hours apply for line maintenance. Failures are reported to OCC and Work-Orders are issued through the ERP Maintenance module. Depot workshop capacities are activated. SCADA cyber-security is a priority currently set.
MONITOR	**Function**	**Already existing (+)/ Possible improvements through RESOLUTE approach (-)**	**Description of the application of the Guidelines**
	Monitor Safety and Security	+	The ‘safety first’ culture is a constitutional element since metro commissioning. Security staffing is a major outsourced (and expensive) activity of metro operations. CCTV cameras and intrusion detector sensors complement the security device.
	Monitor Operations	+	The Operations Control Centre/OCC at SYNTAGMA station monitors everyday metro operations. Each train is equipped with on-board control units.

	Monitor Resource availability	+	The Maintenance (components, installations and equipment status) and Stock Management module of Metro's ERP monitors capital resource availability. HR management, Crew fostering and Maintenance scheduling sections monitor human resources with the support of specialised s/w tools. The Power Control Centre manages traction and station power needs. The market cares for outsourced activities' availability. Reserve (buffer) capacities are foreseen. Periodic reporting is a direct output of the ERP system.
	Monitor user generated feedback	-	RESOLUTE will contribute to a crowd sensing approach in the Athens case (e.g. via geo-located tweets). Unstructured contents have to be automatically aggregated and validated in semantic terms before/during/after an incident. All bi-directional communication tools (internet, smart devices and mobile phones) are useful in this respect. RESOLUTE game-based training complements the picture.
RESPOND	**Function**	**Already existing (+)/ Possible improvements through RESOLUTE approach (-)**	**Description of the application of the Guidelines**
	Coordinate emergency actions	+	The Operational Centre 199 SEKYPS (Fire Service) of the GSCP is the overall coordinator in case of major emergencies. Supporting agencies are the Police (GADA & Traffic Police), EMAK Rescue Team, EKAB first aid, hospitals and –in case of metro incidents- the metro OCC. The interconnection with the first responders is in the latter case secured. Emergency rules & procedures apply.
	Restore / Repair operation	-	A very central contribution of RESOLUTE is the development of a Pre-event Recovery Plan for the Athens UTS in case of a catastrophic metro attack. The focus is on the short-/mid-term recovery of UTS through the use of alternative modes (e.g. bus bridging). Line closure scenarios and retraction of vehicles (based on SLAs to be developed) will be modelled as a further use (sub)case by means of the multi-modal Transportation Model owned by ATTIKO METRO. Static resilience KPIs for demand recovery/transport capacity restoration are to be estimated.
LEARN	**Function**	**Already existing (+)/ Possible**	**Description of the application of the Guidelines**

		improvements through RESOLUTE approach (-)	
	Collect event information	-	Static as well as real-time data are collected in the process of the everyday operations of the Athens UTS (historic traffic figures, PT telematics and smart card transactions etc.) Tools provided by RESOLUTE (eg CRAMSS) will improve the informational state facilitating cooperation and coordination among UTS stakeholders.
	Provide adaptation & improvement insights	-	Protocols and de-briefing of regular drills, exercises and 'what-if' scenarios is a common practice in the Athens metro. Customer complaints are categorised and considered for everyday operations improvements. RESOLUTE will certainly improve the overall adaptation.

Summarizing the table above, there are expected improvements of metro system resilience due to ERMG implementations for all function categories. In particular, the functions: "Perform risk assessment", "manage awareness and user behaviour", "develop/update procedures" (anticipating functions), function "monitor user generated feedback" (monitoring function), restore/repair operation (responding function and all learning functions are expected to be improved in terms of system resilience by ERMG implementation.

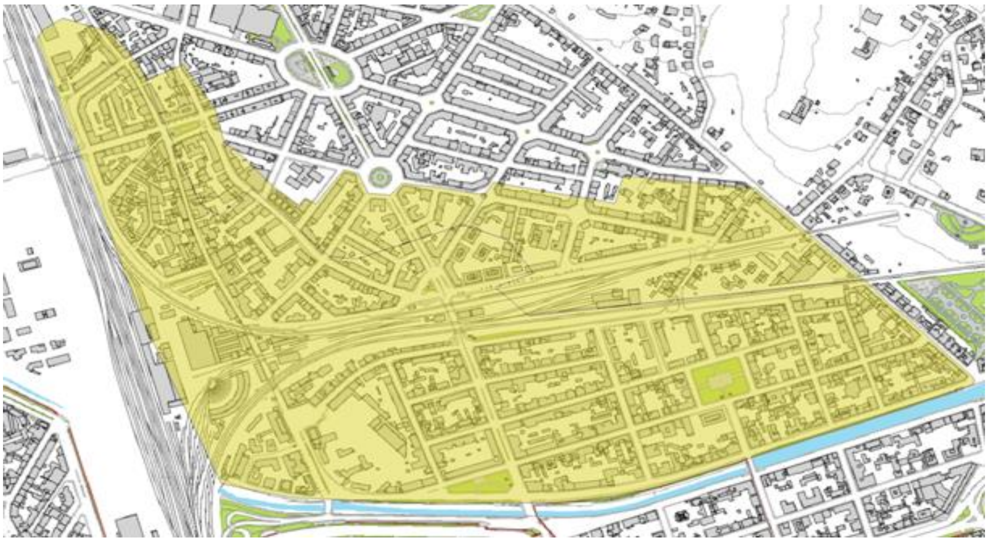
Table 3 : Existing system resilience without ERMG

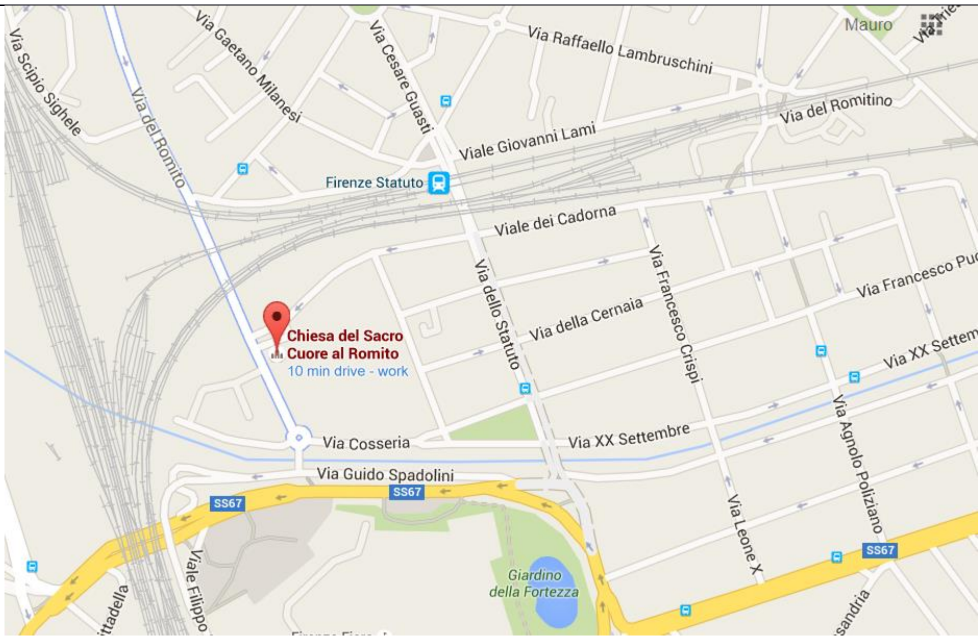
FUNCTIONS MOST AFFECTED BY ERMG IMPLEMENTATION	EXPECTED PERFORMANCE FOLLOWING THE EVENT ACCORDING TO THE USE CASE SCENARIO
ANTICIPATE: Manage awareness and user behaviour	Current system conditions ensure that short –term information is provided to users of the metro system, mainly through the Public Address system, as well as information signs and visual displays. Following a disruption of service in the metro system due to a man-made event, there will also be need for long-term actions, such as awareness campaigns to influence user behaviour from fearful to simply worried.
RESPOND: Restore/ repair operations	With respect to UTS, in case of an adverse event, the mobilization of stand-by O&M personnel, activation of a staff recall system or a HR replacement plan, are actions possibly needed (see 5.3.2.1). These issues are addressed by current metro system procedures and operations. In case of a disruption of metro service due to a bomb attack, bus bridging is going to be used to provide alternative service operation until metro infrastructure is restored. The time needed to provide adequate alternative service is going to be greater without SLAs for bus bridging.

Table 4: Most important improvements of system resilience with ERMG implementation

FUNCTIONS MOST AFFECTED BY ERMG IMPLEMENTATION	EXPECTED PERFORMANCE FOLLOWING THE EVENT ACCORDING TO THE USE CASE SCENARIO
ANTICIPATE: Manage awareness and user behaviour	Implementation of ERMG to design awareness campaigns aimed at developing enhanced confidence to the transport system (see 5.1.6) is expected to attract passengers back to the metro system in a shorter time period than without ERMG implementation, thus enhancing system resilience in the long term.
RESPOND: Restore/ repair operations	ERMG implementation and in particular the use of SLAs for bus bridging during disruption of metro service due to an event such as a bomb attack will provide adequate post-event UTS capacity, improving the system's response time, thus improving UTS resilience.

7.2 30-Years flood scenario

Use Case Scenario	**30-YEARS FLOOD SCENARIO**
Overview	Florence knows a statistical 30 years recurrence interval probability of being hit by dramatic, concentrated rains. The main Arno river, the two minor streams Mugnone and Terzolle, and many more minor waterways may be stressed, up to possible flood, even with localized and short-duration events. From historical precedents and considering the present state of the urban framework, and the impact of present and upcoming tramline infrastructures, the Municipality of Florence has focused on a narrow, but very critical area, along the Mugnone stream, including the old Romito street and neighbourhood, and the SacroCuore parish.
Area	



A snapshot of the area, highlighting the neighbourhood bordered by critical tramlines and railways and the Mugnone stream.

A snapshot showing the area, north of the Florence historical center, near the easy recognizable Fortezza da Basso

Actors

The Mayor of Florence is the main responsible for civil protection on the ground of the city during an emergency.

The following Municipal bodies are involved:
- Mobility Department
- Infrastructure Maintenance Dept

	- the Local Police Dept - the Civil Protection Authority, which concentrates every power in case of emergency Tuscan regional authorities are involved, in particular the Tuscany Civil Protection, because they have technical instruments and scientific bodies able to forecast floods and to trigger flood alarms. The Metropolitan City of Florence is another body involved in the supervision of traffic and mobility on a metropolitan-wide scale. Public utilities (buses, taxi companies, car-sharing companies). Private commuters (four-wheels and two-wheels). Other authorities, bodies, forces are involved in case of emergence, under the coordination of the Florence Civil Protection Authority (whose responsible is the Mayor of Florence): - Fire-guard brigades - Ambulances and other mobile health units - State police troopers - Railways personnel - Civic and religious associations and their volunteers
Triggers	Control points that trigger the emergency situation are: - forecast issued by Tuscan bodies of weather forecast (12-36 hours notice) - rain and water sensors along the Mugnone watercourse (0-3 hours notice) - human observation driven local alarms, coming from the upstream (0-1 hours notice) - declaration of emergency from the regional (or national) civil protection - meeting of the Emergency Coordination Center which defines priorities and controls activities through the control room
Goals	Main targets of the present scenario: - private traffic reduction or block since the early warning of the flood - avoiding traffic jam in the Rifredi and Novoli suburbs (north of the block) - ordering people to stay home (or wherever they are at the moment the alarm is triggered) - ordering people to climb up at upper floor of the building if there is any available - ordering people to shut doors and windows and hold onto tables and beds if they remained imprisoned in ground floor only buildings - ordering people to absolutely avoid any attempt of putting in security cars and other goods at ground zero or, even worse, underground
Preconditions	Assumptions and preconditions for the present scenario: Climate conditions as registered in past emergency declaration (2012) and past floods (1992). Knowledge of the territory through GIS data. Knowledge of the available communication channels. Written procedures describing who is going to do what and when and how.
Critical infrastructures	Critical infrastructures involved in this case scenario in the chosen area: Via del Romito and Via delloStatuto, two streets which are crucial for commuting between the North of Florence, the avenues' ring, and the historical downtown. We notice that national railways which border the north of the area, are supra-elevated and then relatively protected from a 30-years class flood – Railways authorities are responsible for the maintenance of their strongholds.
Risks on service disruptions and alternatives	Considering that a 30-years flood is likely to have a few hours evolution, the Florence Civil Protection has the power to shut down public and private commuting. Residual, emergency traffic can be redirected towards South of the railways stronghold, if flood is circumscribed. Once the flood is terminated, authorities may grant emergency access from the hillside of Florence (Via Faentina and related minor old narrow paths).

<table>
<tr><td>Data elements</td><td colspan="3">Data elements supporting resilience in relation to addressed scenario:
inhabitants
5.600 families geo-referenced
1.784 over-75 years old inhabitants
34 registered disabled, fragile people
Kindergarten and 2 Schools
retirement homes
1 day-time center for elderly people
137 shops, bars and similar
pharmacies
4.627 parking lots
Garden area
Churches and theatres
schools</td></tr>
<tr><td>Data flows</td><td colspan="3">Data flows in relation to above described data elements:
Data related to inhabitants are taken from the Demographics Information System of the Municipality, then geo-referred to the Street Number database.
Other data are taken from other public or private bodies and associations or from the city Open Data. Data related to local transport buses are managed by the ATAF Automatic Vehicle Management system.</td></tr>
<tr><td>(Current) Systems</td><td colspan="3">The emergency mitigation process at the moment is mainly based on a collection of written procedures and a set of activities carried out mainly by the Civil Protection department, the Mobility Department, and the Local Police department.
Particular attention is paid to:
- early information to commuters
- early warning to residents
- prompt reaction on the streets
- prompt adoption of acts to modify and adapt traffic routes
- consequent communications to citizens, as well as to interested mobility actors (bus local transport authority, etc)</td></tr>
<tr><td>Evolution of the mitigation systems within RESOLUTE</td><td colspan="3">The RESOLUTE project is promoting deeper synergies among the Mobility, Civil Protection and the IT department, in all the different phases of an emergency.
A more aware and more structured usage of data will be possible thanks to RESOLUTE approach, and the City is expecting to organize a wider set of data sources, and of output communication digital channels through which population can be more effectively alerted.
Synergies among traffic monitoring and control systems and prompt communication to the city will also be achieved.
A deeper awareness and knowledge of the involved stakeholders will also be achieved through RESOLUTE game-based training solutions.</td></tr>
<tr><td colspan="4">ERMG operationalization</td></tr>
<tr><td rowspan="2">ANTICIPATE</td><td>Function</td><td>Already existing (+)/ Possible improvements through RESOLUTE approach (-)</td><td>Description of the application of the Guidelines</td></tr>
<tr><td>Develop Strategic Plan</td><td>+</td><td>The City of Florence has a strategic urban development planning, implying a transition towards increasing sustainability and liveability. Civil Protection plans are adopted by the Mayor and the Deputy Mayors. A Smart City Plan has been adopted in order to create a comprehensive vision of the city of tomorrow with sustainable mobility, energy consumption, and security.</td></tr>
</table>

			Resilience is a key part of this Smart City Plan, allowing also for a better coordination among Civil Protection and Mobility strategies.
	Manage financial affairs	+	The City of Florence budget covers also Civil Protection planned resources. There is the possibility to fund also sudden emergencies.
	Perform Risk Assessment	+	The Civil Protection of the City of Florence is able to coordinate competences, expertise, and inputs from many scientific bodies and administrations, in order to perform a city-wide risk assessment including mobility and urban transport systems. Other transport authorities manage their own assets and related risks are estimated and assessed by their supervision.
	Training staff	+	The City has a training office and training activities in every department are carried out periodically. Civil Protection employees receive a specific training, and mobility department is composed of very skilled people mainly coming from transport management and civil engineering studies.
	Coordinate Service delivery	+	Each public utility (bus company, taxi companies, car-sharing companies) have its own. The City Mobility Division and the City Police have their capacity of monitoring ordinary traffic. During emergency, the emergency coordination center dispatches guidelines and traffic configuration rules for the different mobility actors of Florence.
	Manage awareness & user behaviour	-	People awareness and stakeholders' skills and behaviour will be improved under Resolute experience through simulations, public meetings, citizens' involvement, education and dissemination. A main event has been on May 28th 2016 – the Civil Protection Exercise of a possible Mugnone stream flooding.
	Develop/update procedures	-	The City of Florence has already several documented procedures for civil protection under different risks, including hydro-geological risk. Thanks to the RESOLUTE project, and to the consequent improved synergies among Mobility, Civil Protection, and IT, the documented procedures and inter-division cooperation within the City Administration will be significantly better-off. Multi-channel communication to citizens and the general public will also be structured on a more systematic approach.
	Manage human resources	+	Civil protection is managed through a specific approach for managing human

			resources: working shifts, attention to stress and team-working are particularly taken into account. Under emergency (such as the one of this scenario) employees are under a special authorised overtime working framework.
	Manage ICT resources	-	The City of Florence Information System is managed continuously on a regular basis. The main assets are remotely reachable and several activities during an emergency can be done remotely via VPN connections. IT assets from the Municipality and from the Local Transport Authorities are managed also with regards to business continuity under special circumstances. By considering the ICT resources as an asset to be used under emergency to improve the effectiveness of the responding operations would significantly help the city workforce.
	Maintain physical/cyber infrastructure	+	The City of Florence IT and Technical Services departments take care of the municipality infrastructure, while public utilities and other local transport authorities (ATAF, Li-nea, ServiziallaStrada, Silfi) manage their own infrastructures and are able to activate working teams or external partners on the streets with extra-ordinary maintenance cases.
MONITOR	**Function**	**Already existing (+)/ Possible improvements through RESOLUTE approach (-)**	**Description of the application of the Guidelines**
	Monitor Safety and Security	-	Several initiatives are carried out within RESOLUTE to improve the knowledge of the territory through digital infrastructures (traffic sensors, WiFi public hotspots, cameras and other devices, information gathered by internal information systems).
	Monitor Operations	+	Operations of each UTS are monitored through the respective supervision system.
	Monitor Resource availability	+	UTS resources are monitored through the respective supervision system, where transport service delivery is also tracked
	Monitor user generated feedback	-	Thanks to RESOLUTE game-based training and dissemination initiatives, user risk awareness and best practices will be improved
RESPOND	**Function**	**Already existing (+)/ Possible improvements through RESOLUTE approach (-)**	**Description of the application of the Guidelines**

	Coordinate emergency actions	+	The City of Florence Civil Protection Authority is organized and structured. Decision-process is performed by trained members of the City Emergency "Crisis Unit".
	Restore/Repair operation	+	Mobility department, the local Police Authority, and the public utilities (mainly those managing local transport and streets) are in charge for restoring the operation of the city UTS.
LEARN	**Function**	**Already existing (+)/ Possible improvements through RESOLUTE approach (-)**	**Description of the application of the Guidelines**
	Collect event information	-	Under RESOLUTE input, an improved knowledge of the territory and of people flows under emergency is expected, also thanks to the tools created in RESOLUTE by the University of Florence
	Provide adaptation & improvement insights	-	Under RESOLUTE input, improvement insight are already produced, to be shared with the City Management, the political bodies, the media, the general public and the different emergency stakeholders. After the scenario simulation, a collection of lessons learned and critical success factors will be very useful for adapting and improving current behaviours and procedures.

The main improvements provided by ERMG implementation in the Florence scenario can be summarized as follows (for each function category):

Table 5: Existing system resilience without ERMG

FUNCTIONS MOST AFFECTED BY ERMG IMPLEMENTATION	EXPECTED PERFORMANCE FOLLOWING THE EVENT ACCORDING TO THE USE CASE SCENARIO
ANTICIPATE: Develop update procedures	Operational procedures in the City of Florence for emergency are already of high-quality and provide several details. However, a better integration among the forces acting on the city mobility in case of emergency would significantly improve the effectiveness of procedures and the preparation of emergency operations during regular functional time.
ANTICIPATE: Manage ICT Resources	ICT resources are usually managed with a vertical point of view: ICT people manage their resources for offering services during regular functional time, ICT people of UTS manage the corresponding systems

FUNCTIONS MOST AFFECTED BY ERMG IMPLEMENTATION	EXPECTED PERFORMANCE FOLLOWING THE EVENT ACCORDING TO THE USE CASE SCENARIO
	during regular functional time. It is important to see at the ICT infrastructure – even the one monitoring and controlling UTS - not only as an asset to be kept under business continuity during emergency, to guarantee a minimum of service, but also as an opportunity to be used actively to collect data and events during the emergency situation.
MONITOR: Monitor Safety and security	A deeper knowledge of the territory, of traffic conditions, and of people presence in the areas affected by the emergency will help cities to improve their effectiveness during the respond phase, and will provide civil protection and UTS managers with more info on the current city conditions.

Table 6: Most important improvements of system resilience with ERMG implementation

FUNCTIONS MOST AFFECTED BY ERMG IMPLEMENTATION	EXPECTED PERFORMANCE FOLLOWING THE EVENT ACCORDING TO THE USE CASE SCENARIO
ANTICIPATE: Develop update procedures	The adoption of an holistic approach to resilience, provided by the ERMG implementation, allows the inclusion of new topics, evaluations, and corresponding tasks within the existing operational procedures that regulate emergency response in a city UTS. A massive involvement and integration of IT, mobility, local police and civil protection people and activities is a key success factor in the coordination of the various procedures performed under emergency.
ANTICIPATE: Manage ICT Resources	ICT resources, if evaluated during an Anticipate phase of ERMG implementation, need to be considered as a strategic asset for the monitoring of the city traffic and citizens conditions under emergency. Usage of bigdata, database integration, provision of realtime data with an option to made them accessible even with no network or power supply conditions, are examples of a useful ERMG improvement when considering the managing of ICT resources.
MONITOR: Monitor Safety and security	Not only video-surveillance systems can be considered with a holistic approach provided by ERMG adoption: the city territory need to properly known, updated, and monitored during quite conditions as well as during emergency. Citizens need to be monitored both for evacuation purposes and for assistance to disabled people. Even new types of sensors can be considered to monitor safety and security and the corresponding

FUNCTIONS MOST AFFECTED BY ERMG IMPLEMENTATION	EXPECTED PERFORMANCE FOLLOWING THE EVENT ACCORDING TO THE USE CASE SCENARIO
	mobility procedures to support this function. Mobile phones, digital signage, and WiFi hotspots and smart objects (such as lightpoles) can become sensors to monitor the situation and channels to deliver alerts to citizens. All this functional requirements need to be taken into account and properly accounted for and tested in the Monitor phase of the ERMG adoption.

8 CONCLUSIONS

What we can notice from all previous work done, within the scope of RESOLUTE deliverable D3.7, is that to create resilient Urban Transport Systems a multidimensional perspective and approach is needed, considering interconnections among different UTS stakeholders and activating at the same time the whole network dynamics to respond timely and effectively in emergencies. This is due to the fact that cities and urban areas represent dense and complex systems of interconnected services and different perspectives and level of understanding among involved stakeholders.

Although, examples from recommendations given in Chapter 5, show that there is actually progress in the field of urban transport resilience, a horizontal approach with holistic guidance to avoid critical UTS emergencies is still missing.

Firstly, it is necessary to identify the drivers of urban transport risks in order to understand them and enhance UTS preparedness following the provided recommendations and towards developing transport disaster resilient systems. To do so, a proper UTS management and coordination among transport related stakeholders is needed, involving civil society and building urban alliances, while ensuring that all actors understand their role in transport risk reduction and preparedness. Towards this target some indicative prerequisites are:

- clear procedures and guidance for UTS resilience,
- budget assigned for UTS resilience management,
- maintenance of up to date data on hazards and vulnerabilities,
- guidance on prioritizing human resource and budget allocation,
- proper connectivity and communications services,
- policies,
- educational and training programs along with awareness campaigns.

By addressing UTS emergency events (based on scenarios) that arise from natural hazards or human intervention and may threaten the operations and/or physical infrastructure of the UTS, the aim is to create sufficient capacities to deal with these emergencies. When it comes to anticipating, managing and/or reducing actual or potential risks, guidance is needed for setting up and/or acting based on early warning systems and establishing specific UTS crisis management structures.

This deliverable provides guidance and recommendations considering all the above and insights to establish the proper resilient UTS organizational and monitoring framework for European resilient transport systems and European urban areas liveable and sustainable.

9 REFERENCES

Bibliography

AEMC, 2002. National Good Practice Review of Public Awareness, Education and Warnings in Emergency Management - High Level Group of the COAG Review of Natural Disaster Relief and Mitigation Arrangements, Australian Emergency Management Committee ,unpublished draft

Natvig B.,2011. “Measures of component importance in nonrepairable and repairable multistate strongly coherent systems,” Methodology and Computing in Appl. Probabil., vol. 13, no. 3, pp. 523–547, 2011

Adjetey-Bahun K., Birregah B., Châtelet E, Planchet J-L.,2016. A model to quantify the resilience of mass railway transportation systems, Reliability Engineering and System Safety 153 (2016) 1–14

Adjetey-Bahun K., Birregah B., Chatelet E., Planchet J.-L., 2014. A simulation-based approach to quantifying resilience indicators in a mass transportation system. In: Proceedings of the 11th international ISCRAM conference, University Park, Pennsylvania; 2014

AG,2011. Organizational Resilience. Australian Government position paper (2011). ISBN: 978-1-921725-62-3, Available online:< http://www.emergency.qld.gov.au/publications/pdf/organisational_resilience.pdf>

Albert R, Barabási AL., 2002. Statistical mechanics of complex networks. Rev Mod Phys 2002;74:47–97

Alexander, David E., 2014. "Social media in disaster risk reduction and crisis management." Science and engineering ethics 20.3 (2014): 717-733.

APCICT , 2010. Communication Technology for Development (APCICT), ICTD Case Study 2, May 2010

Ash J, Newth D., 2007. Optimizing complex networks for resilience against cascading failure. Phys: Stat Mech Appl 2007;380:673–83

Ash J, Newth D., 2011. Optimizing complex networks for resilience against cascading failure. Physica A: Stat Mech Appl 2007;380:673–83; | Ip W, Wang Q. Resilience and friability of transportation networks: evaluation, analysis and optimization. IEEE Syst J 2011;5(2):189–98

ASME, 2009. Innovative Technological Institute (ITI). American Society of Mechanical Engineers (ASME). Washington, D.C.: ASME ITI, LLC; 2009.

Asprone, D., Cavallaro, M., Latora, V., Manfredi, G., Nicosia, V., 2013. “Assessment of urban ecosystem resilience using the efficiency of hybrid social-physical complex networks”, in Computer-aided Civil and Infrastructure Engineering 29, February 2013

Australian Government,2010. Critical Infrastructure Resilience Strategy, Commonwealth of Australia, ISBN: 978-1-921725-25-8

Avvenuti, Marco, et al., 2015. "Pulling information from social media in the aftermath of unpredictable disasters." 2nd international conference on information and communication technologies for disaster management (ICT-DM). 2015.

Baroudi, B., & Rapp, R., 2013. Disaster Restoration Projects: A Conceptual Project Management Perspective. In Australasian Journal of Construction Economics and Building-Conference Series (Vol. 1, No. 2, 72-79).

Bevan, N., 1995. Human-Computer Interaction Standards. In Anzai & Ogawa (eds.). Proceedings of the 6th International Conference on Human Computer Interaction, Yokohama, July 1995, Elsevier.

Bevan, N.,1995. Human-Computer Interaction Standards. In Anzai & Ogawa (eds.). Proceedings of the 6th International Conference on Human Computer Interaction, Yokohama, July 1995, Elsevier.

Boccaletti S., Bianconi G., Criado R., del Genio C. I., Gmez-Gardees J., Romance M., Sendia-Nadal I., Wang Z., Zanin M.,2014. The structure and dynamics of multilayer networks, Phys. Rep. 544, 1, 2014

Brown, K., 2015. Global environmental change I: a social turn for resilience? Prog. Hum. Geogr. 38, 107–117 (2014)

Brown, K.,2014.: Global environmental change I: a social turn for resilience? Prog. Hum. Geogr. 38, 107–117 (2014)

BS OHSAS 18001 - Occupational Health and Safety Management (OHS), OHSAS 180001 http://www.bsigroup.com/en-GB/ohsas-18001-occupational-health-and-safety/>

BSI, 2014. Guidance on organizational resilience, ISBN 9780580779497

Bush et al, 2005. Critical Infrastructure Protection Decision Support System –Intentional System Dynamics Conference 2005

Cardillo A., Zanin M., Gómez-Gardeñes J., Romance M., García del Amo A. J., Boccaletti S.,2013. Modeling the multi-layer nature of the european air transport network: Resilience and passengers re-scheduling under random failures, Eur. Phys. J. Spec. Top. 215, 23, 2013.

Caschilli, S., Medda, F.R., Wilson, A., 2015."An Interdependent Multi-Layer Model: Resilience of International Networks", Netw Spat Econ (2015), 15, 313-335.

CGI,2013. "Developing a Framework to Improve Critical Infrastructure Cybersecurity", 2013

Chen A, Yang C, Kongsomsaksakul S, Lee M., 2014. Network-based accessibility measures for vulnerability analysis of degradable transportation networks. Netw Spat Econ 2007;7(3):241–56). (Ouyang M, Zhao L, Hong L, Pan Z. Comparisons of complex network based models and real train flow model to analyze chinese railway vulnerability. Reliab Eng Syst Saf 2014;123:38–46

Chen L, Miller-Hooks E., 2012. Resilience: an indicator of recovery capability in intermodal freight transport. Transp Sci 2012;46(1):109–23

CIRS, 2010. CRITICAL INFRASTRUCTURE RESILIENCE STRATEGY, ISBN: 978-1-921725-25-8

Clay-Williams et al.2015. Where the rubber meets the road: using FRAM to align work-as-imagined with work-as done when implementing clinical Implementation Science (2015) 10:125 DOI 10.1186/s13012-015-0317-y

Conrad L. Dudek,2004. "Changeable Message Sign Operation and Messaging Handbook", Operations Office of Travel Management, ederal Highway Administration, U.S. Department of Transportation, 2004

Council of the European Union, 2008. Council Directive on the identification and designation of European critical infrastructures and the assessment of the need to improve their protection, (2008/114/EC)

Crawford, L., Langston, C., & Bajracharya, B., 2013. Participatory project management for improved disaster resilience. International Journal of Disaster Resilience in the Built Environment, 4(3), 317-333.

Cupac V, Lizier JT, Prokopenko M., 2013. Comparing dynamics of cascading failures between network-centric and power flow models. Electr. Power Energy Syst 2013;49:369–79

CWIN, 2008. Critical Infrastructure Warning Information Network –CWIN http://ec.europa.eu/dgs/home-affairs/what-we-do/networks/critical_infrastructure_warning_information_network/index_en.htm

DARWIN Project, 2015. D1.1 Version 0.6: Consolidation of resilience concepts and practices for crisis management.

De Domenico M., Solé-Ribalta A., Cozzo E., Kivelä M., Moreno Y., Porter M., Gómez S. A, Arenas A., 2013. Mathematical Formulation of Multilayer Networks, Phys. Rev. X 3, 041022, 2013

De Domenico M., Solé-Ribalta A., Gómez S., Arenas A., 2014. Navigability of interconnected networks under random failures, Proc. Natl. Acad. Sci. U.S.A. 111, 8351, 2014

DHS, 2006. U.S. Department of Homeland Security,National Infrastructure Protection Plan, 2006. Available online at: www.dhs.gov/nipp.

DHS, 2008. NIAC Insider Threats to Critical Infrastructure Study (2008) < https://www.dhs.gov/xlibrary/assets/niac/niac_insider_threat_to_critical_infrastructures_study.pdf>

DMBC, 2010. Recovery Plan. Contingency and disaster management. Dudley Metropolitan Borough Council (2010).

Doran, G. T., 1981. "There's an S.M.A.R.T. way to write management's goals and objectives". Management Review (AMA FORUM) 70 (11): 35–36

Dorbritz R., 2011. Assessing the resilience of transportation systems in case of large-scale disastrous events. In: Proceedings of the eighth international conference on environmental engineering, Vilnius, Lithuania; 2011. p. 1070–1076

Dugundji, E., Walker, J., 2014. Discrete Choice with Social and Spatial Network Interdependencies: An Empirical Example Using Mixed Generalized Extreme Value Models with Field and Panel Effects. Transportation Research Record: Journal of the Transportation Research Board , Volume 1921, pp. 70–78

Duque, P. A. M., Dolinskaya, I. S., & Sörensen, K., 2016. Network repair crew scheduling and routing for emergency relief distribution problem. European Journal of Operational Research, 248(1), 272-285.

EC, 2012. Action Plan on Urban Mobility – State of Play, European Commission, 2012. < http://ec.europa.eu/transport/themes/urban/urban_mobility/doc/apum_state_of_play.pdf >

EEMUA , 2002. Engineering Equipment & Materials Users Association (EEMUA) Publication 201: 2002 available via EEMUA on 020 7628 7878

EmerGent, 2014. Deliverable 3.1 "usage Patterns of Social Media in emergencies", EU-FP7-SEC project EmerGent (Emergency Management in Socia Media Generation), available at: http://www.fp7-emergent.eu/wpcontent/uploads/2014/09/D3.1_UsagePatternsOfSocialMediaInEmergencies.pdf

Environmental Impact Assessment Directive, 1985 (85/337/EEC)

Ernst &Young, 2013.ORGANISATIONAL RESILIENCE: The relationship with Risk related corporate strategies, An analysis by Ernst and Young and the Commonwealth Attorney-General's Department.

EU, 2010. Commission Staff Working Paper 1626-2010. Risk Assessment and Mapping Guidelines for Disaster Management. The European Commission

EU, 2012. Commission staff working document on the review of the European programme for critical infrastructure protection (EPCIP), SWD (2012)190 final

EU, 2013. Commission staff working document on a new approach to the European Programme for Critical Infrastructure Protection Making European Critical Infrastructures more secure, SWD(2103)318 final

EU,2006.. Communication from the Commission on a European Programme for Critical Infrastructure Protection, COM(2006)786 final

EU,2008. Proposal for a Council Decision on a Critical Infrastructure Warning Information Network (CIWIN), COM (2008)676 final

EU,2014.Handbook on European data protection law. European Union Agency for Fundamental Rights, 2014 Council of Europe, 2014. <http://www.echr.coe.int/Documents/Handbook_data_protection_ENG.pdf>

EUROCONTROL, 2013. From Safety-I to Safety-II: A White Paper. European Organisation for the Safety of Air Navigation (EUROCONTROL) < http://www.skybrary.aero/bookshelf/books/2437.pdf>

EUROCONTROL,2014. System Thinking for Safety: Ten Principles – Moving towards Safety –II, August 2014 – European Organisation for the Safety of Air Navigation (EUROCONTROL) < http://www.skybrary.aero/bookshelf/books/2882.pdf>

Fang Y., Pedroni N., Zio E., 2016. Resilience-Based Component Importance Measures for Critical Infrastructure Network Systems, IEEE TRANSACTIONS ON RELIABILITY 2016

Fekete, A., Tzavella, K., Armas, I., Binner, J., Garschagen, M., Giupponi, C., Mojtahed, V., Pettita, M., Schneiderbauer, S., Serre, D., 2015. "Critical Data Source; Tool or Even Infrastructure? Challenges of Geographic Information Systems and Remote Sensing for Disaster Risk Governance", ISPRS Int. J. Geo-Inf. 2015, 4(4), 1848-1869.

FEMA, 2011. National disaster recovery framework: Strengthening disaster recovery for the nation. https://www.fema.gov/pdf/recoveryframework/ndrf.pdf (Mar. 24, 2016)

Ferreira, P., Simoes, A., 2015. State of the art review. RESOLUTE Deliverable 2.1.

Ferreira, P., Simoes, A., 2016. Conceptual Framework. RESOLUTE Deliverable 2.2.

FETSM, 1999. Fields of Education and Training Supplementary Manual 1999 (Statistical office of the European Communities-EUROSTAT)

Fiskel J., 2015. "Connecting with Broader Systems", Resilient by design, (2015), 191-208

Freeman L. C., 1979. "Centrality in social networks conceptual clarification,"Social Networks, vol. 1, no. 3, pp. 215–239, 1979

Freeman L. C., Borgatti S. P., White D. R.,1991. "Centrality in valued graphs: A measure of betweenness based on network flow," Social Networks, vol. 13, no. 2, pp. 141–154, 1991

FY, 2013. US. HUMAN CAPITAL MANAGEMENT PLAN. Department of Energy. http://energy.gov/sites/prod/files/2013/05/f0/OCIOWorkforcePlan.pdf.

Gaitanidou, E., Bekiaris, E., 2015. Guidelines Methodology. RESOLUTE Deliverable 3.4

Gaitanidou, E., Bellini, E., 2016. European Resilience Management Guidelines. RESOLUTE Deliverable 3.5

Gander, Philippa, et al., 2011. "Fatigue risk management: Organizational factors at the regulatory and industry/company level." Accident Analysis & Prevention 43.2 (2011): 573-590.

Gao, J., Liu, X., Li, D., Havlin, S., "Recent Progress on the Resilience of Complex Networks", Eergies 2015, 8, 12187-12210.

GFDRR, 2014. Financial Protection Against Natural Disasters, An Operational Framework for Disaster Risk Financing and Insurance, World Bank report, 2014. <https://olc.worldbank.org/sites/default/files/Financial%20Protection%20Against%20Natural%20Disasters.pdf>

Gomes, L., 1990. Modelling interdependencies among urban transportation system alternatives within a multi-criteria ranking framework, Journal of Advanced Transportation, Volume 24, Issue 1, pages 77–85, Spring 1990

Gustin, J., 2007. Safety Management: A guide for facility managers. CRC Press

Haimes YY., 2009. On the definition of resilience in systems. Risk Anal 2009;29 (4):498–501

HAZUS-MH, 2004. HAZUS-MH Software Programme for Estimating Potential Losses from DisastersFederal Emergency Man. Agency, Washington, DC (2004)

Hernandez-Fajardo I, Duenas_Osorio L., 2013. Probabilistic study of failures in complex interdependent lifeline systems. Reliab Eng Syst Saf 2013;111:260–72

Hines P. and Blumsack S.,2008."A centrality measure for electrical networks," in Proc. IEEE 41st Annu. Hawaii Int. Conf. Syst. Sci., Jan. 2008, pp. 185–185

Hoegl, Martin, and Hans Georg Gemuenden, 2001. "Teamwork quality and the success of innovative projects: A theoretical concept and empirical evidence." Organization science 12.4 (2001): 435-449.

Hollnagel E.,2013. An Application of the Functional Resonance Analysis Method (FRAM) to Risk Assessment of Organizational Change. Report number: 2013:09, ISSN 2000-0456

Hollnagel, E. et al, 2013.From Safety-I to Safety-II: A White Paper EUROCONTROL 2013

Hollnagel, E., 1998. Cognitive Reliability and Error Analysis Method – CREAM. Oxford: Elsevier Science.Oedewald, P et al – Intermediate report MoReMo Modelling Resilinece for Mantainance and Outage – NKS-262 – ISBN 979-87-7893-335-5 Feb 2012

Hollnagel, E., 2004. Barriers and accident prevention. Aldershot, UK: Ashgate.

Hollnagel, E., 2009. The four cornerstones of resilience engineering. In: Nemeth, C. P., Hollnagel, E. & Dekker, S. (Eds.), Preparation and restoration (p. 117-134). Aldershot, UK: Ashgate.Ferreira, P., Simoes, A., (2016). Conceptual Framework. RESOLUTE Deliverable 2.2.

Hollnagel, E., 2014. Safety-I and Safety-II: the past and future of safety management. Ashgate

Homeland Security, 2015. National Critical Infrastructure Security and Resilience Research and Development Plan.

Hosseini S., Barker K.,. Ramirez-Marquez J. ,2016. A review of definitions and measures of system resilience, Reliability Engineering and System Safety 145 (2016) 47–61.

HSE,1997. Successful Health and Safety Management - Health and Safety Executive. Publication HS(G)65 (1997).

Hubbard, D., 2014. How to Measure Anything: Finding the Value of Intangibles in Business. Wiley.

HVHF , 2007. High Velocity Human Factor (HVHF) – High Velocity Human Factors: Human Factors of Mission Critical Domains in Nonequilibrium Proceedings of the Human Factors and Ergonomics Society Annual Meeting October 2007 51: 273-277, doi:10.1177/154193120705100427.

ICT for Disaster Risk Reduction - The Indian Experience, Ministry of Home Affairs, National Disaster Management Division Government of India

IETF, 2007. Delay-Tolerant Networking Architecture, IETF, RFC 4838 <https://tools.ietf.org/html/rfc4838>

IFRC, 2011. International Federation of Red Cross and Red Crescent Societies (2011) Public awareness and public education for disaster risk reduction: a guide

Institute of Medicine, 2002. Speaking of Health, Washington D.C., The National Academies Press.

ISDR,2006. Developing Early Warning Systems: A Checklist – International Strategy for Disaster Reduction – ISDR 2006

ISO 22301:2012, Societal security- Business continuity management systems- Requirements < http://www.iso.org/iso/catalogue_detail?csnumber=50038>

ISO 22320:2011, Societal security – Emergency management – Requirements for incident response

ISO 31000: Risk management – Principles and guidelines

Jassbi, J., Camarinha-Matos, L.M., Barata, J., “A Framework for Evaluation of Resilience of Disaster Rescue Networks”, in L.M. Camarinha-Matos et al. (Eds.): PRO-VE 2015, IFIP AICT 463, pp. 146–158, 2015.

Jenelius E., Petersen T. , Mattsson L. G. ,2006. “Importance and exposure in road network vulnerability analysis,” Transportation Res. A: Policy and Practice, vol. 40, no. 7, pp. 537–560, 2006

Johansson J, Hassel H., 2010. An approach for modelling interdependent infrastructures in the context of vulnerability analysis. Reliab Eng Syst Saf 2010;95 (12):1335–44

Jokeren, O., Azzini, I., Galbusera, L., 2015. “Analysis of Critical Infrastructure Network Failure in the European Union A combined Systes Engineering and Economic Model”, Netw Spat cEcon (2015), 15:253-270.

Kangaspunta, J., Salo, A., 2014. “A Resource Allocation Model for Improving the Resilience of Critical Transportation Systems”, (2014) available at https://www.google.it/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0ahUKEwix8MGiv-PLAhVIzRQKHeJwALcQFggeMAA&url=http%3A%2F%2Fsal.aalto.fi%2Fpublications%2Fpdf-files%2Fmkan14.pdf&usg=AFQjCNE-hfNMSKsL7KPFur0C92aI3vzhyg&sig2=_0m2KeH8mD_g6h4JSmLRgQ

Kappos A., Sextos, A., Stefanidou, S, Mylonakis, G. Pitsiava, M. Sergiadis, G., 2014. Seismic Risk of Inter-urban Transportation Networks. 4th International Conference on Building Resilience, Incorporating the 3rd Annual Conference of the ANDROID Disaster Resilience Network, 8th – 11th September 2014, Salford Quays, United Kingdom. In Proceedia Economics and Finance, Volume 18, 2014, pp 263.270

Karen M., 2013. Adaptive self-deployment algorithms for mobile wireless substitution networks. Networking and Internet Architecture [cs.NI]. Université des Sciences et Technologie de Lille - Lille I

Karwowski, W., 2005. Handbook of Standards and Guidelines in Ergonomics and Human Factors. New Jersey: Lawrence Erlbaum Associates, Publishers.

Kasthurirangan, Gopalakrishnan, Srinivas, Peeta, 2010. Sustainable and Resilinect Critical Infrastrucutre System A framework for Manifestation of Tacit Critical Infrastructure Knowledge: Simulation, Modelling and Intelligent Engineering - Springer 2010

Khaled AA, Jin M, Clarke DB, Hoque MA.,2015. Train design and routing optimization for evaluating criticality of freight railroad infrastructures. Transp Res B 2015;71:71–84

Kivelä M., Arenas A., Barthelemy M., Gleeson J. P., Moreno Y., Porter M. A., 2014. Multilayer networks, J. Complex Netw. 2, 203, 2014

Koc Y, Warnier M, Kooij RE, Brazier FMT, 2013. An entropy-based metric to quantify the robustness of power grids against cascading failures. Saf Sci 2013;59:126–34

Kochs, A., & Marx, A., 2009. Innovatives Instandhaltungsmanagement mit IDMVU, Leitfaden Teil 1 Überblick Gesamtprozess. Forschungsvorhaben Infrastruktur-Daten-Management für Verkehrsunternehmen (IDVMU).

Kröger W. and Zio E.,2011. Vulnerable Systems. Berlin, Germany: Springer, 2011

Kyriakides, E., Polycarpou, M.,2015. “Intelligent Monitoring, Control, and Security of Critical Infrastructure Systems”, Springer 2015, ISBN 978-3-662-44159-6

Labaka, L., Hernantes, J., Sarriegi J.M.,2016. “A holistic framework for building critical infrastructure resilience”, Technological Forecasting & Social Change, 103, (2016), 21-33.

Latora V. and Marchiori M., 2007. “A measure of centrality based on network efficiency,” New J. Phys., vol. 9, no. 6, p. 188, 2007

Lazari, A., 2014. “European Critical Infrastructure Protection”, Springer Cham Heidelberg New York Dordrecht London, 2014.

Lindell, M. K., 2013. Recovery and reconstruction after disaster. In Encyclopedia of natural hazards (pp. 812-824). Springer Netherlands.

Macdonald, J, 1998. Primary Health Care, Medicine in its place. London: Earthscan Publications Ltd

Merk, O., 2014, “Metropolitan Governance of Transport and Land Use in Chicago”, OECD Regional Development Working Papers, 2014/08, OECD Publishing. http://dx.doi.org/10.1787/5jxzjs6lp65k-en

Mucha P. J., Richardson T., Macon K., Porter M. A, Onnela J.-P.,2010. Community structure in time-dependent, multiscale, and multiplex networks, Science 328, 876, 2010

Nagurney A, Qiang Q., 2007.A network efficiency measure for congested networks. Europhys Lett 2007;79; | Nagurney A, Qiang Q. Robustness of transportation networks subject to degradable links. Europhys Lett 2007;80

NATO,2012. RTO Technical Report TR-SAS-059 Human Resources (Manpower) Management < http://natorto.cbw.pl/uploads/2012/2/$$TR-SAS-059-ALL.pdf>

NCHRP, 2013. A Pre-Event Recovery Planning Guide for Transportation, TRB report, WASHINGTON, D.C. 2013<https://www.massport.com/media/266266/Report_A-Pre-Event-Recovery-Planning-Guide-for-Transportation-2013.pdf >

NCIS, 2015. National Critical Infrastructure Security and Resilience Research and Development Plan-NCIS R&D. USA Homeland Security 2015

Newman M. E.,2005. "A measure of betweenness centrality based on random walks," Social Networks, vol. 27, no. 1, pp. 39–54, 2005

Newman M.,2010. Networks: An Introduction Oxford University Press, New York, 2010

NIAC, 2009. National Infrastructure Advisory Council (NIAC) Critical Infrastructure Resilience Final Report and Recommendations 2009

NIAC, 2014. Critical Infrastructure Security and Resilience National Research and Development Plan. National Infrastructure Advisory Council (2014)

Nicholson C., Barker K., Ramirez-Marquez J.,2016. Flow-based vulnerability measures for network component importance: Experimentation with preparedness planning, Reliability Engineering and System Safety 145 (2016) 62–73

Nieminen J., 1974."On the centrality in a graph," Scandinavian J. Psychol., vol. 15, no. 1, pp. 332–336, 1974

NIPP, 2013. Partnering for critical infrastructure security and resilience. USA: Homeland Security 2013

NORC, 2013. The Associated Press-NORC Center for Public Affairs Research (2013) Communication during disaster response and recovery.

NRF, 2008. National Response Framework. United States Department of Homeland Security. (2008). <http://www.fema.gov/pdf/emergency/nrf/nrf-core.pdf >

O'Neil LR et.al, 2015. US DOE - SPSP Phase III Recruiting, Selecting, and Developing Secure Power Systems Professionals: Behavioural Interview Guidelines by Job Roles < http://www.pnnl.gov/main/publications/external/technical_reports/PNNL-24140.pdf>

OECD, 2013. Disaster Risk Financing in APEC Economies, Practices and Challenges <https://www.oecd.org/daf/fin/insurance/OECD_APEC_DisasterRiskFinancing.pdf>

OECD, 2014. Guidelines for resilience systems analysis, OECD Publishing

Omer M, Mostashari A, Lindemann U.,2014. Resilience analysis of soft infrastructure systems. Procedia Comput Sci 2014;28:565–74

OSHAS 18001:1999. Occupational health and safety management systems. Specifications.

Ouyang M, Duenas-Osorio L. , 2014. Multi-dimensional hurricane resilience assessment of electrical power systems. Struct Saf 2014;48:15–24

Ouyang, M.,2014. "Review on modelling and simulation of interdependent critical infrastructure systems", Reliability Engineering and System Safety, 121, (2014), 43-60.

PAHO, 2009. Information management and communication in emergencies and disasters: manual for disaster response teams. Pan American Health Organization (2009).Washington, D.C.

Pengcheng Z., Srinivas P., 2011. A generalized modeling framework to analyze interdependencies among infrastructure systems. Transportation Research Part B: Methodological, Volume 45, Issue 3, March 2011, Pages 553–579

Peter O'Neill, 2004. Developing A Risk Communication Model to Encourage Community Safety from Natural Hazards –State Emergency Service, JUNE 2004

Pollack, L.J., Simons, C., Romero, H. and Hausser, D., 2002. "A Common Language for Classifying and Describing Occupations: The Development, Structure, and Application of the Standard Occupational Classification", Human Resource Management, Vol. 41, No. 3, pp. 297-307, Fall 2002.

Pregenzer A.,2011. Systems resilience: a new analytical framework for nuclear nonproliferation. Albuquerque, NM: Sandia National Laboratories; 2011

Queensland Government, 2013. Queensland 2013 Flood Recovery Plan for the events of January– February 2013. <http://www.statedevelopment.qld.gov.au/resources/plan/local-government/lg-flood-recovery-plan.pdf>

Ramachandran, V., Long, S., Shoberg, T., Corns, S., & Carlo, H., 2016. Post-disaster supply chain interdependent critical infrastructure system restoration: A review of data necessary and available for modelling. Data Science Journal, 15.

Reggiani A., 2013. Network resilience for transport security: some methodological considerations. Transp Policy 2013;28:63–8

Richard A. Caralli, Julia H. Allen, David W. White., 2011. "The CERT resilience management model : a maturity model for managing operational resilience", ISBN 978-0-321-71243-1, Pearson Education, 2011

Rodriguez-Nunez E, Garcia-Palomares JC., 2014. Measuring the vulnerability of public transport networks. J Transp Geography 2014;35(1):50–63

Rodrigue, J-P *et al,*. 2017. The Geography of Transport Systems. Hofstra University, Department of Global Studies & Geography, http://people.hofstra.edu/geotrans.

Sabidussi G., 1994. "The centrality index of a graph," Psychometrika, vol. 31, no. 4, pp. 581–603, 1966

Schupp, B.A., Zaccardo, A., Nordvik, J.-P. ,2006. Estimation Of Incidence Of Terrorist Attacks Involving Road Transport Based On Open Source Data, Institute for the Protection and Security of the Citizen, EUR 22472 EN

SEI, 2010. Strategic Planning with Critical Success Factors and Future Scenarios: An Integrated Strategic Planning Framework Linda Parker Gates November 2010, TECHNICAL REPORT CMU/SEI-2010-TR-037 ESC-TR-2010-102

Shah, J., 2009. Supply chain management: text and cases. Pearson Education India.

Sheffi Y., 2005. The resilience enterprise: overcoming vulnerability for competitive enterprise. Cambridge, MA: MIT Press; 2005.

Simon, H.A.,1979. Rational decision Making in business organization. American Economic Review 69 (4), 493-513 (1979)

Sodhi, M., Tang, C., 2012. Managing Supply Chain Risk. Springer

Solé-Ribalta A., Gómez S., Arenas A.,2016. Congestion Induced by the Structure of Multiplex Networks, Physical Review Letters 116, 108701, 2016

Staal, Mark A., 2004. Stress, Cognition, and Human Performance: A Literature Review and Conceptual Framework. NASA/TM—2004–212824. Ames Research Centre Moffett Field, California 94035. Website: http://human-factors.arc.nasa.gov/flightcognition/Publications/IH_054_Staal.pdf

Sterbenz JPG et al., 2010. Resilience and survivability in communication networks: strategies, principles, and survey of disciplines. Comput Netw 2010;54:1245–65

Stergiopoulos G., Kotzanikolaou P., Theocharidou M., Lykou G., Gritzalis D, 2016. Time-based critical infrastructure dependency analysis for large-scale and cross-sectoral failures, International Journal of Critical Infrastructure Protection, Volume 12, March 2016, Pages 46-60,

Strano E., Shai S., Dobson S., Barthelemy M.,2015. Multiplex networks in metropolitan areas: generic features and local effects, J. R. Soc. Interface 12, 2015

Su Z., Li L., Peng H., Kurths J., Xiao J., Yang Y., 2014. Robustness of interrelated traffic networks to cascading failures. Scientific Reports 2014;4:1–7. Article number: 5413

Sullivan JL, Novak DC, Aultman-Halla L, Scott DM., 2010. Identifying critical road segments and measuring system-wide robustness in transportation networks with isolating links: a link-based capacity-reduction approach. Transp Res Part A: Policy Pract 2010;44(5):323–36

TRB,2005. NCHRP Guide for Emergency Transportation Operations, Report 525, Surface Transportation Security, Volume 6.

Trucco, P., Petrenj, B., Bouchon, S., Di Mauro, C., 2015. “The rise of regional programmes on critical infrastructure resilience: identification and assessment of current good practices”, Disaster Management and Human Health Risk IV, WIT Transactions on the Built Environment, 150, (2015), 233-245.

UNISDR & GFDRR, 2015. How to make cities more resilient. A handbook for local government leaders.

Vajda, A., H. Tuomenvirta, P. Jokinen, A. Luomaranta (FMI), L. Makkonen, M. Tikanmäki (VTT), P. Groenemeijer (ESSL), P. Saarikivi (Foreca), S. Michaelides, M. Papadakis, F.Tymvios, S. Athanasatos (CYMET), 2011. Probabilities of adverse weather affecting transport in Europe: climatology and scenarios up to the 2050s. Deliverable 2.1 of the RTD-project EWENT (Extreme weather impacts on European networks of transport) funded by the EC under FP7. Project coordinator: VTT, Espoo. Online: ewent.vtt.fi

Van Brabant, K.,2015. ”Mainstreaming the Organisational Management of Safety and Security”, HPG Report 9,March 2001

VOLPE,2013. Beyond Bouncing Back: Critical Transportation Infrastructure Resilience -

Vos, M., & Sullivan, H., 2014. Community Resilience in Crises : Technology and Social Media Enablers. Human Technology, 10 (2), 61-67.

Wang J, Jiang C, Qian J., 2014. Robustness of internet under targeted attack: a cascading failure perspective. J Netw Comput Appl 2014;40:97–104

Wasserman S. and Faust K., 1994.Social Network Analysis: Methods and Applications. Cambridge, U.K., ENG: Cambridge Univ., 1994

Welsh, M., 2014. “Resilience and responsibility: governing uncertainty in a complex world”, The Geographical Journal, 180, (2014), 15-26.

White, K.J.S., Pezaros, D.P., Johnson, C.W.,2014. “Using Programmable Data Networks to Detect Critical Infrastructure Challenges”, In: 9th International Conference on Critical Information Infrastructures Security (CRITIS'14), 13-15 Oct 2014, Limassol, Cyprus.

WHO, 2012. Integrated Risk Assessment. World Health Organazization <http://www.who.int/ipcs/publications/new_issues/ira/en/>

Wu J, Barahona M, Tan Y-J, Deng H-Z., 2011.Spectral measure of structural robustness in complex networks. IEEE Trans Syst Man Cybernetics Part A: Syst Hum2011;41(6):1244–52

Xu, T., Masys, A.J., 2016. “Critical Infrastructure Vulnerabilities: Embracing a Network Mindset”, A.J. Masys (ed.) Exploring the Security Landscape: Non-Traditional Security Challenges, Advanced Sciences and Technologies for Security Applications (2016).

Yondong, Z., 2013. Social networks and reduction of risk in disasters: an example of Wenchuan earthquake. In: Yeung, W.J.J., Yap, M.T. (eds.) Economic Stress, Human Capital, and Families in Asia, vol. 4, pp. 171–182. Springer, Berlin (2013)

Zhao L., Lai Y.-C., Park K., Ye N., 2005. Onset of traffic congestion in complex networks, Phys. Rev. E 71, 026125 2005.

Zio E. and Sansavini G.,2011. “Component criticality in failure cascade processes of network systems,” Risk Anal., vol. 31, no. 8, pp. 1196–1210, 2011

Websites

http://cyborginstitute.org/projects/administration/monitoring-tactics/

http://ec.europa.eu/clima/policies/adaptation/what/docs/non_paper_guidelines_project_managers_en.pdf

http://ec.europa.eu/dgs/home-affairs/what-we-do/policies/crisis-and-terrorism/tftp/index_en.htm

http://ec.europa.eu/eurostat/documents/64157/4392716/ESS-QAF-V1-2final.pdf/bbf5970c-1adf-46c8-afc3-58ce177a0646

http://ec.europa.eu/transport/themes/urban/studies/doc/2007_urban_transport_europe.pdf

http://ec.europa.eu/transport/themes/urban/studies/doc/2007_urban_transport_europe.pdf

http://ec.europa.eu/transport/themes/urban/urban_mobility/doc/apum_state_of_play.pdf

http://emergency.cdc.gov/planning/

http://floridadisaster.org/documents/CEMP/Emergency%20Operations%20Plan.pdf

http://hrdailyadvisor.blr.com/2012/06/07/emergency-management-preparedness-what-is-hr-s-role/#sthash.kngr3C7W.dpuf

http://managementhelp.org/strategicplanning/models.htm#one

http://rahat.up.nic.in/undp/TransportSOP.pdf

http://sydney.edu.au/whs/emergency/emergency2.shtml http://www.100resilientcities.org

http://www.ijbts-journal.com/images/main_1366796758/0026-Hossein.pdf

http://www.odpm.gov.tt/sites/default/files/NEMA%20Disaster%20SOPs%20and%20Contingency%20Plans%202000.pdf

http://www.organisationalresilience.gov.au/resources/Pages/default.aspx

http://www.resolute-eu.org

http://www.sadc.int/themes/infrastructure/transport/roads-road-transport/

http://www.scidev.net/global/communication/feature/early-warning-of-disasters-facts-and-figures-1.html

https://www.dhs.gov/sites/default/files/publications/niac-transportation-resilience-final-report-07-10-15-508.pdf

https://www.fas.org/sgp/crs/homesec/RL32520.pdf

https://www.gatwickairport.com/globalassets/publicationfiles/business_and_community/regulation/economic_regulation/14-10-01-operational-resilience-report-and-monitoring-report-final-for-publication.pdf

https://www.massport.com/media/266266/Report_A-Pre-Event-Recovery-Planning-Guide-for-Transportation-2013.pdf

https://www.oecd.org/daf/fin/insurance/OECD_APEC_DisasterRiskFinancing.pdf

https://www.volpe.dot.gov/events/beyond-bouncing-back-critical-transportation-infrastructure-resilience

ANNEX A: UTS ADAPTED FUNCTIONS

<table>
<tr><td>Name</td><td>Develop Strategic Urban Transport Plan</td></tr>
<tr><td>MTO Category</td><td>Human(M) - Technology (T)- Organization (O)
Prevalent category: Organization (O)</td></tr>
<tr><td>Description</td><td>In Europe, Sustainable Urban Transport Plans (SUTPs), usually developed by Regional Transport Authorities, are in fact Strategic Urban Transport Plans. These Plans address the whole urban transport system, involve all relevant actors and stakeholders and have to comply with relevant guidelines set by the E.C.

A SUTP is developed by the responsible Transport Authority, includes a vision for urban transport and defines the long term objectives for planning transport in urban areas. Safety and security needs, access to goods and services, air pollution, noise, greenhouse gas emissions and energy consumption, land use, cover passenger and freight transportation. All modes of transport are taken into account. In terms of resilience, critical resource needs and their allocation are identified and analyzed within the SUTP. Critical infrastructure may include all important transport hubs and stations, such as train/central bus stations, transfer terminals, fixed rail network, (suburban rail/metro/tram network), road network or city (air)ports.

Unimodal and cross-modal risks and uncertainties are considered in the transport planning stage.</td></tr>
<tr><td>Input</td><td>Transport authorities' needs for planning transport in urban areas, incorporating system sustained adaptability insights, usually set in Master Plans, start the function. At the same time, public consultation for identifying market/socioeconomic trends (e.g. user needs, new products/services, economic situations) is considered an essential process both for the development and update of SUTPs.
<table>
<tr><th>lemma</th><th>SOURCE Function</th><th>relation</th></tr>
<tr><td>System Sustained adaptability insights</td><td>Provide adaptation & improvement insight</td><td>is_output</td></tr>
</table></td></tr>
<tr><td>Output</td><td>The main output of the function is the Sustainable Urban Transport Plan. It consists of transport-related measures and scenarios. Secondary outputs, based on the SUTP are financial plans of transport providers.
<table>
<tr><th>lemma</th><th>Destination Function</th><th>relation</th></tr>
<tr><td>Strategic plan</td><td>Collect event information</td><td>is_control</td></tr>
<tr><td>Strategic plan</td><td>Manage financial affair</td><td>is_input</td></tr>
<tr><td>Strategic plan</td><td>Provide adaptation & improvement insight</td><td>is_input</td></tr>
<tr><td>Strategic plan</td><td>Maintain physical/cyber infrastructure</td><td>is_input</td></tr>
<tr><td>Strategic plan</td><td>Manage awareness & usage behaviou</td><td>is_input</td></tr>
<tr><td>Strategic plan</td><td>Coordinate Service delivery</td><td>is_resource</td></tr>
</table></td></tr>
<tr><td>Resources</td><td>Resources required for the function include transport experts trained in SUTPs, technical equipment promoting the "smart" use of transport networks, adequate budget for the implementation of the SUTP, as well as traffic survey data and algorithms (model projections).
<table>
<tr><th>relation</th><th>SOURCE Function</th></tr>
</table></td></tr>
</table>

<table>
<tr><td></td><td>
<table>
<tr><td>is_output</td><td>Manage financial affair</td></tr>
<tr><td>is_resource</td><td>Coordinate Service delivery</td></tr>
</table>
</td></tr>
<tr><td>Preconditions</td><td>A Master Plan for the urban area under consideration should be in place, as well as an overall responsible organization, adequately staffed and funded. In case an overall responsible organization for the implementation of SUTP has not been established, the training of experts of existing urban transport organizations is required. In the typical case there are budget constraints, targets should be adjusted to existing budgets.</td></tr>
<tr><td>Control</td><td>Governments providing funding and approval of SUTPs, local authorities responsible for the implementation of SUTPs and stakeholders participation (including the general public) control the function.
EU policies relevant to SUTPs (e.g. White Paper Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system, March 2011) and respective national policies, laws and regulations control the function too.
Budget constraints may also control the function. Strategic transport KPIs are to be developed.
<table>
<tr><th>realtion</th><th>SOURCE Function</th></tr>
<tr><td>is_control</td><td>Coordinate Service delivery</td></tr>
<tr><td>is_control</td><td>Restore/Repair operations</td></tr>
<tr><td>is_control</td><td>Monitor Operation</td></tr>
<tr><td>is_output</td><td>Regulate domain and operation</td></tr>
</table>
</td></tr>
<tr><td>Time</td><td>Planning milestones are essential part of a SUTP. SUTPs need to be updated at predefined time periods (usually 4-5 years).</td></tr>
</table>

<table>
<tr><td>Name</td><td>Manage UTS financial affairs</td></tr>
<tr><td>MTO Category</td><td>Human(M) - Technology (T)- Organization (O)
Prevalent category: Organization (O)</td></tr>
<tr><td>Description</td><td>Develop financial control and plan financial assets in accordance to financial needs of the operation and financial obligations of urban transport infrastructure and service providers.

Financial affairs refer i.a. to urban road agencies (public administration/private concessionaire), urban rail (metro, LRT, tramway), bus operators, transit authorities, transportation hub operators (terminals, P+R), parking operators, city (air-) ports as urban gates.</td></tr>
<tr><td>Input</td><td>Financial needs of operations and transport investments activate the function.

The programming and budgeting process of transport providers is typically framed by mid-/long-term business plans. The strategic transport plan provides also the frame for the investment plan and the procurement policy.

Current and future cash flows are essential to secure availability of financial resources for (non-) routine tasks. Financial provisions and reserves should be met for unforeseen events taking into account risk consequences.

Financial operating requirements are drawn from activities of service deliverance and infrastructure maintenance.

Transport demand and pricing policy (fare structure, toll level, parking fees) determine core revenue elements. Ancillary revenue sources contribute too.
Public subsidies covering positive externalities are common in the urban transport field.

Remuneration policy, materials/spares/equipment, energy consumption and outsourcing (SLAs) are the main drivers on the operating cost side.

Risk costs and revenue losses are envisaged items of financial resilience.

<table>
<tr><th>lemma</th><th>SOURCE Function</th><th>relation</th></tr>
<tr><td>Strategic plan</td><td>Develop Strategic Plan</td><td>is_output</td></tr>
</table>
</td></tr>
<tr><td>Output</td><td>The programming process of transport providers results into a (multi) annual budget. Accounting items are aggregated under cost and profit centers.

The financial reporting is typically an automated procedure of specialized ERP modules.

Cross-modal SLAs (Service Level Agreements), when activated, have financial consequences and are important tools in case of a modal impairment

Investment plans follow the revision of the strategic transport plan when adapting to evolving priorities.

<table>
<tr><th>lemma</th><th>Destination Function</th><th>relation</th></tr>
<tr><td>SLA(Service Level Agreement)</td><td>Coordinate Service delivery</td><td>is_control</td></tr>
<tr><td>SLA(Service Level Agreement)</td><td>Coordinate emergency actions</td><td>is_control</td></tr>
<tr><td>Budget</td><td>Develop Strategic Plan</td><td>is_resource</td></tr>
<tr><td>Budget</td><td>Coordinate Service delivery</td><td>is_resource</td></tr>
</table>
</td></tr>
</table>

	SLA(Service Level Agreement) / Monitor Resource availability / is_resource
Resources	*Business & financial accountants are part of the supporting staff in the transport business, O&M personnel belonging to the core staff.* *Funding opportunities set the budget constraints.* *Main funding sources of transport provision are user fees and general taxation. Eligibility of receiving financial assistance in emergencies has to be clarified in advance.* *Alternative funding sources for transport investments in an era of scarcity are land value surplus capture due to accessibility improvements as well as private funding for collaborative projects.* *IT resources (hardware & ERP software) are essential backups of financial tasks.*
Preconditions	*Clarification of the investment, operating & maintenance needs in the transport field is essential to accomplish financial & controlling tasks.*
Control	*Controlling activities are crucial to impose corrective actions when deviations from financial targets arise. Revenue protection, cost and budget control are essential in this respect.* *Monetizable risk factors have to be accounted for.* *Reporting of cost recovery ratio vs. targeted ratio is the most important financial KPI.* *Fiscal control by the public administration in case of public subsidies to the transport provider.* *Necessary compliance with laws and international financial accounting standards.* *Financial statements are controlled by external auditors.*
Time	*Financial affairs are an ongoing function.* *Periodic financial controls on monthly, quarterly and annual base are a task for all hierarchy levels and a top management responsibility.* *(Multi-) annual fiscal obligations set the timeframe for a sustainable transport provision.*

Resources:

lemma	SOURCE Function	relation
Revenues	Use of the service	is_output
Funds	Supply financial resources	is_output

Control:

lemma	SOURCE Function	relation
Law	Regulate domain and operation	is_output

Name	**Perform Risk Assessment for the UTS**
MTO Category	Human(M) - Technology (T)- Organization (O) Prevalent category: Technology (T)
Description	*Assess feasibility of financial plans and compliance with legal and operational obligations, assess operational risk* *+ Risk assessment guidelines definition by EU doc* *Risk assessment for CIs such as in the transport sector is a strategic activity. The conduct of risk assessment needs both engineering science and intelligence.* *In the urban transport industry, cross-modal risks have ample consequences. Intermodal hubs and signaling for mixed road traffic carry network-wide risks in this respect.* *Unimodal risk assessments may refer to modal links and nodes of critical importance. Control rooms, tunnels and central transfer stations are vulnerable modal components.*
Input	*Development of classification schemes for threat types and emergency incidents in the urban transport sector.* *Identification of critical risks in terms of network consequences. Statistical analysis of more frequent events based on historic data. Expert assessment of rare event likelihoods.* *Empirical operationalization of risk variables feeding risk and safety models ('what-if' scenarios). Genuine risk assessment refers to expected consequences of threats accounting for urban transport vulnerabilities.* *The decision to conduct cross-modal network-wide risk assessments is virtually a political one. Top management decides for unimodal risk assessments.* *Risk assessments may lead to revised safety and emergency regulations of transport providers.* *Compliance with ISO/EC 31010 standard on risk management streamlines a methodology to derive risk mitigation measures.* *Event_analysis_insights* *Event occurrence* *Political decision* *Update of safety regulations (driven by new scientific findings)* *EU/International regulations*
Output	*Risk assessment ensures the ability to control risks. This applies to staff and public behavior as well as to urban transport infrastructure.* *Expected risk consequences per 'what-if' scenario are the core of risk assessment reports. Sensitivity analyses identify critical gaps and redundancies. Risks below a tolerable level are sorted out.* *Cross-modal network-based risks are considered as strategic. Unimodal risks reside mainly (but not exclusively) at the tactical/operational level.* *Risk interdependencies with other CIs (for instance energy, telecoms, healthcare) are acknowledged.* *Transport providers may prioritize accordingly risk mitigation actions. Staff at all hierarchy levels is trained to assess downside risk consequences when a negative event is in progress.*

<table>
<tr><td></td><td>
<table>
<tr><th>lemma</th><th>Destination Function</th><th>relation</th></tr>
<tr><td>Risk assessment report</td><td>Monitor Safety and Security</td><td>is_input</td></tr>
<tr><td>Risk assessment report</td><td>Train Staff</td><td>is_input</td></tr>
<tr><td>Risk assessment report</td><td>Define procedures</td><td>is_input</td></tr>
<tr><td>Risk assessment report</td><td>Coordinate Service delivery</td><td>is_resource</td></tr>
</table>
</td></tr>
<tr><td>Resources</td><td>
Field staff experience and tacit knowledge complement internal/external expertise as most valuable resources. Safety, security and emergency rules are both parameters of risk models and results of risk assessments.
ICT technologies (sensor networks, loops, CCTVs, social web), acquired big data and intelligence software extracting relevant information are important tools for transport providers. They enable historic data repositories and have a preventive function.

Safety_regulation
Big data
Social data
Historical data
Sensor networks & data
Technologies for acquiring necessary data
Algorithms & processing units for risk calculation
<table>
<tr><th>lemma</th><th>SOURCE Function</th><th>relation</th></tr>
<tr><td>Safety regulation</td><td>Regulate domain and operation</td><td>is_output</td></tr>
</table>
</td></tr>
<tr><td>Preconditions</td><td>
Consultation of field staff, experts and public
Intelligence mapping
Vulnerability mapping and ranking
Clear roles and responsibilities within transport organization.
</td></tr>
<tr><td>Control</td><td>
Risk assessment is a step to develop realistic risk mitigating strategies. Safety and emergency procedures inform risk assessment. Thresholds of expected risk consequences set the acceptance level for transport providers and travelling population. The accuracy of risk models may be validated with historic data. Assessment priorities pertain to safety-critical and vulnerable components of the urban transport system.
</td></tr>
<tr><td>Time</td><td>
Risk assessments have to be revised when threats, vulnerabilities or consequences of harmful incidents increase significantly.
</td></tr>
</table>

<table>
<tr><td>Name</td><td>Train Staff</td></tr>
<tr><td>MTO Category</td><td>Human(M) - Technology (T)- Organization (O)

Prevalent category: Human (M)</td></tr>
<tr><td>Description</td><td>Train the employees as planned, including quality control of the training, in order to improve the resilience of the urban transport

- Per transport infrastructure & service provider

- Per staff category

Qualified employees of transport infrastructure & service providers are trained for routine operations. Collateral training refers to safety, security and emergencies. The intention is to motivate and reduce at-risk behaviour of the staff.

Staff categories pertain to Operations &Maintenance (transport service providers), Engineering studies & Construction site overseeing (transport infrastructure providers) as well as Administration. Staff can be in-house or subcontracted.</td></tr>
<tr><td>Input</td><td>The function starts with the technical needs of urban transport provision, determining the training requirements.

Training objectives specify key competencies of (as much as possible: multi-skilled) personnel and consider coordination of normal service delivery as well as defined rules & procedures. The latter refer to routine procedures, safety rules for prevention of incidents and emergency procedures for response and abatement.

Risk and vulnerability mapping in the transport sector supports the assessment of training needs with respect to incidents. Common drills with first responders support an improved co-operation in case of emergencies.

Adaptation processes of SOPs and impact mitigation strategies or use of new IT learning technologies (e.g. driving simulators) set up revisions of training protocols, curricula, courses design and methodologies.

Training courses suit to new starters/changers of job positions as well as to event-driven case studies. The former complement practical exercises.

<table>
<tr><th>lemma</th><th>SOURCE Function</th><th>relation</th></tr>
<tr><td>Risk assessment report</td><td>Perform Risk Assessment</td><td>is_output</td></tr>
<tr><td>Training staff requirements</td><td>Coordinate Service delivery</td><td>is_output</td></tr>
<tr><td>Safety regulation</td><td>Regulate domain and operation</td><td>is_output</td></tr>
</table>
</td></tr>
<tr><td>Output</td><td>Successfully trained staff is able to deliver service, monitor transport operations, safety & security and respond to emergencies in an invariant (i.e. resilient) manner. Improved skills of understanding safety environment or pro-actively analyzing safety-critical incidents are acquired. Flexible, multi-skilled staff with increased operative perception emerges.

A common language arises across in-house staff categories, subcontractor personnel and external first responders.</td></tr>
</table>

<table>
<tr>
<td></td>
<td>
An assessment of training (e.g. debriefing of drills) and trainees (e.g. score set by trainers) is indispensable. HR managers responsible for training may compare employee evaluation before and after training to assess training effectiveness.
<table>
<tr><th>lemma</th><th>Destination Function</th><th>relation</th></tr>
<tr><td>Training performance data</td><td>Collect event information</td><td>is_input</td></tr>
<tr><td>Staff trained</td><td>Coordinate emergency actions</td><td>is_precondition</td></tr>
<tr><td>Staff trained</td><td>Monitor Operation</td><td>is_precondition</td></tr>
<tr><td>Staff trained</td><td>Monitor Operation</td><td>is_resource</td></tr>
</table>
</td>
</tr>
<tr>
<td>Resources</td>
<td>
A competence-based training needs a programme, competent trainers, material & curriculum as well as IT tools (e.g. virtual simulators).
The transport provider needs a dedicated internal training entity and locations for training.
Training_performance_data
Human resources availability (PM availability – trainer&trainee)
Training tools/material/curriculum
</td>
</tr>
<tr>
<td>Preconditions</td>
<td>Internal/external trainers and already defined procedures are preconditions of the said activity.</td>
</tr>
<tr>
<td>Control</td>
<td>
Existing training certification schemes.
Formal & informal safety culture within transport providers is of paramount importance (‘living safety’).
Ensure compliance with national legislation and European safety directives
Training hours spent, number of drill participations, scores of tests on SOPs/defect handling/firefighting/transport safety communications are exemplary metrics of trainee performance.
Public transport drivers have to accomplish additional psychometric tests.
</td>
</tr>
<tr>
<td>Time</td>
<td>
Periodic training
The following resembles a (chrono)logical sequence of training activities in the transport sector:
Initial training and instructions off-the-job is followed by certification of basic competencies. The training on-the-job is conducted by supervisors and colleagues (internal sharing of knowledge). Refreshing of training for rare incidents is recommended. Emergency drills are performed annually.
The revision of training content is both periodic and event-driven.
</td>
</tr>
</table>

<table>
<tr><td>Name</td><td>Coordinate urban transport service delivery</td></tr>
<tr><td>MTO Category</td><td>Human(M) - Technology (T)- Organization (O)
Prevalent Category: Organization (O)</td></tr>
<tr><td>Description</td><td>The coordination of urban transport (ut) service delivery involves all aspects of providing urban transport service and all relevant stakeholders. In particular, aspects to be considered may include:

Public transport service with Operation control Center (OCC)
Transport infrastructure (road network infrastructure, shared rail/road infrastructure, transport hubs)
Traffic Management Center (TMC)
Paratransit management
Accessibility management (parking/park&ride/kiss&ride, pedestrians, cycling)
Integrated smart ticketing & telematics
Information to the public (language-independent or multilingual, through different sensorial channels)
Timetable coordination (dynamic/schedule based)

An overall supervising organization for the integrated service delivery should be established /in place for the coordination of different stakeholders involved in the delivery of UT service. For the successful coordination, the nomination of a representative at each involved organization for the coordination of service is also recommended (input from Strategic Transport Plan).

The said function is interrelated with other functions of the UTS. The budget for the coordination of urban transport service should be included in the Strategic Transport Plan. The said function is required to deliver the transport service (core function). (see tables below).

Provide service plan, trigger the emergency alert, coordinate operational procedures.</td></tr>
<tr><td>Input</td><td>The function requires input from the Operation Plans of urban transport providers and depends on the mobility patterns (transport demand) in the area under consideration.

Coordination of transport service delivery will use available resources to identify maintenance requirements, improve accessibility and transfer conditions in general at major transport hubs (metro/rail stations, city ports, etc), while energy supply considerations are taken into account in relevant reports. Operation requirements are to be updated as needed. Transport surveys are essential in this respect.
As far as emergencies are considered, the risk assessment report and the emergency response plan are to be updated regularly depending on critical event detection, which may also be user generated.

<table>
<tr><th>lemma</th><th>SOURCE Function</th><th>relation</th></tr>
<tr><td>Operation restored/repaired</td><td>Restore/Repair operations</td><td>is_output</td></tr>
<tr><td>Operation requirements</td><td>Monitor Operation</td><td>is_output</td></tr>
<tr><td>Install Mantainance requirement</td><td>Monitor Operation</td><td>is_output</td></tr>
<tr><td>Service sustained adaptability improvement insights</td><td>Provide adaptation & improvement insight</td><td>is_output</td></tr>
<tr><td>Resource supplied Critical event detection</td><td>Monitor Resource availability</td><td>is_output</td></tr>
<tr><td>Energy supply report</td><td>Monitor Resource availability</td><td>is_output</td></tr>
</table>
</td></tr>
</table>

	Infrastructure restored/repaired	Restore/repair physical infrastructure	is_output
	User generated critical event detection	Monitor user generated feedback	is_output
	Official risk warning	Provide risk warning	is_output

Output

As a result of the said function, transport service requirements may be used to update the operation plans of transport service providers.
Budget allocation, resource and training requirements and timetables of different transport providers may also change according to user demand fluctuations reflecting service effectiveness. User generated feedback on service effectiveness is also important in updating the coordination of transport service delivery. All the above, together with maintenance of assets, will be taken into account by the supervising transport management, which is responsible to perform the function.

lemma	Destination Function	relation
Operation plan	Manage awareness & usage behaviou	is_control
Operation HR plan	Human resources	is_function
Training staff requirements	Train Staff	is_input
Operation Restore service request	Restore/Repair operations	is_input
Operation HR plan	Manage Human resources	is_input
Service improvement plan	Maintain physical/cyber infrastructure	is_input
Operation plan	Manage awareness & usage behaviou	is_input
Operation plan	Define procedures	is_input
Operation plan	Manage ICT resource	is_input
Infrastructure restore request	Restore/repair physical infrastructure	is_input
Service delivery plan	Use of the service	is_resource
Service delivery plan	Manage awareness & usage behaviour	is_resource
Operation plan	Monitor Resource availability	is_resource
Restore timing plan	Restore/Repair operations	is_time
Restore infrastructure timing plan	Restore/repair physical infrastructure	is_time

Resources

To perform the function, adequate budget should be provided per transport provider. Transport service demand impacts optimal budget allocation.
Transport infrastructure (mainly road and rail) as well as vehicles and trained staff are also essential. ICT infrastructure with its many transport applications (e.g. Variable Message Signs, Operation Control Centers, Traffic Management, integrated smart ticketing), is particularly important for the coordination of transport service delivery.

lemma	SOURCE Function	relation
Strategic plan	Develop Strategic Plan	is_output
Budget	Manage financial affair	is_output
Risk assessment report	Perform Risk Assessment	is_output
Emergency response status	Coordinate emergency actions	is_output

	Emergency response plan	Coordinate emergency actions	is_output
	Operation restore/repair status	Restore/Repair operations	is_output
	Operation Restore service plan	Restore/Repair operations	is_output
	Supply status	Supply Resources	is_output
	ICT infrastructures	Manage ICT resource	is_output
	Infrastructure restored/repaired	Restore/repair physical infrastructure	is_output
	Infrastructure restored repaired status	Restore/repair physical infrastructure	is_output
	Infrastructure resotore/repair plan	Restore/repair physical infrastructure	is_output
Preconditions	*A responsibility matrix, operating, safety and emergency rules and procedures as well as trained staff are preconditions of the said function. Preventive and failure-driven maintenance of transport infrastructure is essential precondition of the function too.*		
Control	*The purpose of the said function is the coordination of transport service delivery to achieve optimal transport operations and respond to user mobility needs.* *National laws establishing supervising transport authorities, service contracts (and respective Service Level Agreements-SLAs) with various transport operators control the function. Service standards may include various Key Performance Indicators (KPIs), such as* • *Quality KPIs (e.g. service reliability),* • *Safety KPIs (e.g. number of accidents)* • *Vehicle KPIs (e.g. vehicle productivity) and* • *Staff KPIs (e.g. drivers' productivity)* • *Maintenance KPIs (e.g. maximize Mean Time Between Failure)*		
	lemma	**SOURCE Function**	**relation**
	Law	Monitor Operation	is_control
	SLA(Service Level Agreement)	Manage financial affair	is_output
	Standards	Regulate domain and operation	is_output
	Law	Regulate domain and operation	is_output
Time	*The function has to be performed continuously throughout the transport service operating and engineering (night) hours.*		

<table>
<tr><td>Name</td><td>Manage awareness & user behavior</td></tr>
<tr><td>MTO Category</td><td>Human(M) - Technology (T)- Organization (O)
Prevalent category: Human (M)</td></tr>
<tr><td>Description</td><td>Signaling, awareness, stakeholder communication, training, etc.
Surveys – communicating outcomes
Training (material, emergency simulation,
Dissemination channels (media, leaflets)
Clear communication of guidance in case of emergency (signing, alternative sensory channels for providing information, info on alternative modes/routes, multilingualism or language independent info)
Software apps
Education of special groups (kids, elderly, disabled etc)
Safety & emergency awareness of the public in view of severe disruptive events is of paramount importance. Public communication for keeping safety procedures by posting information and graphics in vehicles & hubs. Public education of schooling population in matters of safety & emergency.
In case of emergencies, guidance for affected travelers is secured through signage, public address system (TETRA) of the transport provider and VMS panels (indicating alternative modes/routes) in road arterials. Special attention to alternative sensory channels for visual & hearing impairments. Instructions for handling wheelchairs during emergencies.
TV-radio addresses the general public. Specific and credible information is requested, as well as consistent expert testimony and confidence-building media coverage. Software apps for mass alerts and bulk SMS may instruct people on the move.
The reduction of the perceived public risk influences positively peoples' cognitive & affective judgment of risks and effectuates panic prevention. Aimed is an enhanced confidence to the transport system.</td></tr>
<tr><td>Input</td><td>Transport Operation Plans define safety & emergency procedures. These procedures build the frame of how to avoid incidents or how to respond correctly to incidents. They describe routine service delivery and a coordinated emergency response to incidents.
A pre-event emergency & communications plan has to be in place.
Information about incidents may be collected via sensors, loops, CCTV surveillance, traffic regulators in control rooms, staff in duty or (non-) traveler tweets.
During an event disrupting operations, guidance to the affected travelers has to be given. In the post-event period the focus is on restoring operations, raising awareness of the population and influencing traveler behavior.
<table>
<tr><th>lemma</th><th>SOURCE Function</th><th>relation</th></tr>
<tr><td>Strategic plan</td><td>Develop Strategic Plan</td><td>is_output</td></tr>
<tr><td>Operation plan</td><td>Coordinate Service delivery</td><td>is_output</td></tr>
<tr><td>Emergency response status</td><td>Coordinate emergency actions</td><td>is_output</td></tr>
<tr><td>Operation Restore service plan</td><td>Restore/Repair operations</td><td>is_output</td></tr>
<tr><td>Operation restore/repair status</td><td>Restore/Repair operations</td><td>is_output</td></tr>
<tr><td>Operation Critical event detection</td><td>Monitor Operation</td><td>is_output</td></tr>
</table></td></tr>
<tr><td>Output</td><td>Routine or emergency communication schemes exercised through the said channels and media - when sufficient - reach a higher situational awareness of travelers and the wider population. Travelers may be diverted to alternative modes and routes.
In catastrophic events, panic may be prevented and fearful people may be switched to concerned or simply worried population. Public response and travel behavior becomes more resilient then. Travelers are adaptively minded subjects.
Travel demand recovery to pre-event levels.</td></tr>
</table>

	lemma	Destination Function	relation
	Early warnings	Use of the service	is_resource
	Service status	Use of the service	is_resource
	Early warnings	Use of the service	is_resource

Resources	*Information drawn from ICT tools, crowd sensing and field observation data as well as from stated choice surveys on risk behavior are important resources.* *Platforms, VMS panels and media channels are needed too.* *Trained communication experts, OCC/TMC announcers through the PA system and public opinion influencers are requested in case.*

lemma	SOURCE Function	relation
Service delivery plan	Coordinate Service delivery	is_output
Operation performance monitoring data	Monitor Operation	is_output
ICT infrastructures	Manage ICT resource	is_output
User behaviour data	Monitor user generated feedback	is_output

Preconditions	*ICT infrastructure (sensors, loops, CCTVs, VMS panels, TMC/OCC mimic panels), communication tools (signage, PA systems, posters)*
Control	*Periodical public awareness surveys results* *Range of coverage of mass alerts/bulk SMS.* *Willingness-To-Accept (WTA) risk of the local population.* *In case of catastrophic events, important KPI metric is the dynamic resilience predictor for the concerned population. Resilient travel behavior exhibit local populations with perceived risk lower than WTA risk threshold. Communication schemes target a public risk perception at a lower level.*

lemma	SOURCE Function	relation
Operation plan	Coordinate Service delivery	is_output

Time	*Event-driven campaigns* *Stronger dynamic public resilience becomes translates to a higher rate of travel demand recovery after a catastrophic event.*

<table>
<tr><td>Name</td><td>Develop/update procedures</td></tr>
<tr><td>MTO Category</td><td>Human(M) - Technology (T)- Organization (O)</td></tr>
<tr><td>Description</td><td>At every organization level, there shall be a function able to produce and upgrade operational procedures according to risk assessment and ex-post event analysis (learning) in a way to also provide re-usable data and be re-applicable

To meet with the Urban Transport complexity we must have several kinds of procedures and different grades of insight.

All documents must be consistent with emergency plans and must be kept up to date.

The general public must be provided with procedures regularly utilized during normal transit operations must be provide essential, synthetic, easy-to-memorize, trans-cultural, pictographic, procedures.

Audio-video tutorials should be carefully considered and generally avoided in every critical ordinary stress or extraordinary emergency, because they are concentration and time consuming tools, removing people from reality.

Security and technical personnel should be provided with materials containing emergency preparedness-related information used in ordinary transit and in emergency.

Standard operating procedures and emergency rules should contain procedures, notification lists, instructions, corresponding to specifically categorized events (fire, flood, collision).

The availability and intelligibility of procedures to internal personnel, security forces, community leaders, along with the general public should be surveyed on a regular basis.</td></tr>
<tr><td>Input</td><td><table><tr><th>lemma</th><th>SOURCE Function</th><th>relation</th></tr><tr><td>Risk assessment report</td><td>Perform Risk Assessment</td><td>is_output</td></tr><tr><td>Operation plan</td><td>Coordinate Service delivery</td><td>is_output</td></tr></table></td></tr>
<tr><td>Output</td><td>New/ updated Procedures
Manuals

<table><tr><th>lemma</th><th>SOURCE Function</th><th>relation</th></tr><tr><td>Safety regulation</td><td>Regulate domain and operation</td><td>is_output</td></tr></table></td></tr>
<tr><td>Resources</td><td>Safety_regulation
Legislation
International standards
Monitor operations
Safety models
Procedure models
Procedure certification</td></tr>
<tr><td>Preconditions</td><td></td></tr>
<tr><td>Control</td><td>Procedure certification
Legislation</td></tr>
<tr><td>Time</td><td>Event driven
Legislation driven
Critical driven</td></tr>
</table>

<table>
<tr><td>Name</td><td>Manage human resources</td></tr>
<tr><td>MTO Category</td><td>Human(M) - Technology (T)- Organization (O)</td></tr>
<tr><td>Description</td><td>Hire employees, manage shifts, burnout and substitutions, assign tasks, manage organization knowledge

There must be a capability of recruit, select, develop, train, and manage a competent workforce for the urban transport system operations.
The personnel must be aware of its social responsibility and civic duty, and be rewarded accordingly.</td></tr>
<tr><td>Input</td><td><table><tr><th>lemma</th><th>SOURCE Function</th><th>relation</th></tr><tr><td>Operation HR plan</td><td>Coordinate Service delivery</td><td>is_output</td></tr><tr><td>Emergency HR request</td><td>Coordinate emergency actions</td><td>is_output</td></tr></table></td></tr>
<tr><td>Output</td><td><table><tr><th>lemma</th><th>Destination Function</th><th>relation</th></tr><tr><td>Human resources availability</td><td>Coordinate emergency actions</td><td>is_resource</td></tr><tr><td>Human resources availability</td><td>Restore/Repair operations</td><td>is_resource</td></tr><tr><td>Human resources availability</td><td>Restore/repair physical infrastructure</td><td>is_resource</td></tr><tr><td>Human resources availability</td><td>Human resources</td><td>is_specific</td></tr></table></td></tr>
<tr><td>Resources</td><td>Financial plan
HR experts<table><tr><th>lemma</th><th>SHARED functions</th><th>relation</th></tr><tr><td>International Standard Classification of Occupations – Isco08</td><td>Occupate for occupational classification</td><td>has_specific</td></tr></table></td></tr>
<tr><td>Preconditions</td><td>Job characteristics and description well defined (HR plan)</td></tr>
<tr><td>Control</td><td>Function Coordinate Service delivery</td></tr>
<tr><td>Time</td><td></td></tr>
</table>

<table>
<tr><td>Name</td><td>Manage ICT resources</td></tr>
<tr><td>MTO Category</td><td>Human(M) - Technology (T)- Organization (O)</td></tr>
<tr><td>Description</td><td>Provide/maintain/update/develop/repair information and communications services to support urban transport system operation and management

Business continuity and emergency recovery are strategic, as the ICT system is actually the main, and most crucial infrastructure of every other infrastructure.

Smart city projects
Ubiquitous Technologies and real-time Urban Transport Information systems.
Traffic lights
TCS
TMC
VMS
VDS</td></tr>
<tr><td>Input</td><td>Operation_plan
Monitor Safety/Security
Monitor operation
<table>
<tr><th>lemma</th><th>SOURCE Function</th><th>relation</th></tr>
<tr><td>Operation plan</td><td>Coordinate Service delivery</td><td>is_output</td></tr>
</table></td></tr>
<tr><td>Output</td><td>
<table>
<tr><th>lemma</th><th>Destination Function</th><th>relation</th></tr>
<tr><td>ICT resource performance</td><td>Monitor Resource availability</td><td>is_input</td></tr>
<tr><td>ICT infrastructures</td><td>Monitor Safety and Security</td><td>is_resource</td></tr>
<tr><td>ICT infrastructures</td><td>Coordinate Service delivery</td><td>is_resource</td></tr>
<tr><td>ICT infrastructures</td><td>Coordinate emergency actions</td><td>is_resource</td></tr>
<tr><td>ICT infrastructures</td><td>Monitor Operation</td><td>is_resource</td></tr>
<tr><td>ICT infrastructures</td><td>Manage awareness & usage behaviou</td><td>is_resource</td></tr>
<tr><td>ICT infrastructures</td><td>Monitor Resource availability</td><td>is_resource</td></tr>
<tr><td>ICT infrastructures</td><td>Monitor user generated feedback</td><td>is_resource</td></tr>
<tr><td>ICT infrastructures</td><td>Collect event information</td><td>is_resource</td></tr>
</table></td></tr>
<tr><td>Resources</td><td>
<table>
<tr><th>lemma</th><th>SOURCE Function</th><th>relation</th></tr>
<tr><td>Supply resources</td><td>Supply Resources</td><td>is_output</td></tr>
</table></td></tr>
<tr><td>Preconditions</td><td>ICT_installed_maintained
Legacy constraints
International standards</td></tr>
<tr><td>Control</td><td>
<table>
<tr><th>lemma</th><th>SHARED functions</th><th>relation</th></tr>
<tr><td>Legislation</td><td>Define procedures</td><td>is_control</td></tr>
<tr><td>Procedures</td><td>Coordinate emergency actions</td><td>is_precondition</td></tr>
<tr><td>Procedures</td><td>Monitor Operation</td><td>is_precondition</td></tr>
</table></td></tr>
<tr><td>Time</td><td>Continuous</td></tr>
</table>

<table>
<tr><td>Name</td><td>Maintain physical/cyber infrastructure</td></tr>
<tr><td>MTO Category</td><td>Human(M) - Technology (T)- Organization (O)</td></tr>
<tr><td>Description</td><td>To keep in good shape and operation and up to date construction, ICT and other infrastructure elements

Vehicles
Hubs
Road infrastr
Road furniture
Signing/signaling
Rail
VMS

There shall be a maintainer of Urban Transport infrastructures.
Maintenance should be done on a regular basis, as a preventive, pro-active reaction, along with reparations provided on event-driven basis.
Plants, furniture elements, furniture, tools, should be classified and being attributed an operation lifetime, with prevision of
- regular inspections
- optimal maintenance (not only at what is theoretically recommended by manufacturers and experts, but considering what is necessary to do when resources might be scarce)</td></tr>
<tr><td>Input</td><td><table><tr><th>lemma</th><th>SOURCE Function</th><th>relation</th></tr><tr><td>Strategic plan</td><td>Develop Strategic Plan</td><td>is_output</td></tr><tr><td>Service improvement plan</td><td>Coordinate Service delivery</td><td>is_output</td></tr><tr><td>Install Maintenance requirement</td><td>Monitor Operation</td><td>is_output</td></tr></table></td></tr>
<tr><td>Output</td><td>Infrastructure_installed_maintained
ICT_installed_maintained
ICT updated</td></tr>
<tr><td>Resources</td><td>operations status, ICT status</td></tr>
<tr><td>Preconditions</td><td>Contracts for performing maintenance</td></tr>
<tr><td>Control</td><td>Service level of operation</td></tr>
<tr><td>Time</td><td>Periodical
Event driven</td></tr>
</table>

MONITOR

Name

Monitor Urban Transport Safety and Security

MTO Category

Human(M) - Technology (T)- Organization (O)
Prevalent category: Technology (T)

Description

Monitor safety and security issues of the operations and service delivery

Safety and security issues of transport operations and service delivery include attention to maintenance problems, accidents, (non) recurrent traffic congestion, extreme weather conditions, as well as unexpected events

ICT equipment is essential in monitoring all aspects of the urban transport system and triggering and communicating safety and security alerts. Traffic Management Centers, Operation Control Centers adequately staffed and equipped, interactions and communication channels with Police, Traffic Police and Data Protection Authorities are important to perform the function.

Input

The need to attend and respond to maintenance problems, accidents, and in general any (non)recurrent or unexpected events during operation that may impact safety and security, as anticipated in the operation plans of transport providers start the function.

Trained staff as well as safety and security rules and procedures are needed.

lemma	SOURCE Function	relation
Risk assessment report	Perform Risk Assessment	is_output
Emergency response plan	Coordinate emergency actions	is_output

Output

A Safety and Security Plan of the transport provider is an output of the function. The function may change the risk assessment report as well as the Emergency Response Plan, according to findings during monitoring safety and security.

Improvement of safety-critical or emergency response timing. Betterment of safety and security performance. Safety and security critical event detection reports may be provided to Civil Protection authorities and LEAs. Risk models may also be updated according to historical data.

lemma	Destination Function	relation
Safety Security control	Monitor Operation	is_control
Safety Security control	Use of the service	is_control
Safety security critical event detection	Coordinate emergency actions	is_input
Safety Security performance data	Collect event information	is_input
Emergency respond timing	Coordinate emergency actions	is_time

Resources

Adequately trained safety and security staff, ICT_ infrastructures (Traffic Management Centers, Operation Control Centers, CCTV cameras, sensor networks, VMS panels), power and budget are important resources for the function.

Most of the transport providers outsource safety tasks to specialized 3rd entities (securitas etc). However, the monitoring function is a core business function.

	<table><tr><th>lemma</th><th>SOURCE Function</th><th>relation</th></tr><tr><td>Emergency response data</td><td>Coordinate emergency actions</td><td>is_output</td></tr><tr><td>Emergency response status</td><td>Coordinate emergency actions</td><td>is_output</td></tr><tr><td>ICT infrastructures</td><td>Manage ICT resource</td><td>is_output</td></tr><tr><th>lemma</th><th>SHARED functions</th><th>relation</th></tr><tr><td>Emergency response status</td><td>Manage awareness & usage behaviour</td><td>is_input</td></tr><tr><td>Emergency response data</td><td>Collect event information</td><td>is_input</td></tr><tr><td>ICT infrastructures</td><td>Coordinate Service delivery</td><td>is_resource</td></tr><tr><td>Emergency response status</td><td>Coordinate Service delivery</td><td>is_resource</td></tr><tr><td>ICT infrastructures</td><td>Coordinate emergency actions</td><td>is_resource</td></tr><tr><td>Emergency response status</td><td>Monitor Operation</td><td>is_resource</td></tr><tr><td>ICT infrastructures</td><td>Monitor Operation</td><td>is_resource</td></tr><tr><td>ICT infrastructures</td><td>Manage awareness & usage behaviou</td><td>is_resource</td></tr><tr><td>ICT infrastructures</td><td>Monitor Resource availability</td><td>is_resource</td></tr><tr><td>ICT infrastructures</td><td>Monitor user generated feedback</td><td>is_resource</td></tr><tr><td>ICT infrastructures</td><td>Collect event information</td><td>is_resource</td></tr></table>
Preconditions	*Operation procedures, part of which are the safety and security procedures, should be in place to perform the function.* *Communication channels with LEAs and Civil Protection entities are to be sustained.*
Control	*Safety and emergency regulations, as well as Key Performance Indicators (eg number of accidents and near-accidents) according to which monitoring activities and procedures may be updated, control the function.* <table><tr><th>lemma</th><th>SOURCE Function</th><th>relation</th></tr><tr><td>Safety regulation</td><td>Regulate domain and operation</td><td>is_output</td></tr></table>
Time	*The function is performed continuously, as well as after any incident and after any new addition/change in the system (safety and security control processes have to be updated).*

<table>
<tr><td>Name</td><td>Monitor Operations</td></tr>
<tr><td>MTO Category</td><td>Human(M) - Technology (T)- Organization (O)</td></tr>
<tr><td>Description</td><td>Monitor employees and service performance
There should be a supervisor center, where the Urban Transport service is monitored in real-time.
Transport infrastructures should be doted of real-time operations monitoring and control capability.
There must be regular collection of data regarding in order to understand as soon as possible unplanned downtime, network intrusion, and resource saturation.
Monitoring should be part of Quality of Service agreements and technologies.
As a contribution to improve social control and cooperation to the service valuation, UT monitoring output should be shared with the public, through apps and open data.</td></tr>
<tr><td>Input</td><td>Service_performance
Coordinate emergency</td></tr>
<tr><td>Output</td><td>
<table>
<tr><th>lemma</th><th>Destination Function</th><th>relation</th></tr>
<tr><td>Operation requirements</td><td>Coordinate Service delivery</td><td>is_input</td></tr>
<tr><td>Install Mantainance requirement</td><td>Coordinate Service delivery</td><td>is_input</td></tr>
<tr><td>Operation Critical event detection</td><td>Coordinate emergency actions</td><td>is_input</td></tr>
<tr><td>Install Mantainance requirement</td><td>Maintain physical/cyber infrastructure</td><td>is_input</td></tr>
<tr><td>Operation Critical event detection</td><td>Manage awareness & usage behaviou</td><td>is_input</td></tr>
<tr><td>Operation performance monitoring data</td><td>Collect event information</td><td>is_input</td></tr>
<tr><td>Operation performance monitoring data</td><td>Manage awareness & usage behaviou</td><td>is_resource</td></tr>
</table>
</td></tr>
<tr><td>Resources</td><td>
<table>
<tr><th>lemma</th><th>SOURCE Function</th><th>relation</th></tr>
<tr><td>Staff trained</td><td>Train Staff</td><td>is_output</td></tr>
<tr><td>Emergency response status</td><td>Coordinate emergency actions</td><td>is_output</td></tr>
<tr><td>ICT infrastructures</td><td>Manage ICT resource</td><td>is_output</td></tr>
</table>
</td></tr>
<tr><td>Preconditions</td><td>
<table>
<tr><th>lemma</th><th>SOURCE Function</th><th>relation</th></tr>
<tr><td>Staff trained</td><td>Train Staff</td><td>is_output</td></tr>
<tr><td>Operation restored/repaired</td><td>Restore/Repair operations</td><td>is_output</td></tr>
</table>
</td></tr>
<tr><td>Control</td><td>
<table>
<tr><th>lemma</th><th>SOURCE Function</th><th>relation</th></tr>
<tr><td>Safety Security control</td><td>Monitor Safety and Security</td><td>is_output</td></tr>
<tr><td>Standards</td><td>Regulate domain and operation</td><td>is_output</td></tr>
<tr><td>Law</td><td>Regulate domain and operation</td><td>is_output</td></tr>
</table>
</td></tr>
<tr><td>Time</td><td>Rate & focus of monitoring differs in normal operation and emergency</td></tr>
</table>

<table>
<tr><td>Name</td><td>Monitor Resource availability</td></tr>
<tr><td>MTO Category</td><td>Human(M) - Technology (T)- Organization (O)</td></tr>
<tr><td>Description</td><td>Keep record of the level of supply in resources that are basic for the system operation
Optimal buffer and operational reserves.

Infrastructure
Vehicles & components
Energy
ICT
Hubs equipment
Network equipment</td></tr>
<tr><td>Input</td><td><table><tr><th>lemma</th><th>SOURCE Function</th><th>relation</th></tr><tr><td>ICT resource performance</td><td>Manage ICT resource</td><td>is_output</td></tr></table></td></tr>
<tr><td>Output</td><td><table><tr><th>lemma</th><th>Destination Function</th><th>Relation</th></tr><tr><td>Energy supply report</td><td>Coordinate Service delivery</td><td>is_input</td></tr><tr><td>Resource supplied
Critical event detection</td><td>Coordinate Service delivery</td><td>is_input</td></tr><tr><td>Resource supplied
Critical event detection</td><td>Coordinate emergency actions</td><td>is_input</td></tr></table></td></tr>
<tr><td>Resources</td><td><table><tr><th>lemma</th><th>SOURCE Function</th><th>relation</th></tr><tr><td>SLA(Service Level Agreement)</td><td>Manage financial affair</td><td>is_output</td></tr><tr><td>Operation plan</td><td>Coordinate Service delivery</td><td>is_output</td></tr><tr><td>ICT infrastructures</td><td>Manage ICT resource</td><td>is_output</td></tr></table></td></tr>
<tr><td>Preconditions</td><td>Supply channels
Time constraints</td></tr>
<tr><td>Control</td><td>Engineering standards & technical specifications
Health regulations
Contracts
Quality of service</td></tr>
<tr><td>Time</td><td>Depending on contracts
Continuous
Event driven</td></tr>
</table>

<table>
<tr><td>Name</td><td>Monitor user generated feedback</td></tr>
<tr><td>MTO Category</td><td>Human(M) - Technology (T)- Organization (O)
Prevalent category: Human (M)</td></tr>
<tr><td>Description</td><td>User behavior, perception, feedback

Surveys
Observations/passengers counts
Social media
Crowd sensing data

Attitudes identification
Route choice
Level of service (LoS)
Awareness of system operations/how to act in emergency
Value of risk
WTA
Fear
Expectations
Complaints/improvement suggestions
Information on events

A bottom-up engagement of travelers in urban transport resilience may be provided through crowd sensing of social web media (‘travelers as moving sensors’). Content analysis and text mining request adequate software tools.
Structured real-time information about road traffic density/LoS/speed or public transport ridership may be derived through ICT technologies (road sensors, smart card ticketing readers). Big data mining modules, able to visualize the extracted aggregate information are then needed.
A combined analysis of smart devices’ geolocation data (crawling detection) and tweet contents (cause of crawling) may provide a remote picture of transport incidents.
Stated choice surveys may derive the value of perceived risk and the WTA risks
in local transportation contexts. The dynamic behavioral resilience of the traveling population is then assessed.</td></tr>
<tr><td>Input</td><td>The detection of anomalies (i.e. high variability) in the travel behavior triggers the function. More focused user-generated information sheds then more light on the incident. The clearing signal initiates alerts and an adequate response.

<table><tr><th>lemma</th><th>SOURCE Function</th><th>relation</th></tr><tr><td>User behaviour</td><td>Use of the service</td><td>is_output</td></tr><tr><td>User feedback</td><td>Use of the service</td><td>is_output</td></tr></table></td></tr>
<tr><td>Output</td><td>Manage awareness and user behavior

User_generated_service_improvement_suggestions
User_generated_critical event_detection
User_behaviour_data/report

The (bottom-up) traveler-generated information may be used in a routine manner for service improvements, whereas incident detection and analysis is related with new ICT technologies. In severe events (top-down) communication actions such as mass alerts and bulk SMS may be then triggered off. The user generated content is the best source to manage awareness & usage behavior. An analysis of possible cascading effects from/to other CIs is a distinct activity.</td></tr>
</table>

	<table><tr><th>lemma</th><th>Destination Function</th><th>relation</th></tr><tr><td>User generated critical event detection</td><td>Coordinate Service delivery</td><td>is_input</td></tr><tr><td>User generated critical event detection</td><td>Coordinate emergency actions</td><td>is_input</td></tr><tr><td>User generated service improvement suggestions</td><td>Collect event information</td><td>is_input</td></tr><tr><td>User behaviour data</td><td>Manage awareness & usage behaviour</td><td>is_resource</td></tr></table>
Resources	*Social web media, networked sensors, loops, smart card readers and related software platforms are ICT resources for the said function.* *Control personnel in TMCs/operator rooms as well as staffed social media monitoring units are also needed.* <table><tr><th>lemma</th><th>SOURCE Function</th><th>relation</th></tr><tr><td>ICT infrastructures</td><td>Manage ICT resource</td><td>is_output</td></tr></table>
Preconditions	*Allocation of clear roles and responsibilities for information analysis.* *Specialized text mining and anonymization algorithms.* *Big data storage capacity.*
Control	*Privacy & other ethics legislation* *Open data requirements/regulations* *Security requirements and legislation* *Inferences from unstructured traveler-generated information are to be validated against factual field observations.* *Outlier thresholds (as multiples of historic standard deviations) for incident alerts are to be set, when big data are analyzed. Focus on signal variability that may indicate trouble.* *Active and passive monitoring of traveler behavior.* *Compliance with data privacy regulations is to be controlled.*
Time	*Continuous* *Annual traveler satisfaction surveys to control experience over time.* *Continuous real-time monitoring (operational level).* *Event-driven compressed analysis of severe incidents and rate of demand recovery.*

RESPOND

<table>
<tr><td>Name</td><td>Coordinate emergency actions in UTS</td></tr>
<tr><td>MTO Category</td><td>Human(M) - Technology (T)- Organization (O)</td></tr>
<tr><td>Description</td><td>Steering the system during an emergency

Coordinate emergency actions is a responsibility usually delegate to a specific responsibility centre, an emergency centre, a civil protection authority, a situation room, a special emergency management agency.

As various groups of emergency response personnel arrive at the scene, a clear chain of command must be maintained.

The same is recommended in the Urban Transport System.
The function should have mandate and power enough to coordinate the emergency in according with laws, bylaws and the emergency plans.
In the case communication with top management and top leadership are impossible, the function might have autonomy and manoeuvre room, expressed in protocols and an appropriate budget.

In particular this function must provide:

Re-assignment of traffic according to emergency
Re-routing & timetables rearrangement of PT
Cooperation with other first responders/law enforcement
Complementarity of modes in case of service level loss, in accordance with service level agreement

Decision on system operation until emergency closed

Before emergency this function is standing by, involved in preparation and awareness activities (see relative functions:
Monitor Safety and Security
Monitor Operation
Manage awareness & usage behaviour)
During emergency this function is fully deployed.

A crucial issue is proximity and knowledge of the ground.</td></tr>
<tr><td>Input</td><td>
<table>
<tr><th>lemma</th><th>SOURCE Function</th><th>relation</th></tr>
<tr><td>Safety security critical event detection</td><td>Monitor Safety and Security</td><td>is_output</td></tr>
<tr><td>Operation Critical event detection</td><td>Monitor Operation</td><td>is_output</td></tr>
<tr><td>Resource supplied Critical event detection</td><td>Monitor Resource availability</td><td>is_output</td></tr>
<tr><td>User generated critical event</td><td>Monitor user generated feedback</td><td>is_output</td></tr>
</table>
</td></tr>
</table>

	detection		

Output

lemma	Destination Function	relation
Emergency response plan	Monitor Safety and Security	is_input
Emergency HR request	Manage Human resources	is_input
Emergency response status	Manage awareness & usage behaviour	is_input
Emergency response data	Collect event information	is_input
Emergency response command	Fight the emergency	is_input
Emergency response status	Monitor Safety and Security	is_resource
Emergency response data	Monitor Safety and Security	is_resource
Emergency response status	Coordinate Service delivery	is_resource
Emergency response plan	Coordinate Service delivery	is_resource
Emergency response status	Monitor Operation	is_resource

Resources

lemma	SOURCE Function	relation
Human resources availability	Manage Human resources	is_output
ICT infrastructures	Manage ICT resource	is_output

Preconditions

lemma	SOURCE Function	relation
Staff trained	Train Staff	is_output

Control

lemma	SOURCE Function	relation
SLA(Service Level Agreement)	Manage financial affairs	is_output

Time

Emergency_respond_timing

<table>
<tr><td>Name</td><td>Restore/Repair UT operations</td></tr>
<tr><td>MTO Category</td><td>Human(M) - Technology (T)- Organization (O)
Prevalent category: Organization (O)</td></tr>
<tr><td>Description</td><td>Recovering UT services
Goal of the function is the restoration of routine UTS activities that were disrupted at a differing scale. The function encompasses activities planned before disruption (such as a Disruption Recovery Plan) and those improvised after a large-impact unforeseeable incident. The function must have availability of sufficient resources at least for short-term recovery at an acceptable level. It aims restoring urban transport services to their initial level.

The restoration of modal services enables cross-modal network operations of the transport system as a whole.</td></tr>
<tr><td>Input</td><td>The function may be started by monitoring signals of sensors, loops, CCTVs or mimic panels transmitted to control rooms of TMCs/OCCs. Social media content (tweets) are also instrumental for disruption alerts.

The function may activate internal procedures, disruption recovery plans and corrective actions such as mobilizing reserve capacities, VMS re-direction updates, SLAs for alternative temporary operations, inter-governmental agreements or temporary traffic interdictions.

Manage HR
Monitoring transport operations
Monitoring resource availability
Monitor user generated feedback
Collect event info

<table>
<tr><th>lemma</th><th>SOURCE Function</th><th>relation</th></tr>
<tr><td>Operation Restore service request</td><td>Coordinate Service delivery</td><td>is_output</td></tr>
</table>
</td></tr>
<tr><td>Output</td><td>Result of the function is a phased upgrading of the UTS operating mode. The successive restoration of UTS functionalities is measured by the rate of service recovery. Final aim is the full use of the service by potential travellers.
<table>
<tr><th>lemma</th><th>Destination Function</th><th>relation</th></tr>
<tr><td>Operation restored/repaired</td><td>Coordinate Service delivery</td><td>is_input</td></tr>
<tr><td>Operation Restore service plan</td><td>Manage awareness & usage behaviou</td><td>is_input</td></tr>
<tr><td>Operation restore/repair status</td><td>Manage awareness & usage behaviou</td><td>is_input</td></tr>
<tr><td>Operation restore/repair performance data</td><td>Collect event information</td><td>is_input</td></tr>
<tr><td>Operation restored/repaired</td><td>Monitor Operation</td><td>is_precondition</td></tr>
<tr><td>Operation restore/repair status</td><td>Coordinate Service delivery</td><td>is_resource</td></tr>
<tr><td>Operation Restore service plan</td><td>Coordinate Service delivery</td><td>is_resource</td></tr>
</table>
</td></tr>
</table>

<table>
<tr><td>Resources</td><td>In case of disruptions may be needed mobilization of stand-by O&M personnel, activation of a staff recall system or a HR replacement plan.
Spare vehicles or a retraction of alternative modal carriers based on SLAs may retain transport capacities.
IT resources such as telematics or a computer-aided dispatch of vehicles and drivers enable the recovery of scheduled services.
A collapse of the TMC or traffic signal system may be temporarily mitigated by traffic police resources.
Interim power shortages in unimodal urban transport may be mitigated by stationary reserve capacitors or mobile power banks.
<table>
<tr><th>lemma</th><th>SOURCE Function</th><th>relation</th></tr>
<tr><td>Human resources availability</td><td>Manage Human resources</td><td>is_output</td></tr>
</table></td></tr>
<tr><td>Preconditions</td><td>The disruption should be finished

A transport infrastructure in good order is a precondition of the transport service restoration.
Capacitated trained personnel with work experience.
Clear roles and responsibilities of the field & management personnel. Responsible body for permission to start operations has to be assigned in advance.
Restore physical infrastructure</td></tr>
<tr><td>Control</td><td>The pre-event recovery plan prioritizes transport services (links & nodes) to be restored.
In the transport industry, a typical target for the said function is 90%_operability in the short-/mid- term.
KPI metrics for service restoration is the time needed up to 90%_operability.
KPI metrics for demand recovery is a static resilience indicator measuring the transport demand covered by alternate carriage capacity as percentage of the transport demand reduction due to the disruption.
<table>
<tr><th>lemma</th><th>SOURCE Function</th><th>relation</th></tr>
<tr><td>Law</td><td>Regulate domain and operation</td><td>is_output</td></tr>
<tr><td>Standards</td><td>Regulate domain and operation</td><td>is_output</td></tr>
</table></td></tr>
<tr><td>Time</td><td>Restore_timing_plan
Depending on how crucial the operation is for the whole system operation

The pre-event recovery plan should define time-critical restoration activities.

In a (chrono) logical order, transport demand recovery follows service restoration.

A continuous (daily) monitoring of the transport operations recovery is advised.</td></tr>
</table>

LEARN

<table>
<tr><td>Name</td><td>Provide adaptation & improvement insights</td></tr>
<tr><td>MTO Category</td><td>Human(M) - Technology (T)- Organization (O)</td></tr>
<tr><td>Description</td><td>We must study both ordinary stresses and emergency situations.

The most intrinsic robustness of a transport system comes from continuous listening to the public, both the commuters and the occasional visitors.
The firsts learn and adapt the system inefficiencies, and can provide suggestions for long term amelioration.
The seconds provides immediate feedback, and because they don't know the system, they may suggest fast, short term amelioration, in communications, signaling, ticketing, availability and quality of comforts.

There shall be emergency training exercises.

After having listened to the people, conducted exercises, and eventually after that real emergency have been resolved, it should be enacted continuous debriefing, circulate the results for review and provide summaries to information exchanges.

Feedback must be shared with other transport systems withing the reach, in order to enforce the diffusion of good practices.

All organization personnel should be debriefed after completing each task.

Learn from ex-post event analysis, de-briefing, daily operations and provide insights for system capacities adaptation, Keep operations record, Examine good practices, perform impact analysis of suggested actions.</td></tr>
<tr><td>Input</td><td><table><tr><th>lemma</th><th>SOURCE Function</th><th>relation</th></tr><tr><td>Strategic plan</td><td>Develop Strategic Plan</td><td>is_output</td></tr></table></td></tr>
<tr><td>Output</td><td><table><tr><th>lemma</th><th>Destination Function</th><th>relation</th></tr><tr><td>System Sustained adaptability insights</td><td>Develop Strategic Plan</td><td>is_input</td></tr><tr><td>Event analysis insights</td><td>Perform Risk Assessment</td><td>is_input</td></tr><tr><td>Service sustained adaptability improvement insights</td><td>Coordinate Service delivery</td><td>is_input</td></tr><tr><td>ICT updated</td><td>Maintain physical/cyber infrastructure</td><td>is_output</td></tr></table></td></tr>
<tr><td>Resources</td><td>Knowledge base
Collect event information</td></tr>
<tr><td>Preconditions</td><td><table><tr><th>lemma</th><th>SOURCE Function</th><th>relation</th></tr><tr><td>Knowledge base</td><td>Collect event information</td><td>is_output</td></tr></table></td></tr>
<tr><td>Control</td><td>Data privacy/transparency legislation</td></tr>
<tr><td>Time</td><td>Periodical
Event driven</td></tr>
</table>

<table>
<tr><td>Name</td><td>Collect event information</td></tr>
<tr><td>MTO Category</td><td>Human(M) - Technology (T)- Organization (O)
Prevalent category: Human (M)/Technology (T)</td></tr>
<tr><td>Description</td><td>Collecting in house and external event data as good practices and/or historical data (archiving)

Archive info
Dynamic info
Post event

The collection, congregation and archiving of event data from disparate sources in the urban transport field is a challenging task. It refers to current/historical real-time data (e.g. structured transaction processing of smart cards or traffic density loop information, CCTV mass surveillance shots, unstructured traveller-generated social web content) as well as semi-structured information of on-duty personnel. Effective and efficient use of data collected is requested, for instance when performing pre-event risk assessments or post-event investigations.</td></tr>
<tr><td>Input</td><td>Routine operations and disruptive incidents in the transport provision produce big data and event information from different sources, asking for classification, aggregation and interpretation. The unimodal data collection is still the SoA. Cross-modal data integration is currently the exception.

<table>
<tr><th>lemma</th><th>SOURCE Function</th><th>relation</th></tr>
<tr><td>Safety Security performance data</td><td>Monitor Safety and Security</td><td>is_output</td></tr>
<tr><td>Training performance data</td><td>Train Staff</td><td>is_output</td></tr>
<tr><td>Emergency response data</td><td>Coordinate emergency actions</td><td>is_output</td></tr>
<tr><td>Operation restore/repair performance data</td><td>Restore/Repair operations</td><td>is_output</td></tr>
<tr><td>Operation performance monitoring data</td><td>Monitor Operation</td><td>is_output</td></tr>
<tr><td>Infrastructure restore/repair performance data</td><td>Restore/repair physical infrastructure</td><td>is_output</td></tr>
<tr><td>User generated service improvement suggestions</td><td>Monitor user generated feedback</td><td>is_output</td></tr>
</table></td></tr>
<tr><td>Output</td><td>Event stores, content repositories and transactional databases (DB) enable data mining, i.e. discovering structures, dependencies or visual threat correlations. Intelligence reporting covers routine performance and trends as a rule. Information about disruptive events – as a good practice - is stored in forms that allow data sharing & exchange with other agencies and law enforcement entities (LEE). Information understandability is critical for right decisions.

<table>
<tr><th>lemma</th><th>Destination Function</th><th>relation</th></tr>
<tr><td>Knowledge base</td><td>Provide adaptation & improvement insight</td><td>is_resource</td></tr>
</table></td></tr>
<tr><td>Resources</td><td>Requested are ICT infrastructure, storage capacity (incl. cloud depositories) as well as data & content mining software.
Backup communication channels for information transmission are essential in case of failures (e.g. normal telephones in case that TETRA/GSM communication breaks down).
DB experts and content mining specialists are needed too.

<table>
<tr><th>lemma</th><th>SOURCE Function</th><th>relation</th></tr>
<tr><td>ICT infrastructures</td><td>Manage ICT resource</td><td>is_output</td></tr>
</table></td></tr>
</table>

<table>
<tr><td>Preconditions</td><td>Data collection and semantic rules

Experienced control personnel and analysts are essential.
Agreed procedures for data integration and data exchange between agencies.</td></tr>
<tr><td>Control</td><td>An access control on collected information has to be in place for reasons of security and data privacy.
Semantic rules are important for valid inferences and reasons of information understandability.
Relevant extracted information has to be periodically validated against real field observations.

<table><tr><th>lemma</th><th>SOURCE Function</th><th>relation</th></tr><tr><td>Strategic plan</td><td>Develop Strategic Plan</td><td>is_output</td></tr></table></td></tr>
<tr><td>Time</td><td>Continuous

Real-time monitoring (operational level) and weekly/monthly reporting (tactical level).
Event-driven data retrieval and analysis.
Short response time when exchanging collected information among agencies is a critical issue.</td></tr>
</table>