TECHNICAL REPORT

ISO/TR 19083-1

First edition
2016-10-15

Intelligent transport systems — Emergency evacuation and disaster response and recovery —

Part 1: Framework and concept of operation

Systèmes intelligents de transport — Évacuation d'urgence et intervention en cas de catastrophe et rétablissement —

Partie 1: Cadre et concept opérationnel

Reference number
ISO/TR 19083-1:2016(E)

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

The committee responsible for this document is ISO/TC 204, *Intelligent transport systems*.

A list of all parts in the ISO series can be found on the ISO website.

Introduction

This document defines the framework and concept of operation for developing a public transport decision support system for evacuations and disaster response and recovery. This includes establishing the criteria under which public transport prepares for, responds to, and recovers from a disaster. The criteria, as established by national, regional and local governance based on the type and severity of the emergency, are used to identify the roles and responsibilities of public transport within the boundaries of the Intelligent Transport System architecture. For example, the criteria for a localized disaster such as a chemical plant fire will be governed by local or regional response plans and requires fast response times. Whereas, a hurricane having a wider impact may be governed by national response plans, as well as local and regional, and allow pre-planning to take place because they are typically slower moving. It is important to emphasize that this document focuses only on those activities related to ground transportation and does not address societal issues (i.e. sheltering, aid, security, etc.) nor does it address air or rail transportation associated with disaster management. The reader is directed to ISO/TC 292 for societal issues and to ISO/TC 20 SC 17 and ISO/TC 269 for air and rail transportation issues associated with disasters. This document adheres to ISO 22300, which contains terms and definitions applicable to societal security to establish a common understanding so that consistent terms are used.

It is also important to note that this document relies on national, regional, and local policies and authorities to create a concept of operation. The concept of operations defines the set of requirements needed for designing, developing, and deploying a Decision Support System for evacuation and disaster response and recovery. The Decision Support System is an interactive software-based system intended to help public transport emergency services personnel compile useful information from a combination of raw data, documents, and personal knowledge, or traffic models. This knowledge is then used to identify and solve evacuation and disaster response and recovery problems and disseminate those decisions to emergency managers, traffic managers, public transport, and the public itself. The Decision Support System is a natural progression from Computer Aided Dispatch and Automatic Vehicle Location systems which has been the core Intelligent Transportation Systems (ITS) used by public transport. The Decision Support System combines the use of traffic models and analytic techniques with traditional ITS data access and retrieval functions to solve less well structured, underspecified evacuation and disaster response and recovery problems that upper level managers may face in a disaster.

The goal of this document is to save lives and aid recovery by using ITS technologies to coordinate a comprehensive transportation response to disaster. This includes using the Decision Support System to identify routes and manage equipment and personnel to ensure public transport is used to evacuate people out of harm's way and provide transportation support for all response and recovery efforts from major disasters such as hurricanes, tsunamis, or catastrophic accidents. This document recommends public transport to serve as the primary mobility agent for all transportation-related actions before, during and after a disaster. This represents a paradigm shift from past response and recovery efforts such as the Great Japan Earthquake 2011 or Hurricane Katrina in the US, which typically see transportation-related activities coordinated by emergency managers who rely on traffic managers and public transport service operators to provide the services. While the emergency manager is the responsible individual for any disaster and will continue to do so, the role of coordinating transportation between traffic management, emergency services and public transport should be assigned to a public transport professional. The reasoning for this shift of responsibility is that public transport has the most experience and the resources to move large numbers of people efficiently and in a timely manner, which is paramount before, during and after a disaster. This may present problems in rural areas as ITS technologies, equipment and personnel may not be available to carry out these assignments. Additionally, problems may exist due to differences in country-based operational methodology between Asia, North America, and Europe. In Asia, public transport is predominantly run by privately owned and publicly traded mass transit and real estate conglomerates. In North America, public transport is predominantly run by municipal transit authorities. In Europe, public transport is predominantly run by both public-owned and private companies. The ideal solution is to ensure that a public entity is responsible for the public transport emergency management and that personnel operating the Decision Support System are professionals from the public transport sector.

The ISO/TR 19803- series recommends the creation of a cloud-based Emergency Evacuation and Disaster Response and Recovery (EEDRR) Decision Support System to assist, coordinate, and direct all transportation services, including those used by emergency management, traffic management and public transport. The cloud-based solution allows different services (i.e. servers, storage and applications) to be delivered to emergency management/public transport computers and devices through the Internet; thus, providing access to the EEDRR even when access to the physical area is not possible because of the disaster. The major actors involved in coordinating transportation services related to a disaster and the systems required for communicating the associated information are shown in Figure 1.

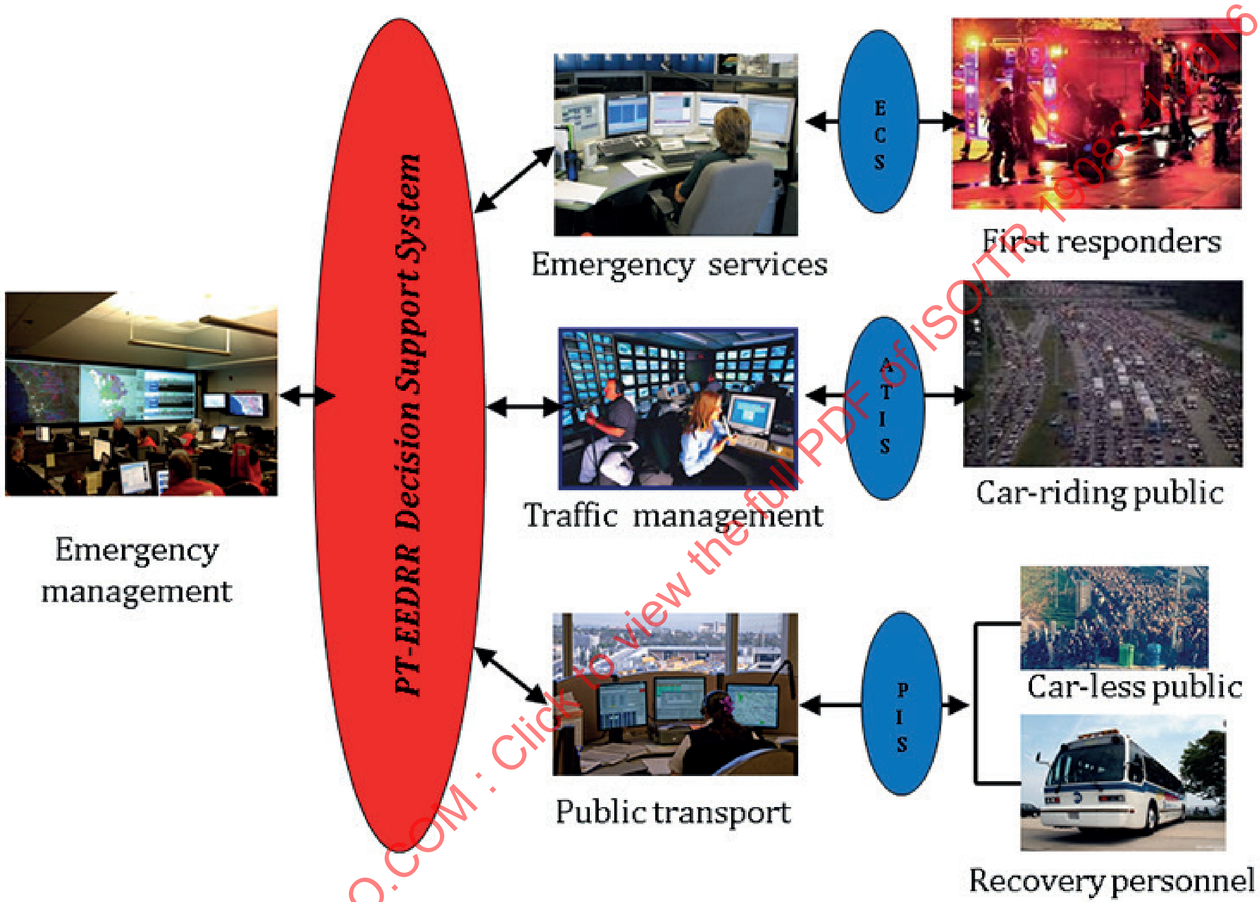

Figure 1 — Coordinated transportation services for disasters

As shown, there are eight major actors associated with transportation service during a disaster. Details of the roles and responsibilities are included in 5.4. The actors are at a group level and may vary from country to country. For instance, first responders include various people such as firefighter, emergency medical personnel, and police. In addition to these, those people who are managing infrastructures like electricity, water, sewage and gas play may also be part of the first responders. Moreover, individuals such as teachers may also act as first responders and be responsible for taking care of their students. The primary role and responsibility addressed by this family of standards is the coordination of emergency transportation services through existing communication channels by professional transportation planners and operators in public transport. The existing communication channels include emergency communications systems (ECS) used by first responders, advanced traveller information systems (ATIS) used by traffic managers, and passenger information systems (PIS) used by public transport. The cornerstone of this document is the EEDRR Decision Support System which will maintain the data and information sets used by public transport to make knowledgeable transportation-related decisions during the chaotic times leading up to, during and after a disaster. Figure 1 depicts the EEDRR Decision Support System being operated by public transport as part of emergency management. Transportation-related information and data are collected from and transportation-related decisions and actions are communicated to the other entities involved in the disaster.

The EEDRR Decision Support System is a computer-based transportation information system that supports critical transportation-related decision making activities during a disaster. The EEDRR Decision Support System is part of the Emergency Operations Centre and serves the emergency management, operations, and planning levels of the emergency management organization where planning levels mean those individuals who are responsible for planning the response as opposed to those individuals that are performing the actions required in a response. This system is operated by public transport emergency services personnel and helps to make transportation routing and equipment and personnel resource decisions, which may be rapidly changing and not easily specified in advance. It is an interactive software-based system that aids decision makers by compiling useful information from a combination of raw traffic and public transport data, policy documents, personal knowledge, and traffic models to identify and solve problems and assist transportation professionals in decision making. To ensure the information is useful and the sources are reliable, requires that data suppliers be vetted, data distribution networks are resilient, data management is expandable and modular, and data processing is organized into thematic applications such as floods, hurricanes, fires, earthquakes, etc.

Typical information that the EEDRR Decision Support System gathers and presents includes:

— local, regional, and national criteria for disaster evacuation, response, and recovery based on policies, plans and directives;

— benchmark evacuation times established by evacuation plans through best practices, regulations, or simulations;

— transportation resources available for evacuation, response, and recovery effort including traffic management and public transport;

— digital maps, images, political boundaries, sensor data, integrated transportation network models and other GIS related information;

— weather forecast, alerts, demand forecast, incident notification, and other real time information for mitigating traffic delays;

— damage assessments, risk factors, situational analysis, desired outcomes, and other real time information from field reporting;

— demographics for the regional population, passenger counts, special needs persons, and other information needed to estimate/determine the number of car-less persons in an area of interest;

— social media reporting of situation awareness as reported from various social media outlets (i.e. Facebook, Twitter, Line, Cyworld, Sina Weibo, etc.)

— and in the future, heuristic classifications that may be used to create an expert system as the use of artificial intelligence matures.

The EEDRR Decision Support System is an information processing system that runs on the public transport emergency services personnel PCs. The framework takes into account that each local jurisdiction has its own requirements, and thus in order to be useful this set of international standard should provide generic text that local jurisdictions can make distinctive to their own needs and communities by adding to and/or replacing the generic text with specific details. ISO/TR 19083 includes three parts:

— Part 1 — Framework and concept of operation for the use of public transport during an emergency evacuation or large scale disaster

— Part 2 — Information flow between Public Transport Passenger Information Systems, Public Transport Command and Control Systems, and Regional Emergency Operation Centres during a disaster

— Part 3 — Use cases needed to support public transport actions in disaster drills/exercises.

The framework for the ISO/TR 19083 series and an associated concept of operation is provided in Clauses 5 and 6, respectively.

Intelligent transport systems — Emergency evacuation and disaster response and recovery —

Part 1: Framework and concept of operation

1 Scope

This document

— defines the framework for the ISO/TR 19083 series of standards related to emergency evacuation and disaster response and recovery,

— establishes the criteria under which public transport should support evacuations and disaster response and recovery based on the magnitude of the disaster and the location as these factors drive the policies, directives and plans for each countries disaster prevention/evacuation systems,

— identifies the types of agencies and organizations involved in a regionally supported evacuation and disaster,

— defines the roles and responsibilities public transport entities should provide in planning, preparing for, and conducting evacuations and disaster response and recovery efforts in support of regional authorities,

— recommends the type of information required and necessary actions to be followed by public transport to ensure efficient and effective transportation in response to recovery from a disaster,

— provides a concept of operation describing the characteristics of the EEDRR Decision Support System from the viewpoint of an individual who will use the system for public transport disaster support, it is the guiding document for public transport services operators who voluntarily wish to develop EEDRR Decision Support Systems, and

— identifies guidelines to improve coordination among regional authorities when public transport disaster support is required.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purpose of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at http://www.electropedia.org/

— ISO Online browsing platform: available at http://www.iso.org/obp

3.1
actor
entity that fulfils a role

Note 1 to entry: The same definition can also be found in EN 302 665.

3.2
command-level decision making
decisions made by managers to manage and mitigate critical incidents

3.3
command-level decision makers
managers within public transport tasked with making decisions during critical incidents

3.4
command-level roles
management positions within public transport tasked with making decisions during critical incidents

3.5
commercial vehicle
any type of motor vehicle used for transporting goods or paid passengers

3.6
computer-aided dispatch/automatic vehicle location systems
central software used by dispatchers for operations management that periodically receives real-time updates on fleet vehicle locations

Note 1 to entry: Computer-aided dispatch systems use one or more servers located in a central dispatch office, which communicate with computer terminals in a communications centre or with mobile data terminals installed in vehicles.

Note 2 to entry: Utilize the capabilities of geographic information systems (GIS) and GPS-based automatic vehicle location (AVL) to show real time vehicle location on a map display.

3.7
data
reinterpretable representation of information in a formalized manner suitable for communication, interpretation or processing

Note 1 to entry: Data can be processed by humans or by automatic means.

[SOURCE: ISO/IEC 15944-5:2008, 3.35 modified]

3.8
disaster
situation where widespread human, material, economic or environmental losses have occurred which exceeded the ability of the affected organization, community or society to respond and recover using its own resources

[SOURCE: ISO 22300:2012, 2.1.11]

3.9
disaster planning
first phase of disaster management cycle consisting of prevention and preparedness

3.10
disaster recovery
recovery phase that starts after the immediate threat to human life has subsided with the immediate goal to bring the affected area back to normalcy as quickly as possible

3.11
disaster response
second phase of the disaster management cycle consisting of warning/evacuation, search and rescue, providing immediate assistance, assessing damage caused by the disaster, continuing assistance and the immediate restoration of infrastructure

3.12
emergency management organization
group of people that has its own functions with responsibilities, authorities and relationships to the overall approach preventing and managing emergencies that might occur

Note 1 to entry: In general, emergency management utilizes a risk management approach to prevention, preparedness, response and recovery before, during and after potentially destabilizing or disruptive events.

[SOURCE: ISO 22320:2011, 3.35 modified]

3.13
emergency operations centre
EOC
central location from which local, regional or national governments can provide interagency coordination and executive decision making in support of disaster response and recovery operations

Note 1 to entry: to entry. The purpose is to provide a centralized location where public safety, emergency response, and support agencies coordinate planning, preparedness, and response activities.

Note 2 to entry: to entry. The EOC does not command or control on-scene response efforts, but does carry out the coordination functions through

a) collecting, evaluating and disseminating disaster related information,

b) analysing jurisdictional impacts and setting priority actions, and

c) managing requests, procurement and utilization of resources.

3.14
exercise
process to train for, assess, practice, and improve performance in an organization

Note 1 to entry: Exercises can be used for validating policies, plans, procedures, training, equipment, and inter-organizational agreements; clarifying and training personnel in roles and responsibilities; improving inter-organizational coordination and communications; identifying gaps in resources; improving individual performance; and identifying opportunities for improvement, and controlled opportunity to practice improvisation.

Note 2 to entry: A test is a unique and particular type of exercise, which incorporates an expectation of a pass or fail element within the goal or objectives of the exercise being planned.

[SOURCE: ISO 22300:2012, 2.4.9]

3.15
hazardous material
any item or agent (biological, chemical, radiological, and/or physical), which has the potential to cause harm to humans, animals, or the environment, either by itself or through interaction with other factors

3.16
incident
situation that might be, or could lead to, a disruption, loss, emergency or crisis

[SOURCE: ISO 22300:2012, 2.1.15]

3.17
man-made disaster
disastrous event caused directly and principally by one or more identifiable deliberate or negligent human actions

3.18
private vehicle
two- or four-wheel vehicle that are not used to carry passengers for a fee

3.19
public safety agency
includes emergency management agencies, law enforcement agencies, fire departments, rescue squads, emergency medical services and other such entities whose purpose is to enhance the public welfare

3.20
public transport
shared transport service which is available for use by the general public and includes city buses, trolleybuses, trams (or light rail) and passenger trains, rapid transit (metro/subways/undergrounds, etc.) and ferries

3.21
public transport emergency management
managerial function charged with creating the framework within which public transport reduce vulnerability to hazards and cope with disasters

3.22
public transport emergency services personnel
persons within public transport responsible for transportation-related mitigation activities in an evacuation or disaster including pre-disaster planning, response, and recovery

3.23
public transport emergency response team
persons within public transport responsible for transportation-related mitigation activities in an evacuation or disaster including pre-disaster response planning and disaster response

3.24
public transport recovery team
persons within public transport responsible for transportation-related mitigation activities in an evacuation or disaster including pre-disaster recovery planning disaster recovery

3.25
public transport emergency manager
person responsible for the overall strategic command of the emergency response effort such as risk identification and mitigation

3.26
public transport emergency operations coordinator
person responsible for managing the tactical functions such as coordination with field supervisors, assigning vehicles and drivers/operators to routes, monitoring traffic flow, etc.

3.27
public transport emergency planning coordinator
person responsible for the collection, evaluation, forecasting, dissemination, and use of the information about the emergency incident and status of resources

3.28
public transport recovery manager
person responsible for the overall strategic plan of the recovery effort to include damage assessment and recovery planning for short-term, intermediate, and long-term mitigation

3.29
public transport recovery communication coordinator
person responsible for informing outside organizations and the public of recovery plans and services

3.30
public transport recovery project coordinator
person responsible for managing mutual aid request and work associated with infrastructure repair

3.31
public transport emergency logistics coordinator
person responsible for managing logistical support such as personnel, vehicles, equipment, and supplies

3.32
public transport operator
private, profit-driven entity that provides shared transport service which are available for use by the general public and includes city buses, trolleybuses, trams (or light rail), passenger trains, rapid transit (metro/subways/undergrounds, etc.) and ferries

3.33
public transport service manager
public entity that manages and may provide shared transport service which are available for use by the general public and includes city buses, trolleybuses, trams (or light rail), passenger trains, rapid transit (metro/subways/undergrounds, etc.) and ferries

3.34
regional
layer within the emergency management hierarchy that exists between national and local

Note 1 to entry: Local is this instances means a government entity covering a small geographic area such as a town or city.

3.35
shared-use vehicle
vehicle used by several different individuals throughout the day

Note 1 to entry: There are three basic shared-use vehicle system models: neighbourhood car sharing, station cars, and multimodal shared-use vehicles.

3.36
strategic command
organization responsible for formulating the strategy for dealing with the incident

3.37
tactical functions
formulated from strategic plans the sets of actions dealing with the incident that are completed in the field

3.38
traffic flow models
use of computer modelling to simulate the of interactions between vehicles, drivers, pedestrians, cyclists, other travellers and infrastructure (including highways, signage, and traffic control devices), with the aim of understanding and developing an optimal road network with efficient movement of traffic and minimal traffic congestion problems

3.39
use case
sequence of actions that an actor (usually a person, but perhaps an external entity, such as another system) performs within a system to achieve a particular goal

[SOURCE: ISO 25102:2008, 2.12 modified]

4 Symbols and abbreviated terms

ATIS	advanced traveller information system
CAD/AVL	computer aided dispatch/automatic vehicle location
DSS	decision support system
ECS	emergency communications system
EEDRR	emergency evacuation and disaster response and recovery
EOC	emergency operations centre
HAZMAT	hazardous materials
ISDM	interagency shared data message
ISO	International Organization for Standardization
ISR	interagency service request
ITS	intelligent transport systems
I2V	infrastructure to vehicle communications.
MOU	memorandum of understanding
NRC	United States Nuclear Regulatory Commission
PIS	Passenger Information System
PT	public transport
PT-EEDRR-DSS	public transport decision support system for emergency evacuation and disaster response and recovery
PTMS-IAM	public transport management system interagency message
TERA	transit emergency response application
TMC	traffic management centre
V2I	vehicle to infrastructure communications

5 Overview and framework requirements

5.1 General

The ISO/TR 19083 series is designed to assist public transport in creating a Decision Support System that is scalable to and integrates with a regional Emergency Operations Centre (EOC). The primary goal is to use this document to develop a formal set of requirements that would be used to acquire an EEDRR Decision Support System. The content and design of the ISO/TR 19083 series provides a foundation from which public transport agencies can develop a customized EEDRR Decision Support System using national, regional, and local guidance, and the wealth of information and expertise available in the emergency management community.

The ISO/TR 19083 series includes three parts:

— Part 1 — Framework and concept of operation for the use of public transport during an emergency evacuation or large scale disaster

  This provides the framework and concept of operation for the ISO/TR 19083 series. The framework describes the criteria required for involving public transport in an evacuation, the actors involved in the event, and the roles and responsibilities of public transport. The concept of operation contains the operational concepts developed by the United States Department of Transportation Federal Highway Administration for evacuation transportation management and includes specific operational scenarios for public transport. It is impossible to list all possible disaster scenarios. But, it is important to note that a scenario should reflect the most catastrophic imaginable disaster. Before the Great East Japan Earthquake occurred on 11 March 2011, the target disaster of a disaster prevention plan had been the maximum one in scale that occurred in the past. However, the Great East Japan Earthquake and the tsunami were beyond expectation and caused unprecedented damages to Japan. Disasters of this kind occur very rarely, once in several thousand years, and hence there is usually no record left in many cases. However, if it does occur, the damage is enormous. Therefore, it is recommended that the most catastrophic imaginable disaster be included in emergency management planning.

— Part 2 — Information flow between Public Transport Passenger Information Systems, Public Transport Command and Control Systems, and Regional Emergency Operation Centres during a disaster

  This identifies the information exchanged between public transport service operators and Emergency Operations Centres during an evacuation or as part of a disaster response and recovery effort. This includes a common message structured in a uniform and open format, to enable the exchange of information among multiple agencies with unique requirements, policies, and operating environments. Two interagency shared data messages (ISDM) are planned, the interagency service requests (ISR) and the Public Transport Management System interagency message (PTMS-IAM). The ISR specifically requests services rendered by public safety agencies and secondary responder services. ISRs may be between Public Transport Decision Support Systems for Emergency Evacuation and Disaster Response and Recovery (PT-EEDRR-DSS) and Emergency Operation Centres (EOC) to specifically request public transport safety and secondary responder services. The IAM relates to public transport control requests between PT-EEDRR-DSS and the EOC.

— Part 3 — Use cases needed to support public transport actions in disaster drills/exercises

  This provides the use cases that are relevant to public transports participation in disaster drills and exercises. The objective is to develop a mechanism that improves the effectiveness of Public Transport Evacuation Decision Support System by employing use case diagrams that can easily be added or changed as the system evolves and be used as a feedback instrument to enhance requirements for future systems.

5.2 Criteria for using public transport for evacuation and disaster response

5.2.1 Overview

Establishing the criteria by which public transport is used to evacuate populated areas and respond to disasters is highly dependent on local, regional and national authorities and policies. Additionally, these authorities and policies often change in response to a large scale disaster. A prime example is the Department of Homeland Security (DHS), formed as a result of the 9/11 terrorist attack, and is the ultimate authority for disaster response and recovery in the United States. Similarly, the Post-Katrina Emergency Management Reform Act of 2006 and the Pets Evacuation and Transportation Standards Act of 2006 were laws enacted by the United States to provide policies and funding for emergency planning as a result of Hurricane Katrina. These authorities and policies define the criteria for using public transport to evacuate residents. Annex A provides a list of those policies and directives for each participating country.

5.2.2 Planning assumptions for evacuations

With regard to authorities and policies around the world, a common logic exists as to when evacuation, response and recovery measures should be taken. The logic is based on need, evacuation times, and resources. However, evacuation is not always required or possible. Whether to evacuate is dependent on the type and magnitude of the disaster. For example, if a strong earthquake occurs in the western part of Japan, a big tsunami will hit the coastal area in five minutes. In this case, evacuation by car or PT is useless. The only way is to go upstairs and shelter in place. In this case, the transportation needs shift from emergency evacuation to disaster response and recovery. Additionally, the machinery and equipment for monitoring and controlling routes will be damaged by the disaster, so these functions will not be available for some time after a big disaster. In these cases, the primary effort will focus on assessing the damage and requesting resources from areas outside the disaster area to aid in the response and recovery efforts.

5.2.2.1 Identifying the need

The information described in this subclause is focused on pre-disaster evacuations such as would occur when a hurricane or cyclone is approaching an area. Transportation need in this case is driven by the demographics of the population to be evacuated and need to develop evacuation models which typically use four population segments:

— permanent residents (employed, unemployed, retired) and transient population (visitors and tourist) using private automobiles;

— public transport-dependent permanent residents and transient population using public transport;

— special facility residents (e.g. hospitals, prisons, nursing homes, etc.);

— school populations.

Additionally, special needs exist for public safety personnel who are involved in the response and recovery efforts as they will require transport into and out of the impacted areas. Each of these populations requires unique transportation services during an evacuation or disaster.

The use of private transportation which includes automobiles, trucks, motorcycles, bicycles, etc. by residents and transient population during a disaster will vary depending on whether the impact area is urban, suburban, or rural. The numbers of private transportation users can overwhelm the available roadways, potentially causing gridlock and posing a significant challenge to traffic management. Traffic managers are the key actor in planning evacuation routes and managing traffic flow for private transportation. Numerous ITS technologies exist to assist with traffic flow models as well as monitoring and controlling routes. The Concept of Operation references the role and responsibility of traffic managers but does not provide detailed operational procedures but rather references to where these procedures can be found and more importantly what information is required from traffic management.

Public transport dependent permanent residents and transient populations include those who do not have access to a vehicle or are dependent upon help from outside the home to evacuate. This population group may include:

— households

  — with no vehicle,

  — with unsupervised latchkey children,

  — with one vehicle that is at work and would not return,

  — where residents have limitations on driving (e.g. elderly who do not drive at night or do not drive distances of more than a few miles), and

  - — dependent on specialized transportation such as wheelchair vans or ambulances;
- — commercial venues and businesses, such as hotels and motels, malls, restaurants, etc. that may house populations without automobiles due to accessibility by public transport;
- — airports, train stations, port terminals, etc. where transient populations may be entering the area.

Identification of this population is a key consideration for any successful evacuation and as such a key function for the Concept of Operation. Surveys are helpful in identifying the site specific demographics of this population group; however, they have proven to be of limited value in the response phase of an evacuation. A more useful method is the development of a network that uses key people and organizations that already have relationships with members of these populations to identify and communicate with during an evacuation. For example in the United States and other countries, public transport service operators provide specialized transportation services to the elderly and disabled. These organizations maintain accurate records of the riders who utilize these services and as such can easily identify the population within an impact area. Other such agencies and organization exist and should be leveraged by public transport service operators to identify and communicate with the public transport dependent populations.

Special facilities residents require specialized transportation such as ambulances, wheelchair accessibility, or secure transport. The number of vehicles available to provide these services are limited and as such require lengthy evacuation times. Additionally, coordination of these services requires significant time and is usually spread across emergency services and public transport or in some cases, traffic managers. Advanced planning is required to ensure this population is accounted for in a disaster. This includes ensuring that these facilities are part of any evacuation exercise and that inventories are maintained of vehicles required by the facilities.

School populations also present a unique challenge because of the wide array of setting that exists. These populations include early years (ages 3 to 4), primary education (ages 5 to 11), secondary education (ages 12 to 18), and tertiary education (18+). Again as with special facilities residents, advanced planning is required and significant coordination is needed to ensure this population receives the resources needed.

But, this identification is not easy as the use of a network that uses key people and organizations does not always work successfully because key people and/or organizations are impacted by a disaster and therefore special agreements must be put in place to ensure that key people especially in public transport understand and accept these responsibilities. In addition, special facilities residents do not always stay at the same place. It may be necessary to trace their movement but enacting similar special agreements with special facilities personnel.

An alternative may be to utilize location data from mobile phones. Most mobile phones in use today transmit time stamped location data to cell towers for use by carriers and phone makers. The resulting massive data sets which are collected almost in real time may be used to identify where people are congregating in a disaster. This is an evolving technology that should be evaluated as a viable source for identifying the need.

This all assumes that people should evacuate if a disaster happens. But, this does not always hold true. Some disasters may not require departure from the building but rather moving to higher areas of the building or just sheltering in place. The need must also delineate between horizontal evacuations (fleeing an area) and vertical evacuations (sheltering in place).

5.2.2.2 Response times

Once the population base has been identified, an estimate is required for the time to evacuate those residents impacted by the disaster. Estimating the response time is accomplished using modelling techniques. This set of standards selected the process published by the United States Nuclear Regulatory Commission *Criteria for Development of Evacuation Time Estimate Studies, Sandia National Laboratories, and November 2011*.

This study identified the importance of reviewing local and regional emergency plans to ensure there are processes and procedures in place to provide transportation to public transport dependent residents during an emergency response. Where local plans exist, they should be used to develop the estimated response times for evacuation. The Emergency Operations Centre (EOC) is responsible for making protective action recommendations and decisions. It is necessary to obtain this information in order to complete the estimated time for evacuation. Developing the routes to be followed by the buses and the time it will take to complete a trip is assumed to be a key function within the Concept of Operation and should be based on evacuation directives issued by the EOC.

Evacuation response times are also impacted by when it occurs, how much warning, and what damage has occurred. The time of day, day of the week and time of year all may have varying impacts to an evacuation. Week day traffic is different at rush hour versus late at night or on the weekend. Holidays, seasons, and special events also impact response times. Additionally, no-warning disasters change the evacuation response times because of the damage in all likelihood will cause road closures and damage electrical and communication infrastructure. Models in these situations will offer little help and it will be the experience and knowledge of the public transport, traffic management, and emergency management personnel that will be needed to make real time life-saving decisions.

5.2.2.3 Resource assignment

With the routes and time estimates for completing an evacuation in place, the task of assigning resources to complete the evacuation becomes the next challenge. The seating capacity of municipal buses is based on adults. A reasonable estimate for buses is 50 % of the stated seating capacity (NRC, 2008a) with no credit taken for standing room capacity. Care should be taken not to double-count resources when calculating transportation needs for populations dependent on public transport and the transportation needs for special facility residents. Special facility residents are those residents that are housed in special facilities which are assumed to provide their own transportation. However, a subset of public transport dependent residents includes people with disabilities and those with access and functional needs that live independent of a special facility. Surveys conducted in the United States found that 6 % of respondents said they, or someone in their household, would need special assistance to evacuate. Information on households with residents dependent on specialized transportation such as wheelchair vans or ambulances should be developed and quantified separately from the other residents. This assumes that wheelchair equipped vans will be dispatched to individual homes while the traditional fixed route buses would be dispatched to staging areas. A summary of the total number of vehicles (e.g. buses, vans, specialized transport vehicles) available to support the evacuation of public transport dependent residents, as well as people with disabilities and those with access and functional needs, not residing in special facilities should be developed. This will support the determination of how many evacuation runs may be needed. Assigning operators, briefing personnel (supervisors, dispatchers, maintenance, operators, etc.) and initiating an orderly pull-out will signal the launch of the evacuation. This describes an optimistic evacuation in an orderly world without damage and loss of life. When a disaster does strike, the infrastructures of public transport and electric power supply may be damaged. In addition, drivers, operators and other persons are not able to assemble. These situations must be considered and planned for in advance. Moreover, the ambulances that may have been used for evacuation will then be used for the rescue of those who are injured. The number of ambulances is, therefore, not sufficient for evacuation.

Once the evacuation is underway, the monitoring phase begins and is required to ensure an orderly response to the changing nature of an evacuation. During the initial stages of the evacuation routes may change or additional resources may be required based on the activities being reported from the field. Public transport responsibilities during the monitoring phase depend on the longevity of the event. For planning purposes, it should be safe to assume that the monitoring phase will last for days or possibly weeks and will include not only the initial evacuation efforts to move people to shelters but also satisfying the continuing need for transportation once an evacuee is settled in a shelter. Intermediate and long term support in the way of new routes or demand response services will require additional resources for those evacuees in shelters and without transportation. Also it is assumed that during the monitoring phase, a plan for returning evacuees is developed.

Another key challenge of an evacuation is the need to transport humanitarian assistance cargo. As the monitoring phase may last for days or possibly weeks, the needs of evacuees change drastically during this time. It will be necessary to transport a large amount of goods to them. For goods transportation, large areas are required for cargo handling and equipment, personnel and routes must be managed to ensure the cargo is effectively and efficiently distributed to the shelters. The staging areas for humanitarian assistance cargo are near airports or seaports where aircraft and ships are able to deliver the cargo. They are managed by a combination of government and non-government agencies. These logistics experts will rely on public transport to plan and manage the transport of cargo from the staging area to the shelters.

Reverse embarkation will return an evacuee to origin (staging area, or home) and will occur when the order is given. It is assumed that the same logic (need, reverse evacuation times, and resources) should be applied for reverse embarkation. This phase continues until the last evacuee is returned home or assigned to other temporary housing.

One other key aspect of the evacuation process is the staging of public transport resources. It is assumed that vehicles will be staged in an area not impacted by the disaster and will be able to remain in service throughout the disaster. This assumes that public transport service operators move vehicles out of harm's way and that public transport facilities are available to monitor and direct these resources during the disaster. Of course a disaster by its nature may destroy these resources and thus it requires the need for mutual aid from service operators outside the affected disaster zone. This need also is required to assemble drivers, operators and their replacements.

Finally, planning assumptions for disaster should also include those activities associated with the recovery phase. It is assumed that planning for recovery begins as soon as a disaster is recognized. Transporting recovery personnel begins as soon as the emergency responders have deemed the impacted area safe. Resources should be assigned to move recovery personnel and heavy machinery from staging areas to impact zones. The time period for recovery personnel transporting may be months or longer depending on the severity of the disaster.

5.2.3 Other key considerations for disaster response and recovery efforts

5.2.3.1 Events with and without warning

Transportation services for disaster response and recovery apply to events for which there are warnings (e.g. hurricanes, flooding) as well as events for which there are little or no warnings (e.g. industrial accident, earthquakes, man-made disasters).

5.2.3.2 Critical infrastructure

Critical infrastructure presents a range of implications for transportation services both within the impacted areas and across the region. The losses of the power grid or cellular networks are two examples that would provide major impacts to the transportation services response and recovery efforts. Access to the Internet, emergency electric power sources, fuel tanks, road closures, rail line failures, bridge closure and ferry service stoppage are additional impacts. The analyses of impacts to critical infrastructure based on computer models operated by national services are a key input to the planning process. These sources can be used to prioritize recommendations and develop protocols for requesting mutual aid from non-impacted areas.

5.2.3.3 Limits in forecasting a disaster

The variables in forecasting track, intensity, and forward speed of weather systems, flooding, wildfires, plumes, and in certain cases hazmat make it extremely difficult for decision makers to commit equipment and personnel as much as five days in advance of a disaster. Thus, monitoring and heeding warning is a key factor in pre-planning preparation and a major function of a decision support system.

5.2.3.4 Interdependencies between shelters and transportation

The transportation solution to a disaster response and recovery is based on the numbers of people needing evacuation, availability of privately owned transportation, numbers of evacuees with special mobility and medical needs, the time available to conduct operations, and the distance to (and availability of) shelters. If shelters are located too far from embarkation points, transportation assets (buses, trains, vans) cannot be recycled and may only make one trip during the operation. As a result, the distance travelled may reduce capacity to respond exponentially. It is critical for public transport service operators to identify and pre-designate transportation dependent and special needs population shelters as near to the embarkation points as safely possible. The designation of shelters that will accommodate pets is peculiar to the United States but the need does exist to develop both shelters with and without pets which may add another challenge to ensure both types are near impact areas to minimize travel time.

5.2.3.5 Interdependencies between response and recovery efforts

Moving emergency personnel, workers, equipment, supplies and also providing a mobile safe space for these entities is also part of the transportation effort in a disaster. As an example, in 2009 a catastrophic wildfire struck Kelowna, British Columbia that caused the evacuation of tens of thousands of people and cut off roads access into this area of British Columbia. The West Coast Express, a public transport commuter rail service in the Greater Vancouver Regional District, quickly put together a plan to use its passenger rail cars to transport response and recovery workers and their equipment and supplies from Vancouver to the British Columbia Interior. Planning should take into account the needs of both the response and the recovery effort since these activities often overlap but are also directed by separate groups within the Emergency Management structure.

5.2.3.6 Special needs of children

It is critically important to recognize the special needs of children during a disaster. In a no-notice evacuation, children could be gathered in large numbers away from their parents, whether at schools, childcare facilities, summer camps, hospitals, or other locations. Reunification of children separated from their parents will be an issue during recovery and consideration must be given to the transportation needs of accomplishing this.

5.2.3.7 Special needs populations

Transportation assistance such as wheelchair access must be made for the special needs of the citizens of the affected area. These needs may include practical and/or functional assistance in communication, mobility (sight and physical) and medical care. Establishing a network of caregivers who are trained and available to assist transportation service providers is a key factor in relocating special needs populations.

5.2.3.8 Animals

The requirements for transporting and arranging for shelter and care of animals when they need to be relocated from their homes are of significant importance. There are special disaster response and recovery requirements for each category of animals:

— Service animals: Service animals include guide dogs, signal dogs, or other animals individually trained to provide assistance to an individual with a disability, including, but not limited to, guiding individuals with impaired vision, alerting individuals with impaired hearing to intruders or sounds, providing minimal protection or rescue work, pulling a wheelchair, or fetching dropped items. It is important that service animals have access to the same transportation resources as the humans they serve.

— Household pets: Planning for and accommodating household pets as a component of disaster response and recovery is critical. History demonstrates that many residents will refuse to relocate or resist rescue if they are forced to leave their household pets behind. Therefore, without advance planning, the tracking, embarkation, transportation, care, feeding, and sheltering of household pets can significantly impact the ability to safely relocate the public transport-dependent population. Transporting household pets require special coordination with the regional and local government to

  — identify shelter locations to which household pets may be relocated,

— provide specifications for vehicles that can be used to relocate household pets, and

— ensure that animal relocation and response instructions and status updates are communicated appropriately and in a timely manner.

5.2.3.9 Environmental contamination causing health related damage

Transportation services may be impacted when they are required in response to a large-scale hazardous materials (HAZMAT) incident. Transportation decision makers should consult with available HAZMAT officials as appropriate regarding the location of embarkation sites and service routes. National Centres may be required to provide assessments for radiological incidents. Advisory teams for health, environment, food, public safety and security (the HAZMAT incident may be security related) provide additional support to decision makers and as such it is an important function of the decision support system to identify these resources based on the type of hazardous material involved in the evacuation response.

5.2.3.10 Victim decontamination

Regional and local officials retain primary responsibility for victim screening and decontamination operations when necessary in response to a HAZMAT incident. Transporting these victims will require coordination and training to ensure that appropriately trained personnel and equipment are available. Without appropriate decontamination and proof of decontamination, neighbouring jurisdictions may resist accepting evacuees that are contaminated. This screening process applies to chemical, biological, and nuclear contamination events,

5.3 Agencies and organizations involved in a regionally supported evacuations and disaster response and recovery

5.3.1 Overview

Agencies and organization involved in an evacuation or disaster response and recovery effort vary around the world. This set of International Standards uses three agency types for easier categorization of the numerous agencies that may take part in disaster event. The purpose of categorizing the agencies was to help in distinguishing the various levels of jurisdiction that agencies may take on in an “ideal” setting. In actuality, there may be agencies that operate in dual roles, such as local and regional roles. These are likely to be more common in rural settings. For the purpose of these standards, a hierarchical structure is assumed.

5.3.2 Local

The local agency would be the jurisdiction in which the incident has occurred. The local agency would determine the severity of the incident and identify the need for evacuation.

Examples of local agencies include:

— Municipal Emergency Management Department;

— Area Traffic Management and Roadway Department;

— Municipal Police Department;

— Municipal or Area Public Transport Department.

5.3.3 Regional

Regional agencies include those jurisdictions that exist between the local agencies and the national agency. Typically, evacuation orders come from the regional level (in Japan, the Meteorological Agency of Japan issues alarm and warning). In most instances, the regional emergency operations centre will assume a lead role and work in conjunction with local and national agencies. Regional agencies may also play a support role, providing additional resources and personnel as needed, to assist local agencies in conducting an emergency evacuation or responding to a disaster. However, the magnitude of the disaster with respect to the area impacted may require establishing a super-regional emergency operation centre that coordinates response and recovery over multiple sub-regional centres.

Examples of regional agencies include:

— County/State/Prefectural Office of Emergency Management;

— County/State/Prefectural Office of Public Safety;

— County/State/Prefectural Regional Department of Transportation;

— County/State/Prefectural Police.

5.3.4 National agencies

National agencies tend to play a coordinating or investigative role after the disaster has taken place. National agencies may also conduct an evacuation operations assessment after local and regional agencies have implemented the evacuation. National agencies also provide direct funding to evacuation effort and as such require detailed information for reimbursements by both local and regional agencies. If the magnitude of a disaster is great, national agencies may play a leading role by giving instructions to local governments and supplying them with necessities

5.3.5 Other agencies

All other non-governmental agencies are categorized as other agencies. These would include the media and private sector agencies that also play an important role in the evacuation such as the Red Cross. They serve and assist the evacuees throughout the process, often having the most direct contact with the affected population. The roles of social networking services and non-profit organizations also play an important role in collecting and disseminating information.

5.4 Roles and responsibilities

5.4.1 General

Examples of the roles and responsibilities of public transport in support of an emergency evacuation and response caused by a disaster are defined in Table 1. The table is organized by the six phases of a disaster response as defined in *Task 5 Operational Concept — Assessment of the State of the Practice and State of the Art in Evacuation Transportation Management, Report Number FHWA-HOP-08-020, Federal Highway Administration, US. Department of Transportation, June 2006*. The six phases of activities that form a general progression of events are:

— Phase 1 — Advanced Planning;

— Phase 2 — Incident Notification;

— Phase 3 — Activation and Mobilization;

— Phase 4 — Evacuation Operations;

— Phase 5 — Re-Entry;

— Phase 6 — Debrief and Assessment.

These phases represent the major activities associated with transportation service in an evacuation or response effort. Given the spontaneous and chaotic nature of emergency incidents, these phases are likely to overlap in time. Therefore, the progression does not indicate a firm timeline.

In addition, it should be noted that these phases are associated with the disaster response activities and do not include the roles and responsibilities of public transport in the recovery phase of a disaster.

The distinction between recovery and response is important. The skills, resources, objectives, time horizons, and stakeholders of the response and recovery phases are dramatically different. From a public transport and ITS perspective, the recovery process has received minimal attention from researcher and government agencies with the exception of Canada. This set of International Standards considers it an important phase to be addressed by ITS technologies since transportation needs are inherent in all phases of the recovery efforts. As such, the standards use the four phases described in the report published by the National Cooperative Highway Research Program[9] and incorporates Canada's experience in this area as the recovery process for transportation services:

— Pre-disaster preparedness — planning for recovery and resilience prior to the event and conducting exercises and drills.

— Short-term recovery — in the days following an event transport support for sheltering, restoring urgent infrastructure and services, and clearing routes.

— Mid-term recovery — in the weeks and months following an event restore service and support impacted areas by providing specialized transportation service based on needs.

— Long-term recovery — in the months and years rebuild the transportation infrastructure for the future, implement mitigation plans from lessons learned, and build in resiliency to the transportation network.

These phases differ slightly from the traditional recovery phases in that a mid-term recovery phase is included. This representation shows agencies borrowing buses, vans, ferries, and commuter from agencies outside the impacted area and as such provides a temporary but not long-term solution to recovering service. Examples of the roles and responsibilities of public transport in the recovery phase of a disaster are in Table 2.

5.4.2 Disaster response roles and responsibilities for transportation services

5.4.2.1 Advanced planning

The primary role and responsibility for advanced planning of all activities associated with disaster response belongs to the Emergency Management organization. However, transportation services associated with disaster response belongs with public transport emergency response organization. Planning and organization of transportation services are required prior to an event actually taking place if total chaos is to be avoided. The primary purpose of the advanced planning stage is to populate the EEDRR Decision Support System with the information needed to make decisions when a disaster strikes. With an emphasis on ensuring accurate information populates the EEDRR Decision Support system to include population identification, evacuation times, and resource availability are in place. The Emergency Management Organization is responsible for working together with the public transport emergency response organization to establish a coordinated system and includes identifying roles and responsibilities, resources, key personnel and communication methodology. Education of the public with respect to transportation services is also covered as advanced planning for the public transport emergency response organization.

5.4.2.2 Incident notification

This phase assumes an incident has occurred and notification efforts have been enacted by Emergency Management. The establishment of an Emergency Operations Centre (EOC) is the key function of this phase as the EOC serves as the nerve centre for the evacuation or response effort. The purpose of the EOC is to provide a centralized location where public safety, emergency response, and all support agencies including public transport coordinate planning, preparedness, and response activities. The EOC does not command or control on-scene response efforts, but does carry out the coordination functions through

a) collecting, evaluating and disseminating disaster related information,

b) analysing jurisdictional impacts and setting priority actions, and

c) managing requests, procurement and utilization of resources.

Typically, incident notification to activate the EOC will be issued by the regional Emergency Management Organization. Public transport emergency personnel and equipment move into the EOC when notified by the Emergency Management Organization. This assumes a warning message has been issued before a disaster occurs. For those little or no warning disasters, the incident notification may occur after the damage has been incurred and thus require establishing an EOC at a physical location that has access to communication.

5.4.2.3 Activation and mobilization

This phase involves the dissemination of information to the public and all preparation for the actual evacuation or response. The EOC becomes operational in this phase. The magnitude of the disaster determines whether the EOC is operated at the local, regional, or in rare occasions national level. Public transport emergency response managers are briefed by emergency managers and in turn activate the required support resources within public transport. The key function of this phase is the identification of evacuees, route, time estimates, and resources required to conduct the evacuation or response. The public transport emergency response manager utilizes models, traffic data, ridership data, demographics, GIS, mobile phone location data and other tools to derive a plan that includes public transport, private vehicle, commercial vehicles, and shared-use vehicles. This includes determining evacuation routes, traffic flow patterns, bus only routes, and any other decisions that prevent traffic congestion and ensures efficient and effective egress from the potential or actual impact area or areas. The public transport emergency response manager working with traffic managers and public safety managers is responsible for deciding what resources are required and what routes are to be followed in response to the incident. The public transport emergency manager is also responsible for coordinating the release of this information to all organizations involved in the disaster including the public with the Emergency Manager.

5.4.2.4 Evacuation or response operations

This phase covers the actual exit movement and transfer of people and goods from the affected area to another. It also covers the transport of response personnel, equipment, aid, supplies to the affected area. Public transport support is coordinated through the EOC by the public transport emergency response team. Public transport resources are directed through the public transport command and control infrastructure if it remains undamaged after a disaster. When Hurricane Katrina, a Category 5 hurricane, hit New Orleans, the emergency communications systems were completely destroyed, including power stations, Internet servers, mobile phone towers, and 911 services. Relief workers used satellite phones but were not interoperable, even when they did work. A few AM radio stations were able to continue broadcasting throughout the storm. Amateur radio was instrumental in the rescue process and maintained signals when 911 communications were overloaded or damaged. During the 2011 Tōhoku Earthquake, the Japan Meteorological Agency's (JMA) early warning system was able to alert millions of people across Japan about the impending earthquake via radio, mobile phone networks, and television. The tsunami warning system alerted people shortly after, although the tsunami was larger than expected. In areas with infrastructure still intact, even though both landline and mobile phone lines were not functioning as might be expected, the Internet was still accessible. In the hardest hit areas satellite phones were often the only form of communication that functioned reliably.

5.4.2.5 Debrief and assessment

The final phase in the response process occurs after the EOC is disassembled, and day-to-day operations are more or less "back to normal." This phase addresses the need for all agencies involved in the response to sit down together and evaluate the overall operation from beginning to end. The objective of the assessment is to record lessons learned and use this information to improve risk assessment. It is widely recognized that risk assessment requires accurate recording of previous disasters and in particular the associated losses in terms of human casualties, property and environment damage as well as economic loss. The transport-related information is recorded by public transport and captures transport-related information in three application areas.

— Disaster loss accounting: Document the transport-related losses and statistics to be used by local, national and international disaster risk reduction programs such as the United Nations sponsored Hyogo Framework for Action (HFA) 2005-2015 or the more recent Sendai Framework for Disaster Risk Reduction 2015-2030.

— Disaster forensics: Identify any transport-related causes of the disaster due to exposure, vulnerability, coping capacity, mitigation and response to the disaster, with the aim to improve disaster management from lessons learned.

— Risk modelling: Advance risk assessment methods by using loss data to calibrate and validate model results.

The transport-related assessment databases are optimized based on the requirements of the application area and incorporated into the EEDRR-DSS.

Table 1 defines the roles and responsibilities of public transport within each phase of an emergency response.

Table 1 — Response phases roles and responsibilities

Response phase	Public transport roles and responsibilities
Advanced planning	Coordinate with regional agencies to develop an emergency response strategy plan. Execute an agreement with the emergency management agency identified in the emergency response strategy plan, stating that it will participate in regularly scheduled exercises/drills testing the response plan against various scenarios (e.g. natural and man-made disaster, industrial accidents, and disease outbreak). Establish guidelines for PT response, including rerouting of vehicles, call back of drivers, dispatchers, etc. in the event of an evacuation or response using existing Computer Aided Dispatching and Automatic Vehicle location systems (CAD/AVL). Maintain accurate information in the EEDRR decision support system to include population identification, response times, and resource availability by updating the data from lessons learned from previous disasters or exercises. Establish uniform communications protocols both within public transport and with the EOC for various kinds of information, fixed, standardized/non-standardized, handwritten, voice, etc. It is necessary to extract valuable information from this mass of information and communicate it to all parties involved in the response including disseminating to people through various channels such as TV broadcasting, radio, social media networks, email, etc. Conduct and maintain high-level analysis of response areas to determine population/need within various jurisdictions. Maintain an inventory of public transport resources within the region and coordinate with regional emergency managers to plan for sharing of public transport resources in an emergency situation (i.e. transportation services mutual aid). Develop a contact list consisting of phone numbers (office, home, cell), fax, pager, and email addresses of key personnel at other local and regional agencies. Provide personnel training and practice regarding evacuation procedures and conduct after-action reports. Obtain evacuation/response routes from regional transportation departments and determine feasibility of using each evacuation/response route, including capacity needs and restrictions, and clearance times under various hypothetical scenarios. Establish uniform communications protocols for notifying the public and the media about public transport transportation services in support of emergency response. Obtain database of possible shelter locations including available resources, special needs, pet shelters, etc. Develop alternative emergency communication channels such as dedicated optical fibre cables to be used in case phones and emails are unavailable because of traffic congestion.
Incident notification	a) Brief supervisors, dispatchers, and other key personnel on the need to implement transport-related emergency response using ITS technologies. b) Develop evacuation/response routes, time estimates, and resource assignments for the emergency response. c) Identify staging areas for public transport resources including those areas where vehicles will be stored. d) Identify and contact special needs clients to determine if van or other transportation measures are required for evacuation. e) Establish communication link with the EOC and Traffic Management Centre (TMC). f) Communicate to the EOC the routes, time estimates, resource assignments, and special needs client ride list. g) Communicate to the public the various public transport transportation services available via websites, social media, and PT passenger information system.

Table 1 *(continued)*

Response phase	Public transport roles and responsibilities
Activation and mobilization	a) Recall and deploy agency response personnel as needed. b) Make all vehicles available to support transportation service response necessary, including special needs populations. c) Roll out public transport resources in an orderly and timely manner using CAD/AVL system if available. d) Move vehicles and other resources to storage areas outside the impact area. e) Coordinate with lead emergency management agency through command and control centre. f) Maintain expenditure records to facilitate reimbursement.
Response operations	a) Conduct response according to emergency plans. b) Monitor and adapt to changing conditions the resources required to stage response. c) Coordinate with EOC through command control centre. d) Maintain expenditure records to facilitate reimbursement.
Re-entry	a) Brief supervisors, dispatchers, and other key personnel on the re-entry plan using ITS Technologies. b) Develop re-entry routes, time estimates, and resource assignments. c) Identify re-entry staging areas for PT resources. d) Contact special needs clients to determine if van or other transportation service is required for evacuation. e) Establish communication link with the EOC and Traffic Management Centre (TMC). f) Communicate to the EOC the re-entry routes, time estimates, resource assignments, and special needs client ride list. g) Communicate to the public PT re-entry services via websites, social media, and PT passenger information system. h) Recall and deploy agency personnel as needed. i) Make all vehicles available to support mobilization of evacuees, including special needs evacuees. j) Roll out public transport resources in an orderly and timely manner. k) Return vehicles and other resources from storage areas to facilities inside impact area. l) Maintain expenditure records to facilitate reimbursement. m) Maintain re-entry logs and records.
Debrief and assessment	a) Discuss/evaluate overall performance in relation to the agency's execution of the tasks described in the emergency response plan. b) Discuss/evaluate overall performance in relation to the emergency response plan's ability to address the issues that were apparent during the actual emergency evacuation. c) Prepare a post-evacuation document detailing the agency's evacuation operations and experiences as well as lessons learned and modify plans as necessary. d) Present expenditure records to facilitate reimbursement. e) Present records of agency's evacuation activities.

5.4.3 Disaster recovery roles and responsibilities

5.4.3.1 Pre-disaster preparedness

Having a recovery plan is different from just modifying or adding on to the existing emergency response plans. To quickly and efficiently implement disaster recovery, a public transport recovery team with clear authority and responsibilities needs to be quickly identified and the roles and responsibilities defined based on the recovery needs. According to effective practices, the team should be involved in the recovery planning process and, given the demands of recovery operations, should be separate from the public transport emergency response team. The difference between the teams is the public transport emergency response team is focused on operations and include supervisors, dispatchers, operators, and planners. The recovery team members are from the administrative and maintenance organizations within the PT organization and are responsible for managing the various projects associated with the recovery effort.

5.4.3.2 Re-entry

This phase involves the return of evacuees. It will require coordination among local and regional agencies, through the EOC, to ensure a safe and orderly re-entry process. It includes notification, activation, mobilization and operations for the re-entry effort. As with the mobilization phase the key function of this phase is the identification of evacuees; route and time estimates; and resources required to conduct the re-entry.

5.4.3.3 Short-term recovery

It is important to understand that the response and recovery phases often overlap and that response efforts have an impact on recovery. Providing access to critical locations while the response effort is still in progress can expedite the recovery. For example, after all survivors were led to safety during the July 7, 2005, London Transit Bombing Event (approximately 4 h after the rescue teams arrived), planning for the recovery became part of the incident team's consideration. The London Underground Recovery Team was given space to begin its project management activities, such as planning for structural surveys and determining the specific equipment needed for the recovery. Access arrangements were made for the structural engineers so that they could determine damage. Permission was granted for equipment needed, and plans were made to bring in equipment such as large cranes in a manner that did not interfere with the investigation.

5.4.3.4 Intermediate recovery

Public transport systems are critical to a community's economic recovery. They provide access to workplaces and commercial businesses. The extended disruption of these systems can have a catastrophic impact on a region's economic health weeks and months following an event. If public transport equipment and facilities have been lost because of the event it is important to replace these resources as quickly and effectively as possible. Mutual aid agreements with other agencies outside a region can provide buses and vans either on loan or as a donation to the recovery to replace equipment. Hurricane Katrina dealt powerful blows to New Orleans in 2005. The RTA lost a majority of its buses and streetcars. Offices and maintenance facilities were wrecked. As it did to other New Orleans citizens, the storm dispersed employees and destroyed their homes. Nevertheless, in the face of great professional and personal adversity, the agency returned public transit to the streets within 60 days after the hurricane through the use of a rag-tag fleet consisting of the handful of buses that survived the flooding and generous but past-their-prime donations from other transit agencies.

5.4.3.5 Long-term recovery

Some of the long-term recovery activities are extensions of short-term activities, such as making permanent repairs to structures that have been temporarily reinforced to mitigate damage. Other long-term efforts begin after short-term tasks of debris removal and restoration of at least minimal service capacity have been completed. An effective recovery process includes not only repairing and rebuilding damaged infrastructure, but also rebuilding infrastructure in a way that reduces future risks.

Table 2 — Recovery phases roles and responsibilities

Recovery phase	Public transport roles and responsibilities
Pre-disaster preparedness	a) Establish budgetary, leadership, coordination, and decision-making structures within public transport and with other local and regional disaster recovery organizations. b) Test and evaluate Disaster Transportation Service Recovery plans through seminars, workshops, and exercises. c) Participate in local and regional disaster recovery planning and related activities. d) Build partnerships with other local government agencies to form the basis for pre- and post-transportation services. e) Integrate pre-disaster recovery planning (e.g. public information, mitigation planning) with other appropriate planning (e.g. capital improvement planning, disaster response). f) Identify transportation service limitations in recovery capacity and the means to supplement this capacity. g) Incorporate financial elements into recovery planning guidelines. h) Develop an accessible transportation services public information campaign that addresses the concerns of the public based an array of possible scenarios. i) Prepare pre-disaster memoranda of understanding (MOUs) transportation resources as a way to establish mutual aid for recovery. j) Create a comprehensive disaster recovery plan for all essential equipment and facilities including vehicles, garages, offices, command and control systems, communications systems, passenger information systems, rebuilding or reinforcement of infrastructures, etc.
Short-term recovery	a) Develop a set of short term recovery goals and objectives based on available resources and identify team members and establish the roles and responsibilities of the public transport recovery team. b) Activate public transport recovery Team to implement short-term recovery process. c) Develop damage assessment of transportation services. d) Identify staging areas for public transport recovery including those areas where vehicles will be stored. e) Identify and contact transportation services mutual aid organizations. f) Establish communication link with the EOC and Traffic Management Centre (TMC). g) Communicate to the EOC the short-term recovery plan. h) Communicate to the public the available public transport recovery services via websites, social media, and local media.
Intermediate recovery	a) Develop an intermediate recovery plan that 1) uses existing plans and footprint to reduce work required to restore service, 2) takes a collaborative approach by engaging vendors in the recovery process and enhances the recovery team, and 3) streamlines administration and accelerates the approval process. b) Assemble reimbursement records and submit to national financial aid bodies. c) Activate mutual aid process to acquire equipment and facilities needed to begin service restoration.

Table 2 *(continued)*

Recovery phase	Public transport roles and responsibilities
Long-term recovery	a) Develop a set of long term recovery goals and objectives based on available resources and identify team members and establish the roles and responsibilities of the Public Transport Long-Term Recovery team. b) Coordinate the long term recovery process by collaborating with other local, regional and national resources to leverage all available recovery resources. c) Evaluate and report to recovery partners what worked, what needs improvement, and what goals and objectives remain to be addressed in an effort to enhance and maintain the collaboration effort.

When responding to or recovering from major disaster, having clearly defined and well understood roles and responsibilities is the critical first step in coordinating and implementing the response and recovery process.

6 Concept of Operations template for Decision Support System for Public Transport Emergency Management

6.1 General

This template will assist public transport emergency managers in creating a Concept of Operations for a Public Transport Decision Support System for Emergency Evacuation and Disaster Response and Recovery. A Decision Support System (DSS) is a computer-based information system that supports organizational decision-making activities. It serves management, operations, and planning levels of an organization and help people make decisions about disaster related problems that may be rapidly changing and not easily specified in advance. The following subclauses provide a foundation that emergency management professionals can expand upon to create an effective, hands-on regional and/or local operational tool.

Recognizing that each regional and local jurisdiction has its own requirements this document does not provide a readymade base template but does identify the key concepts required in designing and developing a decision support system for managing transportation resources during and after a disaster. Additionally, it draws upon research and publications from numerous entities around the world to draft a set of operational scenarios that focus on catastrophic or large-scale events that result in mass evacuations.

6.1.1 Background

Typically, when a community experiences a disaster requiring sheltering and/or evacuation those activities are generally sustainable by the local jurisdiction with help from neighbouring jurisdictions. However, a catastrophic or widespread event may require evacuation to another region to find safe haven and assistance. However, not all disasters require evacuation and as such there may be a need for sheltering in place.

As the number of catastrophic events increase, emergency managers have expanded and adjusted their planning and operational responses to meet the unique challenges of a mass evacuation and response. It is also important to consider that some evacuation and response activities may be occurring at the same time with some populations evacuating while others are sheltering in place. The use of Intelligent Transportation System technologies plays an important role in meeting these challenges. This is accomplished by using the vast troves of data, collected by public transport, traffic management, and emergency management systems from vehicles, roadside equipment, and people operating in the transportation network, to populate the databases that are used by operators of the EEDRR C=Decision Support System to develop effective and live saving decision. These existing ITS systems are also used to communicate the commands and controls associated with these decisions to the ground transport network during a disaster.

6.1.2 Overview

This Concept of Operations template describes the use of a Public Transport Decision Support System for Emergency Evacuation and Disaster Response and Recovery (PT-EEDRR-DSS). It is non-technical and bridges the gap between the needs of the system and the specific technical requirements as viewed by the stakeholders. Public Transport Emergency managers will use the Concept of Operations template to:

a) obtain stakeholder agreement on

   1) how the system operates,

   2) who is responsible for specific functions, and

   3) what lines of communication exist between public transport, emergency management, traffic management and the public;

b) define the concept for the Decision Support System and justify that it is superior to the other alternatives;

c) define the environment in which the Decision Support System will operate;

d) derive high-level user requirements for the Decision Support System;

e) provide criteria for validation of the completed Decision Support System.

6.2 Scope of the PT-EEDRR-DSS

The PT-EEDRR-DSS is a computer-based intelligent transportation information system that supports critical transportation-related decision making activities during and after a disaster. The PT-EEDRR-DSS is part of the Emergency Operations Centre and serves the emergency management, operations, and planning levels of the Public Transport Emergency Management organization. Public transport emergency services personnel operate the system. The system assists them in making transportation-related decisions, which may be rapidly changing and not easily specified in advance. It is an interactive software-based system that aids decision makers by compiling useful information from a combination of traffic management and public transport data, policy documents, lessons learned, and traffic models to assist transportation professionals in evacuation, response, and recovery decision making.

Typical information that the PT-EEDRR-DSS gathers and presents includes:

— needs — local, regional, and national criteria for disaster evacuation, response, and recovery based on policies, directives, and needs;

— timing — benchmark evacuation times established by evacuation plans through best practices, regulations, or simulations;

— resources — transportation resources available for evacuation, response, and recovery effort including traffic management, movement of first responders and resources, and public transport.

The PT-EEDRR-DSS is an information processing system that runs on the public transport emergency services managers PC. This information is gathered from the various ITS networks to include; public transport, traffic management, and emergency management. These networks vary from nation to nation but typically include a combination of Internet, dedicated radio networks, cellular, fibre optics, and wired networks used for mobility management. It is imperative PT–DSS-EEDRR have access from the Emergency Operations Centre to these networks in order to gather and disseminate information during a disaster.

6.2.1 Operational need

Integrating PT-EEDRR-DSS into public transport incident/event response and recovery plans and management involves coordinating public transport, traffic management, and regional/national response organizations into the structure of the host organization. In most cases, Emergency Managers take the lead for primary incident response and establish the EOC in a location outside of the public transport facilities. Therefore, the PT-EEDRR-DSS should be portable to allow for its use from the EOC.

PT-EEDRR-DSS should provide a framework that all entities involved in transportation can work from using a common blueprint for emergency planning and management with accepted protocols that take the incident or event through all stages: planning, initiation, response, recovery, and return to regular operations. This framework should also allow for the activation of mutual aid for those incidents and events that out strip the capabilities of the local public transport service operators.

The relationship between PT-EEDRR-DSS and a daily PT operation system needs to be clear. If PT-EEDRR-DSS is designed only for an emergency and is not used in daily business, it will not be used in an emergency after all. PT-EEDRR-DSS should be incorporated into a daily PT system. Migrating PT-EEDRR-DSS to into daily PT system requires commitment and direction from top management with an understanding that the focus should be on accountability. Policies, such as staff training, emergency exercise participation, and PT-EEDRR-DSS data updates, should be placed in writing and distributed by the General Manager. Because of the irregular occurring nature of catastrophic events, it may be difficult to justify and maintain a ready state for the PT-EEDRR-DSS. However, the risk of being unprepared to respond to a disaster should outweigh the impact to daily operations.

Another operational challenge for PT-EEDRR-DSS is ensuring acceptance by stakeholders outside public transport. The planning effort begins with integrating teams with traffic management and emergency management to review response and recovery plans and identify any procedures that might have a negative impact or duplicate each other's respective plans. These discussions also provide an opportunity for each entity to add provisions that would facilitate transportation resource coordination and communications, with the objectives of streamlining the process and identifying gaps in memorandums of understanding (MOU).

The building of scenario-based exercises where all stakeholders can test and validate the transportation functions against the PT-EEDRR-DSS is an important training operation. Command exercises and table-top exercises may take place on-site or from remotely connected platforms, thereby allowing outside stakeholders to "play" the problem from their own offices. The field exercise, which involves responding to a mock-up incident/event that allows responders to exercise their response protocols, is the closes test of the PT-EEDRR-DSS to an actual deployment.

Further integration of PT-EEDRR-DSS occurs by expanding the scenarios to include situations that are not necessarily emergencies, but that require a substantial effort to manage. Non-emergency situations, such as peak travel days during holidays where roadways can experience choking traffic, can create an irregular operations situation. If a severe weather event occurs on such a day, then thousands of people could be stranded on roadways and need food and shelter. Having a PT-EEDRR-DSS coordinated team deployed in an EOC to manage the situation can significantly improve management of the event and ultimately normalize operations more quickly.

Using the PT-EEDRR-DSS for nonemergency events and incidents enables public transport personnel to apply PT-EEDRR-DSS on a regular basis so when a catastrophic event occurs and lives and equipment are potentially at stake, the operational response proceeds smoothly.

6.2.2 User-oriented operational description

The following user oriented operational description for the PT-EEDRR-DSS is based on the result of extensive research performed under Transit Cooperative Research Program (TCRP) A-36 Command-Level Decision Making for public transport emergency managers. Where command level decision making are those decisions made by managers to manage and mitigate critical incidents. The research found that in general public transport emergency response and recovery training is conducted one time each year, with varying quality, thereby limiting the opportunities that staffs have to improve their incident management skills. The report was released in October 2013 and may be downloaded at http://www.trb.org/Main/Blurbs/169839.aspx.

As a result of the research the project team developed and tested a Transit Emergency Response Application (TERA) that trains public transport command-level decision makers through simulation guided experiential learning. Simulated guided experiential learning provides gradual and consistent guidance while using a blend of instructional strategies to aid learners in achieving expert performance. TERA focused on training command-level roles in a public transport emergency operations centre related to mitigating public transport specific emergencies. It also addressed the role of regional and local emergency management authorities in natural or man-made disaster incidents. PT-EEDRR-DSS uses the simulation guided experiential learning model to develop a real time application. The following paragraphs define the user operations associated with this application.

6.2.2.1 Needs analysis

Based on the data collected for the TERA project, PT-EEDRR-DSS should address five concentration areas in ground transportation emergency response (see Table 3). Additionally, the data revealed four primary command-level roles relevant across the five concentration areas. These primary roles include:

a) public transport emergency manager who is responsible for the overall strategic command of the emergency response effort such as risk identification and mitigation;

b) public transport emergency operations coordinator who is responsible for managing the tactical functions such as coordination with field supervisors, assigning vehicles and drivers/operators to routes, monitoring traffic flow, etc.;

c) public transport emergency planning coordinator who is responsible for the collection, evaluation, forecasting, dissemination, and use of the information about the emergency incident and status of resources;

d) public transport emergency logistics coordinator who is responsible for managing logistical support such as personnel, vehicles, equipment, and supplies.

During an incident, these command-level positions are assigned to the EOC and coordinate all transportation-related emergency support functions with the emergency manger co-located at the EOC. Detailed profiles for each of these roles are in Annex B.

Table 3 — Ground transportation concentration area

Ground transportation concentration areas
1. Buses (public and private)
2. Railways (heavy, light, commuter rails)
3. Bridges, roads and highways
4. Tunnels (above and below ground)

In addition to identifying the concentration areas and transit command-level roles, the data also revealed five primary functions that public transport should achieve during an emergency response. Table 4 provides a list of the emergency response functions, categorized between regular and emergency services. These functions drive the design and development of the disaster response objectives.

Table 4 — Primary task functions associated with service types

Public transport emergency response function	Regular service	Emergency service
1. Life safety	X	X
2. Property conservation	X	X
3. Evacuate or move people “quickly and efficiently”	X	X
4. Move responders into and out of the areas		X
5. Provide resources (offering additional routes, increased service clearing roads, highway/roadway or waterway accessibility, etc.)	X	X
6. Communicate shelter in place directives		X

The data also revealed three high-level cognitive processes that public transport decision makers should perform during emergencies. A cognitive process is defined as a series of interdependent actions executed during multi-agency response to an emergency where multi-agency is defined as outside of public transport and may include traffic management, public safety, or emergency management. These actions form an evolving response pattern aimed at resolving the crisis. Through these actions, it is possible to employ, maintain, and revise plans. These processes involve activities such as leveraging previously established relationships with other transportation authorities, establishing morale, and establishing internal communication and information flows that promote effective multi-agency (public and private) public transport response. As described below, there are three main cognitive processes, which include Develop Situation Awareness, Synchronize Information and Resources, and Execute Actions and Decisions.

— Cognitive Process 1 — Develop ITS related transportation situation awareness (Assessment)

  — Identify, gather, and prioritize information to understand the impact of the situation on ground transportation: Effective public transport command-level decision makers are able to determine quickly how and where to identify, gather, and prioritize ITS generated information necessary to be used by a decision support system invoke action regardless of transportation mean or mode (buses, roads, bridges, boats, etc.).

  — Recognize context of the situation and predict transportation future needs: Effective public transport command-level decision makers are able to construct a coherent picture of unfolding events impacting transportation and see the overarching implications and potential public transportation needs of possible actions.

— Cognitive Process 2 — Synchronize ITS related transportation information and resources (Routing and Scheduling)

  — Coordinate and communicate transportation-related decisions internally and externally: Effective public transport command-level decision makers are able to collaborate internally and with outside agencies to develop routes and assemble resources to achieve transportation goals and objectives by using the decision support system and other ITS related resources. For example, if the decision support system shows the demographic make-up of 10 000 people to be moved; the routes to a safe location; and the need for additional buses, vans, and ambulances are required, then the decision maker may be required to coordinate with other public agencies or private groups to acquire additional vehicles and communicate the information to all agencies and individuals involved. The public transport command-level decision makers should be prepared for disasters of all sizes.

  — Acquire, prioritize and allocate available assets to meet the transportation needs of the public: Effective public transport command-level decision makers are able to assess and meet transportation needs of the public. For instance, this function may entail developing detailed pull-out plans which identify times, drives and vehicles and assign routes using existing CAD/AVL systems.

— Cognitive Process 3 — Execute Actions and Decisions (Implementation)

  — Recognize critical decision points: Effective public transport command-level decision makers are able to recognize critical decision points during a crisis and take action quickly. For example, a public transport emergency manager and/or Public Transport Operations Coordinator can make a decision to stop or interrupt services if presented with a critical situation such as a fire or reassign services if there is a significant public need such as a hurricane. Other critical situations may involve flooding, traffic flow, and breakdown.

  — Maintain transportation mission priorities: Effective public transport command-level decision makers are able to recognize their primary mission which is to protect human life by providing the resources needed to quickly and efficiently move people and goods in response to a disaster.

6.2.2.2 PT-EEDRR-DSS objectives

Based on the Needs Analysis, the following objectives associated with ITS related transportation were designed for each identified role, incident phase and performance tasks. The objectives describe the major transportation intended outcomes expected from performing tasks. Table 5 and Table 12 lists the objectives by incident phase and role and assign a number to each based on the response phase and objective. (i.e. 1.1 is first objective assigned to Activation phase and 4.1 first objective assigned to the assessment phase). To communicate how system users will achieve the intended outcomes will require system developers to match these objectives with an appropriate PT-EEDRR-DSS system strategy or function (e.g. send an email or call using the address book). Additionally, performance measures in the form of time increments should be paired with the objectives to indicate the duration users would have to achieve a task.

Table 5 — Response objectives by incident phase and role

Response Phase	Role	Objective
Activation	PT Emergency Manager	1.1 The PT Emergency Manager immediately gathers information to gain situation awareness of ITS related transportation.
Activation	PT Emergency Manager	1.2 The PT Emergency Manager activates and staffs the EOC.
Activation	PT Emergency Manager	1.3 The PT Emergency Manager schedules the Initial Transportation Action Plan meeting.
Activation	PT Emergency Manager	1.4 The PT Emergency Manager establishes communication between the PT EOC and other agencies.
Activation	PT Emergency Operations Coordinator	1.5 The PT Emergency Operations Coordinator coordinates with the PT Emergency Manager (TEM) to activate the EOC.
Activation	PT Emergency Planning Coordinator	1.6 The PT Emergency Planning Coordinator communicates and coordinates with the PT Emergency Manager in supporting the activation of the EOC.
Activation	PT Emergency Logistics Coordinator	1.7 The PT Emergency Logistics Coordinator coordinates with the PT Emergency Manager to activate the EOC.
Operations	PT Emergency Manager	2.1 The PT Emergency Manager maintains appropriate transportation-related documentation during all phases of the response.
Operations	PT Emergency Manager	2.2 The PT Emergency Manager coordinates and communicates with EOC personnel.
Operations	PT Emergency Manager	2.3 The PT Emergency Manager responds and collaborates with external agencies in supporting transportation services for all emergency response efforts.
Operations	PT Emergency Manager	2.4 The PT Emergency Manager maintains consistent communication with the press and media outlets regarding transportation-related actions.
Operations	PT Emergency Operations Coordinator	2.5 The PT Emergency Operations Coordinator maintains appropriate documentation throughout all response and recovery phases.
Operations	PT Emergency Operations Coordinator	2.6 The PT Emergency Operations Coordinator oversees public transport personnel performance of the Operations Section.
Operations	PT Emergency Operations Coordinator	2.7 The PT Emergency Operations Coordinator supports coordination of public transport resource requests to the EOC.
Operations	PT Emergency Planning Coordinator	2.8 The PT Emergency Planning Coordinator maintains appropriate documentation throughout all response and recovery phases.
Operations	PT Emergency Planning Coordinator	2.9 The PT Emergency Planning Coordinator supports transportation planning for EOC's response.
Operations	PT Emergency Planning Coordinator	2.10 The PT Emergency Planning Coordinator identifies transportation resources and coordinates requests with the PT Emergency Operations and Logistics Coordinators.

Table 5 *(continued)*

Response Phase	Role	Objective
Operations	PT Emergency Planning Coordinator	2.11 The PT Emergency Planning Coordinator provides PT EOC members with updated Transportation Action Plans.
Operations	PT Emergency Logistics Coordinator	2.12 The PT Emergency Logistics Coordinator maintains appropriate documentation throughout the emergency response and recovery.
Operations	PT Emergency Logistics Coordinator	2.13 The PT Emergency Logistics Coordinator oversees the performance of transportation logistics personnel.
Operations	PT Emergency Logistics Coordinator	2.14 The PT Emergency Logistics Coordinator maintains communication with PT coordinators regarding the status of transportation resources throughout the incident.
Demobilization	PT Emergency Manager	3.1 The PT Emergency Manager coordinates and supports transportation-related actions during demobilization phase.
Demobilization	PT Emergency Operations Coordinator	3.2 The PT Emergency Operations Coordinator supports transportation operations actions during the demobilization phase.
Demobilization	PT Emergency Planning Coordinator	3.3 The PT Emergency Planning Coordinator coordinates with the PT Emergency Manager to support transportation planning during the demobilization activities.
Demobilization	PT Emergency Logistics Coordinator	3.4 The PT Emergency Logistics Coordinator supports transportation logistics during the demobilization.

To adhere to sound instructional design practices which make the acquisition of knowledge and skill more efficient, effective, and appealing, the transportation operational objectives are segmented by tasks, conditions, standards, expected actions, enabling requirements, and measurement methods.

— **Task(s)** are descriptions of action(s) learners will perform.

— **Condition(s)** are criteria for measuring how the tasks will be performed.

— **Standard(s)** are guidelines for how the tasks should be performed.

— **Expected Action(s)** are the anticipated task performance activity.

— **Enabling Requirement(s)** are decision support requirements derived from the objective.

— **Measurement Method(s)** identify the Decision Support System strategies and associated performance measure.

Table 6 provides an example of a segmented operational objective. Each objective listed in Table 5 will require a similar segment table.

Table 6 — Segmented operational objective example

Objective:
1.2. The PT Emergency Manager activates and staffs the PT EOC.
Task:
Identify and notify all ITS related transportation personnel involved in the emergency response.
Condition:
Inform each transportation section and member assigned to assess, coordinate, and execute transportation response to the emergency incident.
Standard:
Given the emergency, the PT Emergency Manager
a) notifies the PT Emergency Coordinator assigned for responding to emergency incidents,
b) requests staffing lists,
c) designs a check-in process for each PT EOC department, and
d) activates the PT-EEDRR-DSS and begin data acquisition from traffic management, public safety emergency management, social networks and other entities involved in the emergency.
Expected actions:
Call, email or meet with each PT EOC member working on the response effort. Activate the decision support system and begin data acquisition process.
Enabling requirements (ER):
1.2.1. When presented with the task of activating and staffing the PT EOC, the PT Emergency Manager notifies PT Emergency Coordinators who are responding to the incident.
1.2.2. When presented with the task of activating and staffing the PT EOC, the PT Emergency Manager designs a check-in procedure and distributes it to each department.
1.2.3. When presented with the task of activating and staffing the PT EOC, the PT Emergency Manager activates the PT-EEDRR-DSS on the PT EOC workstation and begins acquiring data from traffic management, public safety, emergency management, social networks, and other entities.

Table 6 *(continued)*

Measurement methods:			
ER	**Cognitive process**	**Decision Support System strategy**	**Performance measure**
1.2.1	CP3 — Implementation	Send an email or call using the address book use emergency communication channels if email or phones unavailable.	The PT Emergency Manager notifies PT Emergency Coordinators responding to the incident within 10 min of activation of the PT EOC to ensure staffing is available to support the emergency.
1.2.2	CP3 — Implementation	Retrieve/modify sample check-in for situation and email or use emergency communication network to circulate.	The PT Emergency Manager designs and implements a check-in procedure for each department within 30 min of activation of the PT EOC to ensure resources are available to support the emergency.
1.2.3	CP1 — Assessment	Activate the PT-EEDRR-DSS and acquire data from list of sources based on scenario.	The PT Emergency Manager identifies, gathers, and prioritizes information to understand the impact of the situation on ground transportation.

6.2.3 Scenario timelines and selections

Because of the unique nature of a disaster, i.e. no two are alike; it is very difficult to develop operational scenarios for all disasters for the PT-EEDRR-DSS. The following four examples use a prototype scenario timeline that outlines and represents the major events and time segments. The prototype approach allows for generalizing a disaster situation. This is accomplished by presenting background information and broad event descriptions that clarifies who, what, where, why, when, and how for each stimulus where a stimulus is the trigger for an action from PT-EEDRR-DSS. The stimulus triggers an action that assists public transport in deciding what tasks to perform with each scenario. As a means of further explaining this stimulus trigger prototype approach, the following example is provided from a real disaster that occurred as a result of the 2011 Tōhoku Earthquake in Japan. If the PT-EEDRR-DSS operational scenario was properly developed for radiation threats then the following actions would have taken place in response to the tsunami-hit Fukushima Dai-Ichi nuclear plant. As officials planned a venting operation certain to release radioactivity into the air, Japan's system to forecast plumes predicted the Karino Elementary School would be directly in the path of the emerging plume. The plume alert would have been issued to the PT EOC via the emergency communication network and served as the stimulus for the PT-EEDRR-DSS prior to the radiation release. This stimulus would have triggered the PT-EEDRR-DSS to generate an evacuation notice for areas impacted by the plume and communicate the information to public transport operators in the area. The evacuation notice would have triggered public transport to assign the necessary resources to evacuate the school rather than using it as a temporary evacuation centre and thus eliminating exposing thousands of people staying at the temporary shelter to radiation risk.

The following design requirements apply for each stimulus:

— ***Stimuli Type:*** What form of communication or information will the stimuli take? While operating in real-time environments, stimuli can take many communicative or information-based forms such as screen displays, data exchanges with other systems, radio voice contact, radio data messages, emails, phone calls, faxes, live conversations, video news reports, etc.

— ***Time:*** What occurrence on the timeline will cause stimuli to appear?

— ***Stimuli content:*** What information or material(s) make up the stimulus?

— ***Incoming and outgoing recipient(s):*** Who will the information be conveyed to and from?

— ***Response(s)/Feedback:*** What are the standards response(s) to stimuli?

— ***Performance standard:*** What are the approximate expected actions of the user to the task in question?

— ***Consequences:*** What are the positive and negative outcomes for completing or not completing the task?

However, a single prototype scenario cannot sufficiently address all stimuli so it is necessary to develop categories of scenarios. Many categories exist and much discussion occurred with national experts during the numerous workshops sponsored by ISO/TC 204. No public transport specific categories exist in any literature. In addition, the national experts agreed that scenarios involving terrorist caused disaster should not be published in this document because of security concerns. The two categories selected for PT-EEDRR-DSS include natural disaster and accident.

Specific scenarios within these categories were evaluated based on the following criteria.

— Each scenario's applicability to public transport emergency management.

— Each scenario's applicability to public transport emergency operations centre (command and control level) mitigation activities as opposed to primarily on-scene activities.

— Each scenario's applicability to public transport operating in cities.

— Each scenario's applicability for all specified exercise participant roles.

— Each scenario's likelihood of occurring.

Two additional criteria describe diversification considerations that were taken into account.

— Ability to exercise a diverse set of Command and Control (C2) mitigation activities across recommended scenarios where Command and Control is defined as the exercise of authority and direction by a properly designated individual over assigned resources in the accomplishment of a common goal or objective.

— Ability to provide all-hazards scenario set.

The following scenarios were selected:

— river flooding with hazmat;

— hurricane with regional evacuation;

— hazardous materials release;

— earthquake with ensuing tsunami.

Outlines for the recommended scenarios are included in Tables 7 to 10. There are numerous other disasters that are not considered in Tables 7 to 10 but also meet the above criteria. For example, landslides, wind storms, volcanic eruptions, and snow storms. However, limited resources to do the work prevent inclusion of every type of disaster. Tables 7 to 10 provide the general description for the scenarios. The information flow for these scenarios will be developed in ISO 19083-2 and use cases for these scenarios will be developed in ISO 19083-3.

Table 7 — Flood with hazardous material spill scenario

Flood with hazardous material spill:	
Casualties	50 fatalities, 100 injured, 30 require hospitalization
Infrastructure damage	Thousands of residential homes, a chemical plant, a nursing home
Evacuations/displaced persons	75 000 people
Contamination	Various hazardous materials including ammonia, synthesis gas, potassium amide, hexane, and potassium metal
Economic impact	Hundreds of millions of dollars

Table 7 *(continued)*

Flood with hazardous material spill:	
Potential for multiple events hazardous	Contamination
Recovery time	Months to years
Details A winter with heavy snowfalls has begun to melt and heavy rains are predicted for the next several days, which have the potential to cause major flooding. Minor flooding has already been occurring in the region. Twenty-four hours after the initial flooding concerns, a levee is breached upstream releasing millions of gallons of water. A few hours after the levee breech, a chemical plant downstream is flooded releasing various hazardous materials including ammonia, synthesis gas, potassium amide, hexane, and potassium metal into the water. To complicate matters, the contaminated flood waters begin to approach a senior citizens home a mile away. Emergency responders call the location transit authority for additional resources to evacuate. **Public transport tasks** — Preservation of the lives of employees and passengers by providing timely, effective, and efficient transportation before, during and after a disaster using the PT-EEDRR-DSS to model, assess, implement and test disaster planning, response and recovery. — Asset preservation to include using ITS technologies such as CAD/AVL to stage vehicles, equipment and material outside flood zones. — Sorting through confusing and conflicting reports by establishing trusted and tested emergency communication networks. — Assessing damage to facilities by using ITS technologies to review inventories and mutual aid plans. — Preparing a long-term plan for replacing transportation services during repairs.	

Table 8 — Hurricane scenario

Hurricane/typhoon, other storms:	
Casualties	62 fatalities, 10 000 injured (1 500 requiring hospitalization)
Infrastructure damage	600 buildings destroyed (many by associated flooding), 10 000 buildings damaged, two bridges destroyed, airport runway temporarily unusable, almost no electrical power without generators
Evacuations/displaced persons	100 000 people evacuate before landfall
Contamination	No potable water for 7 days
Economic impact	Estimated $10 billion
Potential for multiple events hazardous	Public unrest, waterborne illness, lack of hospital bed availability
Recovery time	Months to years

Table 8 *(continued)*

Hurricane/typhoon, other storms:
Details A hurricane is expected to hit the city. It is predicted to have winds of 130 mph to 156 mph, 209 km/h to 251 km/h. There is widespread flooding and wind damage. **Service disruption** Medical services: One hospital unusable, other hospitals running on generators. Fire and emergency medical services: Most stations are operational with at least 50 % of staff, but roads are frequently impassable. Response times are greatly increased. Transportation: Two bridges have been destroyed. Train tracks withstand the hurricane but need to be inspected before they can be used. Flooding restricts travel through some areas, and there is widespread debris on the streets. Traffic lights and street lights are not operational. Energy: Almost all buildings without generators are without power. Power is expected to be restored to 80 % of buildings within 7 days after landfall. Water: Residents are advised that the water from the tap is unsafe to drink and thus water which is essential for survival must be supplied. Water treatment facilities are essentially non-operational. Homelessness: 30 000 people need shelter pre-landfall and for the first few days after. One thousand people need long-term shelter. Communication: Cellular phones do not work for the most part until power is restored. Local television and radio stations cease operations, but national television news is highly effective. **Public transport tasks** — Preservation of the lives of employees and passengers by providing timely, effective, and efficient transportation before, during and after a disaster using the PT-EEDRR-DSS to model, assess, implement and test disaster planning, response and recovery. — Asset preservation to include using ITS technologies such as CAD/AVL to stage vehicles, equipment and material outside flood zones. — Providing routes to and from shelters using the PT-EEDRR-DSS. — Possibly providing temporary shelter to employees so that they are available to work and using ITS technologies to develop work schedules. — Transport response and recovery personnel and resources (e.g. busloads of engineers, inspectors, workers, equipment, supplies) using the ITS technologies such as CAD/AVL. — Restoring service as much as possible under the conditions including using ITS technologies to develop new routes and services. — Preparing a long-term plan for offering service during recovery efforts. — Facility restoration. — Keeping track of expenditures.

Table 9 — Hazmat scenario

Hazmat:	
Casualties	Zero deaths, one injury
Infrastructure damage	Bus Station windows broken, fire damage
Evacuations/displaced persons	600 people evacuated from nearby office buildings
Contamination	Ammonia spill, bleach spill
Economic impact	Minimal
Potential for multiple events hazardous	None
Recovery time	Hours for the initial danger to pass, 1 to 2 days for clean up

Details

A bus station employee accidentally knocks over a barrel of hazardous materials in an attempt to remove the barrels from a storage closet after a small fire breaks out. HAZMAT Teams are immediately dispatched and develop a Hot, Warm, and Cold Zone. Nearby buildings and residences should be evacuated, and all persons who were located in the Bus Station when the evacuation was ordered should be checked for contamination.

Service disruptions

Train service: Not affected.

Air travel: Not affected.

Roads: The call for residents of nearby buildings to evacuate and the shutdown of the city streets cause traffic delays, which make it more difficult for emergency responders to reach their destinations during the first hour.

Public transport tasks

— Preservation of the lives of drivers and passengers who may be exposed by using ITS technologies to assist in evacuation from hazmat areas to include residential, commercial, and public facilities.

— Use PT-EEDRR-DSS to review disaster plans to determine need for decontamination of people and transportation facilities such as stations.

— Use PT-EEDRR-DSS to identify how to certify decontamination of station.

Table 10 — Earthquake with tsunami scenario

Earthquake with tsunami:	
Casualties	650 fatalities, 15 000 injuries (4 000 requiring hospitalization)
Infrastructure damage	35 000 buildings destroyed, 180 000 damaged, widespread power outage, breaks in water and gas lines, bridges collapse, airport runway unusable, many streets impassable and nuclear power plant in the impact zone
Evacuations/displaced persons	215 000 people
Contamination	Various hazardous materials including radiation
Economic impact	Hundreds of millions of dollars
Potential for multiple events hazardous	Aftershocks, tsunami, fires, people trapped
Recovery time	Hours for the initial danger to pass, 1 to 2 days for clean up

Details

An earthquake of magnitude 7,4 hits suddenly, with its epicentre very near the city, which is located on the coast. Damage is most severe within a five-mile radius. A bus yard and a fuel yard become inaccessible. Because of location near the coast, an immediate threat exists for a major tsunami. Relief shift workers are unable to reach the new transit EOC location for 2 days. A significant aftershock occurs early on the second day.

Service disruptions

Medical services: Only two hospitals remain open; one at less than 50 % capacity. Both are running on generators, and there is a desperate need for more hospital beds.

Fire and emergency medical services: Only 16 % of the stations are operating at greater than 50 %. Dozens of trucks were damaged to the point of no longer being functional.

Transportation: Bridges have collapsed and there are significant obstructions on major highways. Damages to several major freeways are hampering incoming assistance. Railways and airport runways have buckled and sustained moderate to severe damage. All airports in the region are closed due to the communication disruptions, damaged runways, and instrument landing system failures.

Energy: Large scale power outages. There are numerous ruptures to underground fuel lines, oil lines, and natural gas lines.

Water: Most people are without water due to ruptured water mains and power outages. Wastewater primary interceptors were broken in the vicinity of the epicentre.

Homelessness: 150 000 people need temporary housing. Half of the existing pre-designed.

Communication: Damage to microwave dishes and other vital parts of the communications infrastructure have resulted in limited communications capabilities. Cellular towers have also been damage and the high cellular traffic after the earthquake has saturated the system.

Public transport tasks

— Preservation of the lives of employees and passengers by using ITS Technologies to communicate immediate needs to shelter in place until immediate threat from the earthquake and then the impending tsunami are over.

— Preservation of assets by using ITS technologies to direct vehicles away from impending tsunami.

— Evacuating people to shelters and temporary medical facilities after the initial impact by using the PT-EEDRR to model, assess, and implement evacuation plan.

— Cleaning and certifying any vehicles used for transporting the injured afterwards.

— Credentialing employees for activity past curfew.

— Informing employees of the need to return to work.

— Restoring service as far as possible.

— Establishing long-term routes to and from shelters.

— Securing fuel for buses and generators.

— Transporting response and recovery personnel and resources by using CAD/AVL system to dispatch vehicles and personnel.

6.2.4 Operational considerations for recovery effort

Although recovery is a critical step in the emergency response cycle, according to research published in National Cooperative Highway Research Program Report 736,[9] it is one of the least understood aspects of emergency management. Many regional and local public transportation organizations have emergency response plans that address immediate operational situations, e.g. Continuity of Operations Plans (COOPs). Few, however, have emergency recovery plans prepared in advance. Most often, planning for recovery happens only after a disaster occurs. As noted by the Federal Emergency Management Agency (FEMA) in standard materials prepared for emergency management training, "Although planning is an action that is conducted in all four of the primary emergency management functions (preparedness, response, recovery, and mitigation), it is more commonly associated with preparedness and mitigation prior to the event" (FEMA Emergency Management Institute).

Recovery is typically considered as a series of discrete efforts that take place after an event or disaster and is often considered in phases. As noted previously, those phases include short-term, intermediate and long-term recovery/reconstruction.

Short-term typically 1 to 7 days after the event often overlap with response phases and response efforts have an impact on recovery and include damage assessments are made; debris clean-up/removal starts; emergency, often short-term, repair of transportation systems occurs such as emergency demolitions and temporary structures; and interim transportation services are provided, if necessary.

Intermediate typically results in activation of mutual aid agreements with other agencies outside a region to provide buses and vans either on loan or as a donation to the recovery to replace equipment.

Long-term recovery (typically several years) consists of the permanent reconstruction and restoration of the transportation system infrastructure.

Table 11 provides a list of the emergency recovery functions associated with transportation, categorized between regular and emergency services. These functions drive the design and development of the transportation-related recovery objectives.

Table 11 — Primary task functions associated with recovery

Public transport emergency recovery function	Regular service	Emergency service
1. Assessment of damages to the transportation infrastructure		X
2. Prioritization of transportation projects including highways, bridges, tunnels, buses, light rail, subways, etc.	X	X
3. Mitigation of economic impacts by providing alternate transportation services	X	X
4. Repair of transportation infrastructure		X
5. Support recovery activities by providing alternate transportation services		X

As information that is more specific becomes available about the extent of damage and requirements for repairs, priorities are adjusted and mid- and long-term strategies may be revised.

Research also revealed three high-level cognitive processes that public transport decision makers should perform during the recovery phase. They include: leadership, capabilities, and accountability. Other researchers have found similar key elements that impact the effectiveness of a recovery process: leadership, ability to act, and knowledge of what to do.

To implement transportation-related disaster recovery, a public transport recovery organization with clear authority and responsibilities for public transportation infrastructure needs to be identified prior to the event. According to effective practices, the public transport recovery team should be involved in the planning process and, given the demands of recovery operations, should be separate from the transportation emergency response organization. The PT-EEDRR-DSS provides access to the data and information associated with identifying transportation recovery team members and transportation recovery plans.

The public transport recovery team needs to understand what their responsibilities are and how they interact with the public transport emergency response team and other organizations involved in the recovery. Accordingly, as part of the recovery process, public transport operators and service managers may be asked to take on specific responsibilities within the emergency management organization along with the responsibilities of their own business recovery needs.

These responsibilities include the following:

— Identify and provide transportation resources to critical facilities to include transporting ambulatory hospitalized people out from the damaged area.

— Conduct damage assessments on the transportation service, system, or infrastructure, and determine the impact this damage has on the overall transportation network.

— Coordinate the provision of public transport resources to support recovery activities, as requested by authorities.

— Provide subject-matter expertise to advise government decision-makers during the recovery phase.

— Implement improved materials and construction methods to prevent similar damage from occurring again.

The data and information associated with public transport recovery team responsibilities is maintained and accessed by PT-EEDRR-DSS.

Appointments to the public transport recovery team should be identified prior to the event so that members of the team can all understand their role in the recovery process and the actions they are expected to perform during the recovery period. This team may include administrators, program managers, engineers, supervisors, and operators from the public transport sector. These individuals should be trained on the use and functions of the PT-EEDRR-DSS with respect to recovery plans, assessment, and implementation.

It is important to know in advance the government, insurance and private resources available to fund the transportation-related 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 recovery planning team to ensure that disaster assistance is effectively utilized. The PT-EEDRR-DSS could be used as the depository for managing transportation recovery funding.

Things happen fast in emergencies and may not follow processes. It is important to make flexibility part of the transportation recovery process. The dilemma in recovery planning is achieving fast results with making lasting improvements. The recovery goals often diverge because of this dilemma. Recovery planning should consider the flexibility needed to address the conflicts between short-term recovery goals and long-term recovery/reconstruction with resiliency being a major focus of the transportation recovery effort. The PT-EEDRR-DSS provides a repository for lessons learned from other disasters and key knowledge areas for capacity building preparedness in the area of transportation to support resilient built environments.

Three primary command-level roles relevant are identified for the recovery efforts. These primary roles include:

a) PT Recovery Manager who is responsible for the overall strategic plan of the recovery effort to include damage assessment and recovery planning for short-term, intermediate, and long-term mitigation;

b) PT Recovery Communication Coordinator who is responsible for informing outside organizations and the public of recovery plans and services;

c) PT Recovery Project Coordinator(s) who is/are responsible for managing mutual aid request and work associated with infrastructure repair.

During the early stages of a disaster it is important that the public transport emergency recovery team be assigned to the EOC and coordinate all transportation-related recovery functions with the

Emergency Manger co-located at the EOC. Upon completing the demobilization of the EOC the public transport emergency team return to the public transport facilities to complete the recovery effort.

Table 12 — Recovery Objectives by Incident Phase and Role

Recovery phase	Role	Objective
Assessment	PT Recovery Manager	4.1 PT Recovery Manager gathers information from ITS related transportation source to gain situation awareness of transportation infrastructure.
Assessment	PT Recovery Manager	4.2 PT Recovery Manager activates and staffs the PT Recovery Team.
Assessment	PT Recovery Manager	4.3 PT Emergency Manager schedules the Initial Transportation Recovery Action Plan meeting.
Assessment	PT Recovery Communications Coordinator	4.4 PT Recovery Communications Coordinator establishes communication between the Transportation Recovery Team and other disaster recovery teams.
Assessment	PT Recovery Project Coordinator	4.5 PT Recovery Project Coordinator activates the transportation recovery plan that streamlines transportation administration and accelerates the transportation project approval process.
Assessment	PT Recovery Project Coordinator	4.6 PT Recovery Project Coordinator establishes transportation-related interagency/cross-jurisdictional coordination protocols.
Prioritization	PT Recovery Manager	5.1 PT Recovery Manager develops a disaster recovery plan for short-term transportation service restoration.
Prioritization	PT Recovery Communications Coordinator	5.2 PT Recovery Communications Coordinator coordinates and communicates the short-term transportation recovery plan with the EOC and communicates to the public the recovery services via websites, social media and local media.
Prioritization	PT Recovery Project Coordinator	5.3 PT Recovery Project Coordinator refines the short-term transportation recovery plan based on feedback from EOC and public.
Prioritization	PT Recovery Project Coordinator	5.4 PT Recovery Project Coordinator identifies staging areas for transportation equipment and contacts transportation service mutual aid organizations.
Mitigation	PT Recovery Manager	6.1 PT Recovery Manager authorizes the PT Recovery Project Coordinator to begin implementing the short-term transportation recovery plan.
Mitigation	PT Recovery Communication Coordinator	6.2 PT Communications Coordinator maintains consistent communication with the press and media outlets and the public through social media.
Mitigation	PT Recovery Project Coordinator	6.3 PT Recovery Project Coordinator activates mutual aid process to acquire transportation equipment and facilities needed for transportation service restoration.
Mitigation	PT Recovery Project Coordinator	6.4 PT Recovery Project Coordinator begins service restoration by using existing plans and collaborating with vendors to get the work done.
Mitigation	PT Recovery Project Coordinator	6.5 PT Recovery Project Coordinator assembles reimbursement records and submits to national financial aid bodies.

Table 12 *(continued)*

Recovery phase	Role	Objective
Infrastructure Repair	PT Emergency Manager	7.1 PT Emergency Manager develops a set of long term transportation recovery goals and objectives based on available resources and identify the roles and responsibilities of the Public Transport Long-Term Recovery team.
Infrastructure Repair	PT Emergency Manager	7.2 PT Emergency Manager coordinates the long term transportation recovery process by collaborating with other local, regional and national resources to leverage all available recovery resources.
Infrastructure Repair	PT Recovery Communications Coordinator	7.3 PT Recovery Communications Coordinator evaluates and reports to recovery partners what worked, what needs improvement, and what goals and objectives remain to be addressed in an effort to enhance and maintain the collaboration effort.

6.3 System overview

The PT-EEDRR-DSS is a computer-based transportation information processing system that supports critical transportation-related decision making activities during a disaster. The PT-EEDRR-DSS is activated as part of the Emergency Operations Centre and serves the emergency management, operations, and planning levels of the emergency management organization. This system is operated by public transport emergency services personnel and assists them in making decisions, which may be rapidly changing and not easily specified in advance. It is an interactive software-based system that aids decision makers by compiling useful information from a combination of raw traffic and public transport data, policy documents, personal knowledge, and traffic models to identify and solve problems and assist transportation professionals in decision making.

Typical information that the PT-EEDRR-DSS gathers and presents includes:

— local, regional, and national criterion by which transportation-related emergency may be declared and thus invoke evacuation, response, and recovery efforts from public transport;

— benchmark evacuation times established by evacuation plans through best practices, regulations, or simulations including determining when to shelter in place;

— transportation resources available for evacuation, response, and recovery effort including traffic management and public transport.

6.3.1 Operational environment

The PT Emergency Manager activates the PT-EEDRR-DSS when an incident occurs that requires a response from the PT Emergency Management team. The PT-EEDRR-DSS interacts with other ITS subsystems using various communications networks. Figure 2 shows the various ITS subsystems and networks. No organization manages Central ITS Subsystems. This is an architectural document used to demonstrate connectivity of the various subsystems. As such, the PT-EEDRR-DSS is contained within the Public Transport Management block within the diagram. The PT-EEDRR-DSS uses the various ITS subsystems and networks identified in Figure 2 to gather information from multiple sources and locations, including from the point of incident, and uses various modelling techniques to make effective strategies and decisions. It also uses these subsystems and network to send the information to vehicles and other nodes in real-time to effectuate tactical responses to disasters. The ultimate goal of the tactical response is to improve the flow of traffic from the afflicted area by balancing the transportation resources thus evacuating a maximum number of people.

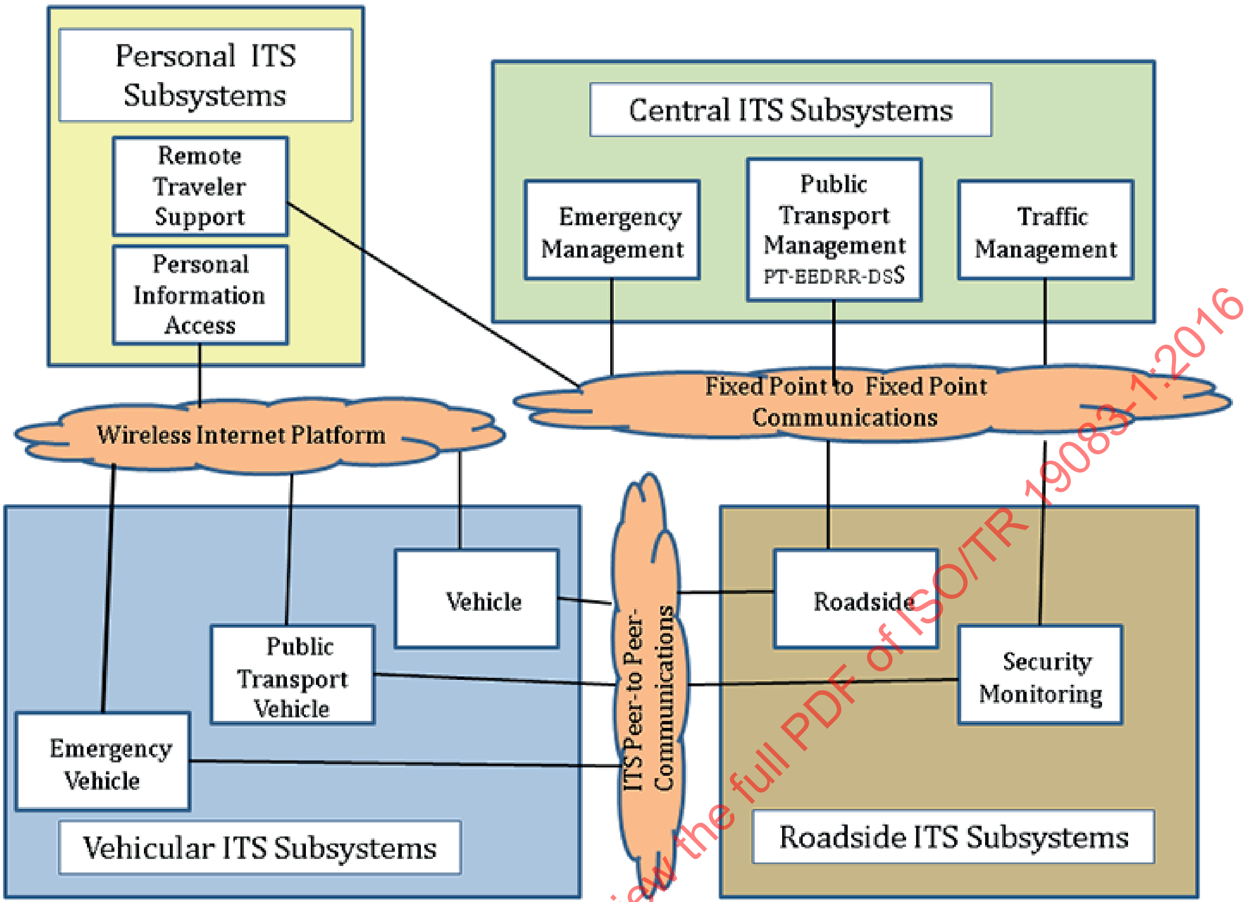

Figure 2 — ITS subsystems interacting with PT-EEDRR-DSS

While Figure 2 depicts where the PT-EEDRR-DSS fits in the ITS world, Figure 3 depicts the system architecture of the cloud-enabled PT-EEDRR-DSS. The system consists of three main layers. The cloud infrastructure layer provides the base platform and environment for the decision support system. The Knowledge Layer provides

— traffic models used for route development,

— algorithms for situational analysis, vulnerability analysis, damage and risk analysis,

— accreditation of thematic maps derived from Satellite or ground based early warning, detecting, monitoring, and mitigation systems, and

— exercise knowledge required to devise emergency evacuation response and recovery strategies by processing the data available from various sources.

The System Interface acquires the data from various gateways including the Internet, public transport infrastructure, traffic management infrastructure, emergency services infrastructure, and social networks to include assets such as roadside equipment units, emergency responder communication, and public transport computer aided dispatch, etc.

Cloud computing involves deploying groups of remote servers and software networks that allow centralized data storage and online access to computer services or resources. Cloud computing can be defined as web applications and server services that users pay for in order to access, rather than software or hardware that the users buy and install onsite themselves. This is an important feature for the PT-EEDRR-DSS architecture as it focuses on maximizing the effectiveness of the shared resources thus allowing users to access a wide variety of applications, services, and hardware, which they might not be able to access otherwise. Additionally, it moves these resources offsite from where in all likelihood there will not be electricity, Internet and mobile communication services available. Cloud computing, based on virtualization, takes a very different approach to disaster recovery. With virtualization, the entire server, including the operating system, applications, patches and data is encapsulated into a single software bundle or virtual server. This entire virtual server can be copied or backed up to an offsite data centre and spun up on a virtual host in a matter of minutes. The virtual host would be operating outside the disaster area and not impacted by network and power outages inflicted by the disaster.

The PT-EEDRR-DSS System Interfaces are used to communicates with various user interfaces and communication gateways including the ITS vehicle to infrastructure (V2I) and infrastructure to vehicle (I2V). The interface gathers, validates and propagates data, information and emergency response operations. Data is validated by collecting it from trusted sources such as traffic management and emergency management networks. Data collected from social networks should be scrutinized as it is not always possible to know whether social media users are who they claim to be or whether the information they share is accurate. Although false messages that are broadcast widely are often rapidly corrected by other users, it is often difficult to separate real signals of a transportation crisis or a material need from background noise and opportunistic scams. Emergency management utilizes the power of social networks to instantly broadcast and amplify emergency warnings to the public. Incorporating these sources ensures data validation as much as possible.

The Knowledge Layer uses this data and information to develop models/simulations of evacuation, responses, and recovery route. The system interface layer is responsible for validating the data and information it receives. It also provides the communication link for command and control information released by the Knowledge Layer.

The Knowledge Layer consists of various mathematical models, algorithms and simulations, both stochastic and deterministic. These models accept traffic and public transport-related data received from various ITS sensors. The modelling and analysis software uses the previously validated data for a particular activity based on the urgency of the situation. In some cases such as when reviewing the outcome of an exercise, it is necessary and/or affordable to employ microscopic traffic models this is due to the demands on higher accuracy and greater flexibility on the available time for decision, optimization and analysis. A higher authority in the emergency management chain of command accredits the results of the microscopic modelling by reviewing the data and testing the results. In other cases, microscopic simulations may not be possible, due to the real-time nature of operations such as a response to major disaster such as a chemical plant fire or earthquake. In these cases, the use of macroscopic modelling is required. A no warning disaster usually limits the availability of real-time data as many communication sources are damaged due to the disaster, and compounding the problem the time period in which the system has to act will be short. Macroscopic models require relatively small computational time and resources. Which models to invoke in a particular situation is an area for automatic model selection algorithm. Additionally, enhancing distributed algorithms to invoke the most precise models for real-time critical situation is an important feature to incorporate in a cloud infrastructure as it provides *virtualization and flexibility by moving it outside the area affected by the disaster*. This is possible considering the capability of cloud technology.

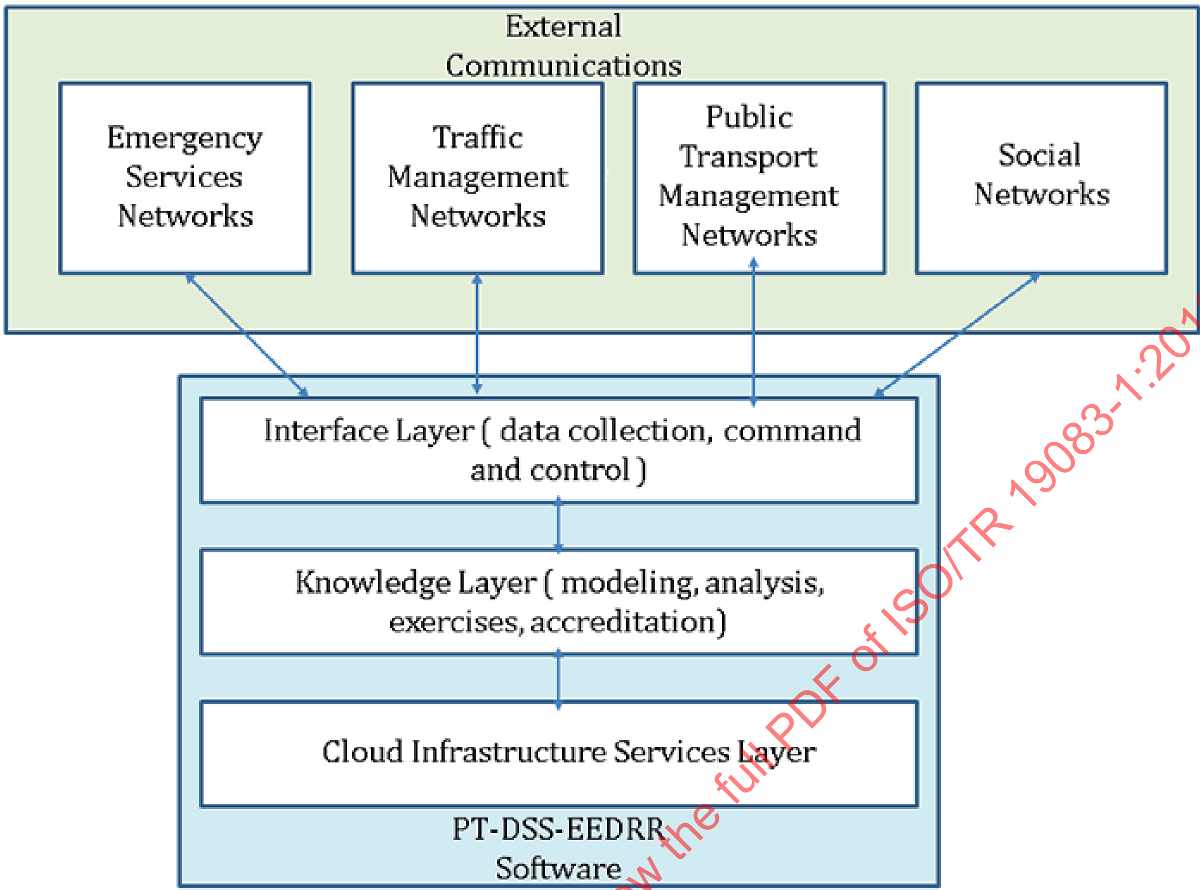

Figure 3 — Cloud-enabled PT-EEDRR-DSS Architecture

6.3.2 Support environment

A disaster by its nature causes people who are in its vicinity to want to move away from the disaster location in one of two ways. If it is a no warning or short warning disaster such as an earthquake or tsunami, sheltering in place is required until the immediate threat passes. An approaching disaster such as a hurricane or cyclone typically allows forewarnings and evacuation decrees thus resulting in a more coordinated evacuation. However, the situation with vehicles in either case becomes no different in the absence of any effective coordination as the roadway sections around a disaster area are blocked. ITS technologies are available to help coordinate an evacuation and to assist with the response and recovery efforts in the aftermath of a disaster. Specifically, traffic signal coordination and traffic probe data provide a control mechanism for the PT-EEDRR-DSS to effectuate an orderly evacuation, response, and recovery effort. For example, if a highway is experiencing congestion due to an evacuation notice, a diversion strategy can be crafted to redirect travellers to frontage roads or arterials where traffic lights are coordinated to produce a "green-wave" to provide maximum flow. These ITS technologies include traffic signal control (pre-emption and priority), traffic-sensing technology on roads, and advanced traveller information (e.g. variable message signs, 511, mobile alerts), both for travellers and transportation managers. Of course as a result of a disaster it is most likely that traffic signals and probe systems may be heavily damaged and not functional. In these cases, vehicles in the impacted areas must travel at their own risk.

Figure 4 shows the conceptual architecture used by ISO for Infrastructure to Vehicle (I2V) and Vehicle to Infrastructure (V2I) communications. Traffic signal control and traffic probe data are communicated via this architecture. This is the underlying architecture for the Traffic Management Network. ISO/TS 19091 and ISO 19082 provide details of the traffic signal control and probe data.

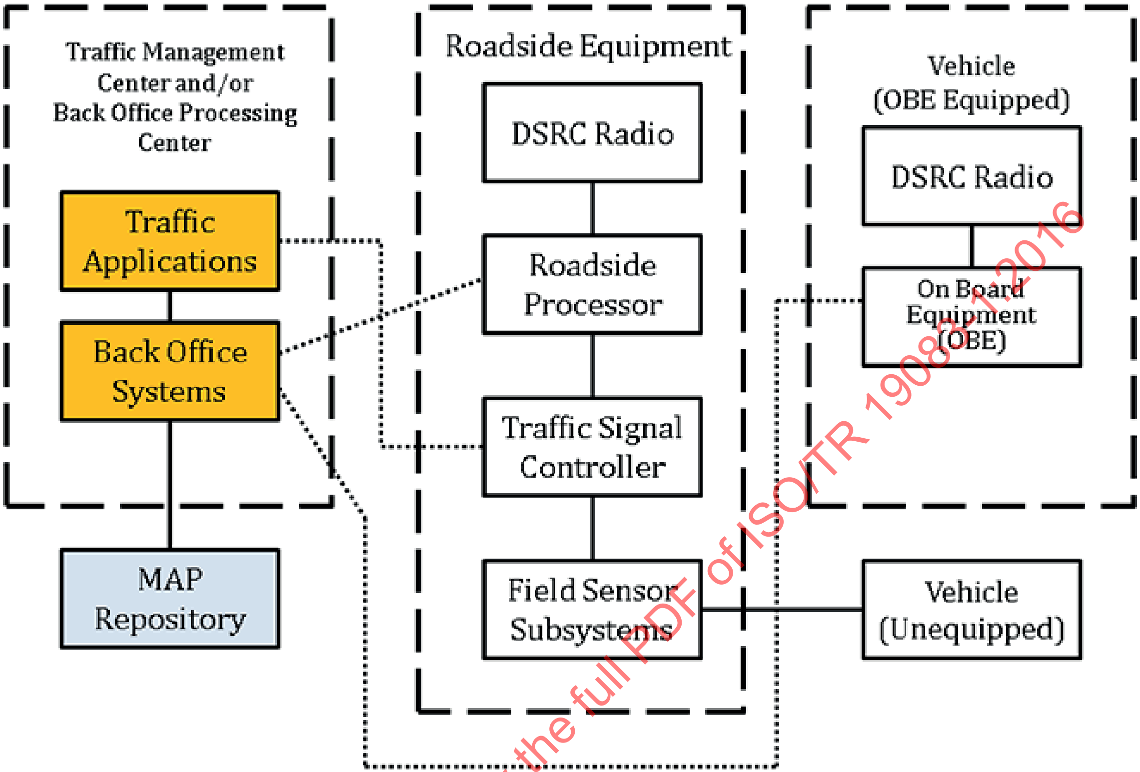

Figure 4 — General Architecture for V2I/I2V Communications ISO/TS 19091

Another important support environment for PT-EEDRR-DSS is the public safety communications network. This is the voice and data network used by public safety which includes the bulk of the first responders to a disaster. The public safety communications network provides PT-EEDRR-DSS with a mechanism for collecting disaster reporting data and more importantly access to command and control communications. In the past public safety communications networks and other governmental mission critical requirements have been met by narrow band private radio systems. These networks often operated on voice only and had minimal data transmission capability. However, the need for video and data has increased considerably, along with the emerging trend towards "voice-over-Internet protocol (IP)" (VoIP). The result is that the need for mobile broadband capabilities is becoming increasingly important to public safety organizations.

International Mobile Telecommunications (IMT) specifications and related systems have drastically changed the global mobile communications landscape, in particular LTE (Long-term evolution), where the general consumer in many countries has gained access to general Internet capabilities.

Therefore, it is useful to understand how IMT-based specifications and standards can play a vital role by enabling Public Protection and Disaster Relief applications such as PT-EEDRR-DSS.

Public Protection and Disaster Relief (PPDR) is defined in ITU-R Resolution 646 (WRC-03) through a combination of the terms "public protection radio communication" and "disaster relief radio communication". Public protection radio communications is used by responsible agencies and organizations dealing with law and order, protection of life and property and emergency situations. Disaster relief radio communications is used by agencies and organizations dealing with a serious disruption of the functioning of society, posing a significant widespread threat to human life, health, property or the environment, whether caused by accident, natural phenomena or human activity, and

