Review of Technologies for Emergency Management of Climate Change Related Impacts on Transport Networks

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***Abstract*—The paper reviews the technologies, which can be used for easing the negative impacts of climate change related extreme weather events on transport networks, including emergency management systems and system recovery mechanisms. A short introduction on emergency management is provided first, aiming to link emergency management operations and procedures with the role of transport networks in the cases of climate change related extreme weather events. Then, the technological aspects for the provision of emergency transport management are presented in detail, covering the fields of data collection, data processing and data transmission.**

***Index Terms*—climate change, emergency management, technologies, transport networks.**

I. Introduction

Emergency management denotes all activities taken to rescue and supply people who are suffering from extreme weather events, such as storms, storm surges, heavy precipitation, sudden ice or heat periods. Emergency management embraces also all activities undertaken to keep infrastructures and critical facilities working under such conditions. Transport infrastructures and services take a particular role in this context, as transport facilities are required for supply, rescue and maintenance operations.

The present paper aims to provide a current situation analysis regarding advances of technological emergency management systems related to the reduction of the negative impacts of climate change related extreme weather events on transport networks.

The paper is structured in two main parts. The first part begins with a top down description of emergency management and its organization, aiming at linking emergency management operations and procedures with the role of transport networks in the case of extreme weather events. The second part analyses the key technological issues for the provision of emergency transport management.

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II. The Context of Emergency Management

A. Basic Concepts

A number of definitions of “emergency” and “disaster” have been proposed over time, many of them focussing on some measure of the cost of the event in terms of loss of life or damage. However, the Emergency Management Australia Report [1] underlines that the focus of concern with emergencies and disasters has moved towards consideration of the situation created by such phenomena rather than simply of the origin, nature, size, speed of onset and other physical attributes of the hazard, which results in the event itself. It is recognized that this change of focus has been brought by the recognition of the limited capability for controlling such attributes, in particular for the cases of natural hazards. But it has also stemmed from the realisation that the consequences of different types of events - the situation that the impact of such events, whether natural or man-made, may create in terms of social, economic, environmental, developmental and political consequences for the communities - can be remarkably similar.

B. Linking Emergency Management Procedures with the Transport Sector

During major emergencies, transportation systems can provide specific functions and services. The functions may include [2]:

- Emergency evacuation of citizens from affected area(s), coordinated with local law enforcement and other public safety agencies
- Identification and transportation of citizens with disabilities, with other forms of reduced mobility and other citizens who are often dependent on public transportation and who may be unable to reach an evacuation staging area
- Temporary/in-place sheltering of evacuated citizens in air-conditioned/heated vehicles and stations
- Transportation, in-facility transfer, or evacuation of populations in hospitals, nursing homes, hospices, and other community and private facilities

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- Transportation of meals, goods, and supplies to an affected area for victims, for emergency responders, or to support recovery operations
- Provision of respite facilities and vehicles for emergency workers
- Communications support for emergency responders, using hand-held and on-board vehicle radios, alphanumeric pagers and Personal Digital Assistants, cell phones, transportation dispatch facilities, and transportation communications infrastructure
- Identification of routes and schedules to support the safe transportation of emergency responders, public utilities and support personnel, and essential personnel to an incident site or staging area
- Provision of vehicles and equipment to support emergency operations and incident stabilization
- Provision of estimates and information on the application of available resources to the movement of people or supplies

Recent developments in the area of emergency management strategies for transport networks are mainly associated with linking climate change impacts to emergency adaptation strategies for transport networks [3] as well as on the estimation of the impacts of climate change on transport networks [4].

III. Technological Issues of Emergency Management in the Transport Sector

A. *Towards All-embracing ITS*

During the last decade, the use of Intelligent Transportation Systems (ITS) has been steadily increasing: advanced traffic signal control systems, dynamic traffic signs and ramp metering are only three examples of a broad range of applications. ITS can handle traffic incidents, such as accidents, road closures and congestion and therefore provide tools to connect other cases of emergency with traffic management.

Emergency managers and emergency management systems have failed to take advantage of new and emerging technologies to improve operations and enhance capabilities [5]. Only during the last years, technological applications (e.g. Geographic Information Systems and Global Navigation Satellite Systems) have become part of the emergency management tool-kit, leading to an increased use of the various available capabilities. These technologies are already commonly used and emergency management personnel can leverage these tools to collect and transmit data and information. For instance, in weather forecasting, the use of information and communication technologies has led to more precise warnings of natural hazards, such as wind storms and floods. Information and communication technologies provide thus the means for improved disaster management during all of its phases (mitigation, preparedness, response, and recovery) [6].

B. *Overview of Technologies*

The management of the impacts of climate change related extreme weather events on the transport sector may be facilitated by Decision Support Systems (DSS) at various levels of automation. The three categories, in which the related processes for DSSs can be broadly divided into, are Data collection, Data processing and Data transmission. Fig.1 provides a schematic overview. The data collection, information processing and information transmission technologies for the management of extreme weather related effects on the transport sector are summarized in Tables I to III.

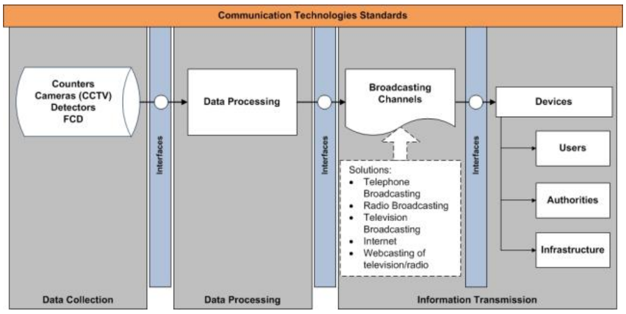

Figure 1. Overview of the data collection, processing and transmission chain.

TABLE I. Data Collection Related Technologies

Modes	Technologies
Traffic	Intrusive detectors (road, rail): inductive loops, magnetic field, piezometer, pneumatic tubes, weight in motion Non-intrusive detectors (all modes): video, radar, passive/active infrared, LASER, ultrasound, beacon/switches, optical, microphones, RADAR, LiDAR Cooperative systems: Car2X, FCD, FTD, SSR (RADAR), RFID
Locating of own location, tracking and tracing of objects, navigation	Dead reckoning (physical forces): Inertial sensors, odometry Round trip delay time or triangulation of electromagnetic and acoustic waves: GNSS, TETRA,WLAN positioning, GSM positioning, wireless sensor networks, SONAR, RADAR, SSR

TABLE II. Information Processing Related Technologies

Modes	Technologies
Data mining	Image/video processing, data fusion and data quality management, data mining techniques (statistics)
Modeling	Weather models, discharge models, GIS (incl. map matching), traffic models
Decision making	Traffic management systems, including traffic signal control, catastrophe management systems

TABLE III. Information Transmission Related Technologies

Modes	Technologies

General communication media	General systems based on electromagnetic waves: VHF radio communications, SMS (GSM), e-mail, RSS-feed, instant messaging, websites, UMTS, wide-band, cell-broadcast, telefon, telefax, tv, radio(FM, internet, DAB, DVB), video-text, dedicated short range communications (DSRC) Traffic-related systems: over-road gantry-signs, traffic lights, dynamic traffic message signs, Car2X, Non-electric systems: Poster, newspaper
Alarming	Emergency call-up (computerized dialling for emergency call-up, paging networks), (indoor loud speakers), SatWaS, multiple alarm devices, Advanced Sirens systems, Car2X, common alerting protocol (CAP)
Information	Information platforms for information integration (traffic management systems, GIS platforms), public internet platforms (flood information, traffic information, weather information and warning)

C. Information Collection Technologies

Traffic detectors may be grouped into three classes: In-Pavement detectors, non-intrusive detectors and cooperative systems.

Intrusive detectors have to be buried in or under the road- or railway. While being relatively cheap and working at a defined place, such detectors require road/railway-closures for installation and repair and they are exposed to mechanical and chemical forces degrading their life-time. They can be used to detect presence, information of the vehicle type (weight/size) and measure speeds when coupled in pairs. They comprise the most common detector types. Non-intrusive detectors do not need a solid surface and can therefore be used with all modes of transport (road, rail etc.). Used as road traffic detectors, they do not require road-closures; however, environmental influences may degrade the measurement quality, e.g. rain, fog, snow combined with video sensors. They can also detect presence and vehicle type information. Additionally, only one device is needed to determine speeds. Cooperative systems rely on communications between a vehicle and another object which may be another vehicle or an infrastructure element. The position of moving objects is important information in case of emergency. Important locating techniques include dead reckoning (via inertial sensors or odometers) and round trip delay time measurement or triangulation of electromagnetic and acoustic waves (GNSS, TETRA, WLAN positioning, GSM positioning, wireless sensor networks, sonar, and radar).

D. Information Processing Technologies

Data are gathered in order to get information about the current situation, to make forecasts and to create and maintain historical databases for future use. Data mining is an analytic process and refers to extracting or “mining” knowledge from large amounts of data [7]. Data mining techniques involve statistics, neighbourhoods and clustering and next generation techniques use trees, networks and rules. The goal of data mining is prediction and the process of data mining consists of three stages: The initial exploration, the model building or pattern identification with validation/verification and the application of the model to new data in order to generate predictions. Data fusion is the use of techniques that combine data from multiple sources and gather information in order to achieve inferences, which may be more efficient and potentially more accurate than those achieved through single data sources. Data fusion processes are often categorized as low, intermediate or high, depending on the processing stage at which fusion takes place [8]. Data pre-processing is also essential, in order to analyse multivariate datasets before clustering or data mining and includes the removal of observations with noise and missing data. Image/video processing is a form of signal processing, where the input is an image and the output may be either another image or video or a set of characteristics or parameters related to it. Most image processing techniques involve treating the image as a two-dimensional signal and applying to it standard signal-processing techniques [9]. Models are a system approach to study complex phenomena of environmental and technical systems and landscapes consisting of interconnected, complex, and functionally related components in order to estimate the current and future state of the situation [10]. Traffic models are used to simulate the traffic conditions aiming at testing alternative traffic interventions/scenarios as well as forecasting the future traffic demand. A classification of traffic models is provided in Table IV.

TABLE IV. CLASSIFICATION OF TRAFFIC MODELS

Criteria	Model categories
Nature of operation	Simulation models Analysis models Prediction models
Level of detail	Macro-scopic Meso-scopic Micro-scopic
System approach	Deterministic Stochastic – Probabilistic
Time approach	Static Dynamic

Traffic simulation models are tools used for system description, analysis and explanation, usually through simplifications of the interactions that exist in real-world systems. Simulation models can assist in determining values, which would otherwise be difficult to measure. Prediction models resemble simulation models. A system can be modelled in different ways according to various approaches, depending on the modeller‘s purposes. Traffic flow can be modelled macro-scopically from an aggregated point of view, based on hydrodynamic analogies by regarding traffic flow as a particular fluid process, whose state is characterized by aggregate macroscopic variables (e.g. density, volume, speed). Traffic flow can also be modelled micro-scopically, from a disaggregated point of view, describing the processes of individual vehicles’ dynamics. Meso-scopic models represent an intermediate modelling alternative, based on a simplification of vehicular dynamics [11]. Deterministic models are models where future events are determined to happen or not without examining the probability of the occurrence. A deterministic model assumes that an outcome is certain. Conversely, in stochastic or probabilistic models randomness is present and the possibility of examined or predicted events occurring is considered. Finally, static models do not account for the element of time, while dynamic models do.

E. Information Transmission Technologies

Information can be transmitted via several communication channels with the form of audio, video and text. Primary communication media, such as speech and nonverbal communication have to be transformed when addressing larger target groups. Moreover, it often seems efficient to promote broadcast solutions from energy-related and bandwidth-related points of view. Broadcasting is the distribution of audio, video or text content to a dispersed audience via radio, television, or other digital transmission media. Receiving parties may include the general public or a relatively large subset thereof. As a result, the dissemination of traffic information may be broadcasted to all drivers or only to those using the infrastructure. The different types of electronic broadcasting solutions include telephone broadcasting (cell broadcast in wireless telephony systems), radio broadcasting (FM, DAB, TMC, cable radio, satellite radio), television broadcasting (SDTV, HDTV, DVB, video-text, satellite/terrestrial), internet (RSS-feed, modern telegraphy: e-mail, instant messaging, web-sites) and webcasting of radio/television, which offers a mix of traditional radio and television station broadcast programming with internet-dedicated webcast programming. The technologies used for the various types of broadcasting are:

- Digital audio broadcasting (DAB) and Digital video broadcasting (DVB) services. DAB+ and DVB+ are upgraded and more efficient versions that provide higher transmission quality.
- Traffic Message Channel (TMC) - primarily used for highway-related traffic information - is based on analogue FM radio and is commonly used in car navigation systems. Due to capacity reasons it may be difficult to be expanded to more data-demanding ITS applications.

An important aspect in case of emergency is alarming. Professional relief units are usually alarmed via emergency call-ups, whereas the general public may be informed and alarmed via SatWaS, Advanced Sirens systems and Car2X.

The possible transmission technologies used in the modern communication media can be either wired or wireless and include:

- Wired technologies: Data can be transmitted using wired technologies such as Public Switched Telephone Network (PSTN), Integrated Services Digital Network (ISDN), Digital Subscriber Line (DSL), Voice over Internet Protocol (VoIP) and Power Line Communications (PLC).
- Wireless Technologies: Used for transferring information over short distances or long distances [12].

Long distance wireless communications include technologies such as Groupe Spécial Mobile (GSM), Wireless Application Protocol (WAP), Universal Mobile Telecommunications System (UMTS), Worldwide Interoperability for Microwave Access (WiMAX), Satellite telephony and High Performance Radio Metropolitan Area Network (HiperMAN). Short and very short distance wireless communication includes technologies such as Wireless Local Area Network (WLAN), Dedicated short-range communications [13] and Bluetooth. The Transport Protocol Experts Group – TPEG [14] has developed a European open standard for the broadcast of multimodal traffic information. It is designed in such a way that it can be delivered via digital broadcasting systems as well as queried via WiFi or GPRS/UMTS. In the transport sector, using the above mentioned technologies, information about the weather, the infrastructure, the traffic conditions etc., can be transmitted either through the infrastructure (On-Roadway information) or directly to the user (In-Vehicle or Off-Roadway Information). Traveller information can also be divided into two categories, according to the time of provision. The first refers to information provided before travellers make their trips and the latter during the trips. Information can be transmitted to the users of the infrastructure using various technologies. Fig. 2 shows common information transmission systems, according to pre-trip or en route use.

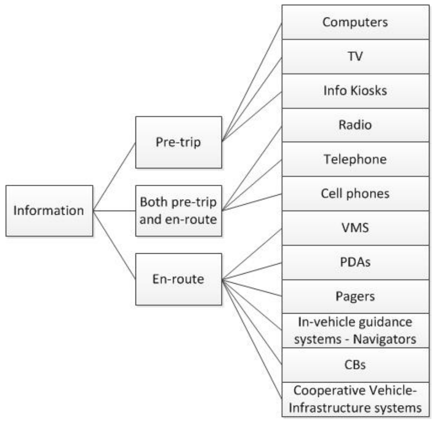

Figure 2. Pre-Trip and En-Route Information Transmission Systems

The output devices for travel information dissemination include:

- Variable Message Signs (VMS) include a variety of different types of signs that display changeable messages to provide users with real-time information. Information transmitted through VMS may refer to roadway surface conditions, traffic conditions, events - incidents, speed advisory, adverse weather and environment conditions, traffic control, special use of lanes, etc.
- In-Vehicle Route Guidance Systems - Navigators may be video display terminals mounted on the dashboard of a vehicle or portable devices that provide real-time route guidance and navigational information to the drivers [15].
- Mobile phones are devices used for two-way radio telecommunication over a cellular network. New

generation smart mobile phones support additional services such as SMS messages, e-mail, internet access, radio, GPS and Bluetooth communications. In the transport sector, mobile phones are used for accessing traffic-related information services with route-specific traffic information using GPRS.

- Commercial radio stations often include traffic reports. In addition, there are special radio stations such as the Highway Advisory Radio (HAR) [16] dedicated to providing information to travellers.
- Citizen-Band radios (CBs) [17] allow two-way communication between the users of the infrastructure and the i.e. Traffic Management Centre, and are useful in driver aid services.
- Internet is one of the most important means for information dissemination. Any computer connected to the internet can receive various types of pre-trip information. Internet can be used for real-time, route specific information, as well as for bus schedules, route distances, etc.
- Commercial television stations provide traffic information, either as a scheduled part of their program, or by interrupting regular programming. Moreover, broadcast information services, such as Teletext, are also provided.
- Cooperative Systems (Car2X) are systems where vehicles communicate either with other vehicles (Car2Car) or with the road infrastructure (Car2Infrastructure) based on WLAN, 5,9 GHz or Bluetooth for bi-directional information exchange.

IV. Conclusions

This paper presented a review on the technologies that can be used for easing the negative impacts of extreme weather events on transport network. The technological aspects for the provision of emergency transport management were presented in regard to data collection, processing and transmission. Work presented herein can be used for further analysis by research institutes and public authorities for dealing with the effects of climate change.

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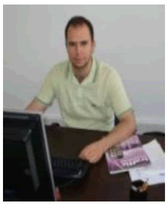

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