SAFETY

The Use of **Intelligent Transportation Systems** in **Risk and Emergency Management** for Road Transport Planning and Operation

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Road transport quality is critical to a country's overall development and sustainable growth. Managing road transportation networks is challenging due to uncertainties induced from related activities, such as agency management, program development, project delivery, maintenance, and operational aspects.

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As transportation agencies aim at optimizing their investment performance, it is incumbent for many of them to develop explicit enterprise risk management strategies, methods, and tools as there are always risks that may impact the achievement of the desired performance level[1].

Transport and mobility management strategies must increase safety and reduce costs to support their sustainability and trustworthiness. Intelligent transportation systems (ITS) assisting these adaptations may lead to additional resource savings and further advance the safety performance of the roadway.

The paper aims at demonstrating the necessity for ITS support during risk and emergency roadway management. Furthermore, it provides a source of references from practice that demonstrate the key role of ITS in risk and emergency management, in enabling traffic authorities for coordinated, effective, and efficient actions for addressing such situations. An overview of basic aspects of risk and emergency management is provided.

Risk Management and Emergency Management Interrelation

ISO 31000 Risk Management – Principles and Guidelines[2] includes the following definitions for risk and risk management:

Risk is defined as the effect of uncertainty on objectives, while risk management is comprised of coordinated activities to direct and control an organization with regard to risk. Moreover, risk management addresses both negative risks (i.e. threats) and positive risks, namely missed opportunities, and aims at reducing the probability of occurrence of a hazard, reducing its impact (consequences), or both. When it comes to opportunities, the previous sentence applies with the term enhancing instead of reducing.

Risk management is closely interconnected to emergency management and business continuity management—however, key differences are exhibited, and are outlined below.

Business continuity is related to the ability of an authority or organization to continue its operations at the required level of service in case of an emergency situation (e.g. a major disaster). It addresses negative risks that may adversely affect the operation of an organization, and is rather focused on the recovery process after an emergency occurs.[2,3]

Emergency management involves both addressing a risk through appropriate plans and ensuring the continuity of the operation of an organization, service, or network. The concept of emergency management includes business continuity management but does not include risk management, since the latter addresses both positive and negative risks. This relationship is shown in Figure 1. Furthermore, emergencies can involve extraordinary situations (e.g. major natural disasters) for which conventional risk management may prove insufficient.[4,5]

The emergency management process has three main stages, related to the evolution of the incident in time[6, 7, 8, 9]: preparedness, response, and recovery. In some risk management manuals, prevention is also mentioned as an additional stage, before the stage of response. Coordination and cooperation of all stakeholders in all stages of the process is vital for effectively addressing any emergency situation.

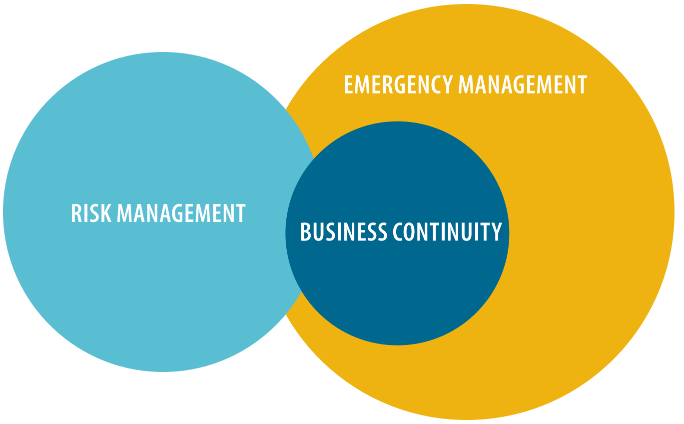

Figure 1. Relationship between risk management, business continuity, and emergency management.

Risk Management Process and Emergency Management Plans

Effective transport and mobility management strategies may greatly improve safety and cost reduction in road transport systems and thereby support their sustainability. Combined with recent technological advances, this may lead to additional resource savings and further advance their reliability.

The rapid and steady technological breakthrough development of ITS during the last decade translates into demonstrated added value when these are applied to road traffic risk and emergency management.[4] Modern ITS, by processing and sharing information, are able to address safety, mobility, and environmental impacts by preventing accidents, reducing traffic congestions, and decreasing emissions, respectively. However, in order for ITS deployment to be effective at the country level, stakeholders need to have in-depth knowledge of both social and economic aspects. Support from thoroughly designed programs operators of traffic management centers (TMC) is also essential.

In risk management, ITS enables traffic authorities to coordinate and act more efficiently in case of planned or unexpected emergency situations. Moreover, ITS applications are able to forecast adverse-impact events on roadway services that are unlikely to occur.[4] Australia and Spain provide good examples on ITS practice for data acquisition and dissemination in order to inform and protect the public from natural disasters.

In Australia, road closures due to natural disasters such as wild fires, strong winds, and flooding are quite common. In the State of Victoria, Australia a series of tools and actions have been implemented to allow for availability of relevant information and access to the public, including:[4]

- A manned 24-hour telephone service for road closure information to be fed from the emergency services to VicRoads (the competent road network coordinating agency).
- An Emergency Incident Control Center that collects road closure information, and coordinates tactical response in case of major emergencies.
- Data collection systems using mobile data networks are able to be operated from Incident Control or Emergency Operations Centers (EOCs).
- Multiple platforms (e.g. website, mobile phone applications) for the public to access the information.
- Emergency management broadcast announcements.
- Supplementary actions such as information databases, website and mobile phone applications development, staff training, and implementation of new procedures.

In forest fire management in Spain, road users are informed about their state and related road closures or traffic disruption through approximately 2,100 variable message signs (VMS) along 11,000 km of the road network. Hourly radio/TV broadcasts communicate to the public relevant information and recommendations obtained from Traffic Control Centers.[4] ITS have also been used in managing potential energy supply shortages or disruption. In 2011, due to the high increase in the price of petroleum, a new law was put in force aiming at reducing petrol consumption and dependency without disturbing the national economy and mobility. Speed limits on highways were reduced by 10 km/h to achieve a reduction in petrol consumption for transport. ITS was a contributing factor in implementing and enforcing the new speed limits through speed control applications, provision of information to the public concerning the new limits via VMS, and automatic generation of speed reports that ensured fining the offenders.[4]

According to the guidelines outlined by various bodies (e.g. Project Management Institute,[10, 11] NCHRP,[12] and FHWA[13]), the following steps are suggested for effective risk management:[1, 2, 4]

- **Context Analysis.** Activate and coordinate public authorities within the legal framework by forming a coordination task group aimed at identifying stakeholders and objectives.
- **Identification.** Identify the risks that may affect objectives, report on their characteristics and on all related consequences (e.g. budget-related, impacted areas, and assets).
- **Analysis.** Define the risk in terms of impact and probability and review the effectiveness and the efficiency of existing control systems and technical procedures.
- **Evaluation.** Compare the risk level obtained from the analysis with the agency's established risk thresholds and tolerances.
- **Treatment.** Consider risk response options and potential resulting risk modification while accounting for related costs and benefits.
- **Monitoring and Review.** Follow the risk management process and report on its performance in addressing the risks and on the effectiveness of the risk treatment plans.
- **Communication.** Analyze and deliver information pertaining to the stakeholder's competence field in a cooperative way for the benefit of the community.

Transportation systems management and operations (TSMO) guidance produced by the American Association of State Highway and Transportation Officials (AASHTO) rely on ITS and must eventually support the risk management process.[14] By implementing risk treatment options during transportation design, construction and operation, some hazards may no longer apply, but new hazards may be revealed. Therefore, the aforementioned risk management process is iterative.

Emergency traffic management plans (TMPs) are valuable tools in terms of optimizing resources, ensuring both mobility and security concerns are met, and achieving effective communication among stakeholders when required. The TMPs primary objectives are:[4]

- quick evacuation of users, and
- fast, safe, and effective access of rescue services to the impact area.

TMPs have been developed for Moto-GPs events hosted in Spain every year that attract a large number of fans from various countries in a short period (1–3 days).[4] In order to ensure road safety and emergency management, the relevant TMPs have specific objectives and include a detailed description of actions to be undertaken. Specific adverse scenarios are considered including the preventive massive evacuation of the circuit site, the evacuation of casualties, the access of emergency vehicles into the circuit, management of incidents and prevention of secondary incidents, and traffic enforcement. Appropriate measures for these scenarios are also identified in the TMPs.

A special TMP for cases of massive traffic demand has also been developed in Spain.[4] The TMP concerns the dissemination of appropriate information and road assistance to vehicles on two main routes, where heavy traffic occurs during the summer period. The TMP includes information about rest area locations, information sites and relevant informative messages provided via VMS. A respective protocol ensures exchange of information among several authorities for the implementation of the TMP.

When substantial risks are identified, a Strategic Scenario for Crisis Management must be produced. Strategic Scenarios, include risk analyses and description of operational measures for risk management. They also include TMPs designed to address extreme cases (e.g. terrorist attacks, adverse weather situations, nuclear accidents, etc.). An iterative and cooperative approach is encouraged that consists of the following stages:

- Stage I: Data and Definitions
  - Characteristics of the affected area (geographical, climatological, road network)
  - Global system of traffic management (traffic level, performance measures, action strategies)
  - Stakeholders (identity, coordination)
  - Live information system (data collection and analysis, information points, messages to information points, recommendations for users)
  - User care and attention system
- Stage II: Decision Tables
  - Scenes tables
  - Measures tables
  - Operating tables
- Stage III: Validation by the Competent Authorities
- Stage IV: Computerization
- Stage V: Implementation and Periodic View

TMCs and ITS Contribution in Risk and Emergency Management

A number of road agencies, in their effort to improve mobility and satisfy increasing transport demand, have introduced the use of electronic devices on roads and TMCs. The evolution of ITS during the last decade has made interaction possible between roads, TMCs, and vehicles,

TMCs consist of a core traffic and mobility management body and hold a key role in road risk and emergency management. In this context, TMCs are focused on collecting data from road ITS; and analyzing, processing, and disseminating data to stakeholders.

An efficient TMC design should facilitate management of traffic operation and be interconnected with other systems (e.g. traffic counters, variable message signs (VMS), etc.) or authorities (e.g. traffic police, road experts, etc.) in order to inform, monitor, control, and enforce compliance by road users. Aiming at improving emergency management, TMCs adopt measures that can be broadly classified into preventive and operational.[4]

Preventive measures are taken before risks occur in order to avoid negative effects and are classified as follows:[5]

- Direct measures to prevent undesired situations
- Measures to prevent a specific threat (medium – short term)
- Measures aiming at minimizing the consequences from an impending threat

From the operational perspective of TMCs, effective implementation of emergency management includes:

- Information and data exchange among involved agencies
- Control and monitoring through air-drones or CCTVs
- Real time information for access control to enable evacuation events
- VMS for reliable and updated on-trip information
- Information on safe and less congested routes
- Dynamic traffic restrictions
- Emergency service routes
- Special measures to increase capacity (e.g. additional lanes)

On modern highways, TMCs supported by ITS are capable of further improving the road network management, the reliability of the provided information, travel decisions, congestion, and road safety.[5]

In terms of emergency management, the use of ITS can fit in the following categories:

- ITS for incident detection, e.g. CCTV cameras, traffic counters, vehicle speed, and over-height detectors.
- ITS for emergency management, e.g. information systems [pre-trip (e.g. smartphone applications) and on-trip (e.g. VMS)], and support systems (e.g. e-Call, Traffic Police).

However, effective decision-making basically relies on the availability and the quality of the integrated ITS data, such as:

- Weather forecasts
- Traffic forecasts
- Speed management
- Automatic traffic enforcement
- Vehicle to vehicle (V2V) communication
- Vehicle to infrastructure (V2I) communication

Several successful examples of effective ITS utilization in risk and emergency management for safe road operations are available.[5] An example is the area of Westgate Bridge in the State of Victoria, Australia, where the strong winds are continuously monitored to minimize the risk of incidents. When various pre-determined thresholds in terms of wind speed are met, the vehicle speed-limit on the bridge is lowered via VMS. Moreover, for wind speeds over certain limits (100 km/h) the number of lanes over the bridge is reduced, or the bridge may even be closed to traffic (120 km/h). In such cases, an overhead lane display, upstream from the incident, designates merge arrows or lane closure symbols respectively.

Fusion Centers have also been created in Australia to provide interdisciplinary expertise and coordinate the information exchange between the TMCs, which are permanent structures, and EOCs that may be created as the situation dictates. Improved situational awareness in conjunction with real-time analysis assists law and homeland security enforcement and civil protection.

Conclusions and Recommendations

This paper examined the potential support ITS provides in risk and emergency management during road transport planning and operation.

Efficiency during risk and emergency management is a basic prerequisite for a reliable and safe road transport system. Improved situational awareness due to ITS integration in emergency management may further support it by inducing more effective decision-making.

ITS offers advanced capabilities for information dissemination and communication. The combined support from ITS and TMCs to road users particularly during the last decade has been considerable. Improvements in managing road networks as well as advances in certain control aspects related to the reliability of the provided information, to better-justified travel decision-making, to the limitation of congestion, and to improved road safety, have been achieved.

Emergency TMPs and related Strategic Scenarios are essential tools for optimizing resources and coordinating actions among stakeholders when required.

Further research is needed in order to introduce guidelines on ITS deployment for risk and emergency traffic management in regard to optimizing its reliability, supporting real-time up-to-date user guidance, improving operational levels, and increasing road safety. **itej**

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