



**EFFECTS OF ADVERSE WEATHER ON TRAFFIC AND SAFETY:
STATE-OF-THE-ART AND A EUROPEAN INITIATIVE**

NOUR-EDDIN EL FAOUZI (*)

ROMAIN BILLOT (*)

PERTTI NURMI (**)

BERNHARD NOWOTNY (***)

(*) Transport and Traffic Engineering Laboratory (LICIT)

INRETS-ENTPE

25 Avenue François Mitterrand Case 24

69675 Bron Cedex, France

(**) Finnish Meteorological Institute

P.O. Box 503, FI-00101 Helsinki

(***) AIT Austrian Institute of Technology

Giefinggasse 2, A-1210 Vienna, Austria

elfaouzi@inrets.fr¹, romain.billot@inrets.fr, pertti.nurmi@fmi.fi, bernhard.nowotny@ait.ac.at

¹ Corresponding author

ABSTRACT

The impacts of adverse weather conditions on traffic operations, quality of traffic flow and safety have been widely recognized. With the advent of ITS and associated advancements in the deployment of road weather information systems (RWIS) and road weather forecasting methods and services, active weather-sensitive traffic management strategies can be developed to mitigate various undesirable impacts. In view of the paramount importance of weather-responsive tools for real-time traffic surveillance, a European initiative was launched in 2008 within the European Cooperation in Science and Technology (COST) framework. The main objective of this COST Action TU0702 is to understand the impacts of adverse weather on traffic operations and develop, promote and implement strategies and tools to mitigate such impacts. Furthermore, the Action fosters the exchange of know-how between interdisciplinary sciences (e.g. road engineering and meteorology), road operators and road maintenance authorities. Altogether 17 European COST member states have joined this research consortium as of late 2009, along with two extra-European countries, Australia and Japan.

This paper reports on the main conclusions of the state-of-the-art and practice research activities conducted as the Action's initial major milestone during its first year of existence. First, the definition and common understanding of "adverse weather conditions" along with weather events to be considered as "adverse" in relation with road traffic operations are proposed. Thereafter, the main findings of related research efforts including good practices with respect to weather effect integration in traffic management are summarized, providing a wide spectrum overview of ongoing research efforts within the EU countries. Finally, identified research gaps and needs are introduced as a basis of future research and collaboration within Action TU0702.

1. INTRODUCTION

Adverse weather conditions have a significant impact on traffic operations, quality of traffic flow and road safety. With the deployment of road weather information services (RWIS) collecting road weather information in real time and ITS traffic data archives, active weather-sensitive traffic management strategies can be developed. Because of the huge importance of weather-responsive tools for real-time traffic surveillance, a European initiative was launched in 2008 within the European Cooperation in Science and Technology framework (COST). This initiative, COST Action TU0702 ², has as its goal to understand the impacts of adverse weather on traffic operations and to develop, promote and implement strategies and tools to mitigate such impacts.

This paper reports on some of the main conclusions of the state-of-the-art and practice research effort conducted as part of the Action's activities. The article is organized as follows: Section 2 provides an insight and makes some proposals on the definition of terminology associated with "adverse weather", with a specific target to reach a common understanding of the terminology within the Action. Section 3 reports on the main findings of the state-of-the-art and practice, while Section 4 is dedicated to the identification of research gaps and research needs to form the basis for a research agenda of this new European initiative.

2. "ADVERSE WEATHER" DEFINITION AND ASSOCIATED TERMINOLOGY

Addressing the effects of adverse weather conditions on traffic operations and more generally on road network quality of service (QoS) needs a clarification of what is meant by "adverse weather". A common, over-arching definition is far from being obvious and unique and, therefore, a general definition of terminology is called for. It was acknowledged early within TU0702 that mixed definitions and conceptions of key words created confusion amongst project partners and end-users and would easily bring about barriers for eventual solutions. Definition of terms associated with adverse weather (events) have been tackled by the Action's Task Force "Adverse Weather Events" and discussed with TU0702's other working groups, hence leading to a general understanding and agreement between the partners.

The term "adverse weather" (and kin words like "severe", "extreme", "rare") may have several definitions, many of them embracing different contexts. The majority of studies discussing the adverse effects of weather on traffic focus on rain, snow and fog. Within the traffic or transportation engineering discipline, most of the papers have adopted the term "adverse" or "inclement" and they deal essentially with rainy or snowy conditions [1-12]. A more recent paper includes sun glare and darkness as an "adverse" event [11]. An analogy from the construction industry³ links together as synonymous "adverse" and "inclement" weather. In the meteorological community, however, the word "inclement" is practically never used. A comprehensive essay on the definitions of weather related terminology in meteorology is given by Stephenson [13]. *Adverse weather condition* can be interpreted as having five dimensions: (i) operational, (ii) economical, (iii) ecological, (iv) social, and (v) cultural or geographical. In the context of RWIS and more specifically within traffic operations *adverse weather condition* and its associated terms are to be seen from the operational perspective as "*atmospheric conditions at a specific time and place that are unfavorable to optimal traffic conditions*". Adverse weather event can from this perspective be distinguished from common or recurrent weather events (rain, snow, wind etc.) or from

² See TU0702.inrets.fr

³ <http://www.usasoft.com/whtpaper.htm>

severe, extreme and rare weather events (e.g. snow storms, hurricanes, tornadoes), which may be understood synonymously for *adverse weather event* but not necessarily in terms of frequency and impacts on road networks.

3. IMPACT ASSESSMENT OF ADVERSE WEATHER ON TRAFFIC AND SAFETY

Research about effects of weather on traffic was published already as early as in the 1950s [14]. Further to the seminal studies by Jones [15] and Hall and Barrow [16], a certain amount of articles have enabled the elaboration of a state-of-the-art about the effects of weather on traffic and safety. The topic of the influence of weather conditions on road safety has resulted in many studies presented at international conferences and published in scientific/technical journals. First, we synthesize here the main conclusions of adverse weather impact on crash rates and crash severity. Adverse weather has a well-known impact on safety with an increase of crash rates and severity. Several studies have covered and focused on the effects of weather conditions on road accident occurrence and severity, attempting to capture these often very complex effects. A thorough review of the most early studies on weather effects can be found in Eisenberg [17]. Since many studies have focused on weather effects on crash rates in North America (e.g. [1]), some recent European results will be covered in the SIRWEC lecture.

Regarding the traffic engineering side, and more particularly the traffic demand, empirical studies have been carried out mainly in the USA, e.g. [18] showed that adverse weather may cause:

- Travel demand reduction, as drivers postpone discretionary trips or activities get cancelled.
- Travel mode share variation, i.e. mode shift in the occurrence of bad weather conditions (e.g. those who travel by bicycle will have to change temporally their traveling mode).

A recent Finnish study confirmed that adverse weather can impact traffic demand. As a matter of fact, the study mentioned that in total 62% of the drivers had received or looked for information on road conditions and weather during their journey or beforehand [19].

The state-of-the-art can be divided into three parts according to the type of data and the level of analysis. First, the majority of analyses use data provided by traffic sensors. Then, traffic data is checked against weather data provided by weather stations or RWIS. In this case, the goal is to quantify the impact of adverse weather on traffic through statistical data analysis. Within this task, the proposals can be separated into two categories according to the analysis granularity. More specifically, the impact of weather can be analyzed at the microscopic or macroscopic level. At the microscopic level, the impact of weather on individual speeds, time and spacing headways, is analyzed and modeled. At the macroscopic level, only aggregated traffic operations are taken into account. Thus, the analysis of impact of adverse weather on traffic at a more aggregated level is performed. First, changes in traffic demand under adverse weather conditions are assessed. Second, the effects of weather on traffic parameters which form the fundamental diagram of traffic flow are quantified (speed, capacity, density...). The main conclusions are summarized in Figure 1. Specific examples of European studies about this subject are also compiled in the COST TU0702 State-of-the-art report [20]. This is the first step toward the integration of weather effects into traffic modeling and simulation tools.

DRIVERS' BEHAVIOR (microscopic level)	Speed and acceleration	↘
	Time Headways	↗
	Spacing	↗
	Lane Changing, Platooning	
TRAFFIC OPERATIONS (macroscopic level)	Capacity	↘
	Traffic flow	↘
	Speed	↘
	Speed Variation	↗
	Congestion Severity	↗

Figure 1: Summary of precipitation effects on traffic and drivers' behavior

4. RESEARCH NEEDS AND PERSPECTIVES

In the light of the state-of-the-art, many issues need to be addressed. First, although adverse weather quantification is relatively well understood, studies about weather impact on traffic are still needed, mainly with respect to comprehensive weather events (fog, wind, visibility etc.) and above all utilizing comprehensive databases in order to be able to address a wide range of weather events intensities impact on traffic. The objective is to identify which types of traffic parameters could be affected by weather events. Next, the main research needs deal with the integration of the results of such quantification studies into traffic models. More specifically, a research effort should be put in designing weather-dependent traffic flow modeling and developing guidelines on how weather impact on traffic operations can be modeled using traffic simulation models. In this respect, three major modeling frameworks are actually undertaken within this COST Action: (i) Deterministic traffic theory-based modeling, with the following tasks: weather-dependent calibration of traffic models (macro/micro models) with an insight on how weather affects car following, lane changing and gap acceptance behavior, (ii) Stochastic modeling approaches with Bayesian filtering-based models, kinetic-based modeling, (iii) Statistical models and other data mining engines aiming at deriving adjustment factors to account for weather impacts on speed or travel time, density, traffic risk, capacity, traffic demand.

Ultimately, weather effects will be included in traffic management strategies and decision support systems (DSS).

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