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Modelling the propagation of smoke from a tanker fire in a built-up area

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HIGHLIGHTS

- The application of a custom-developed model of pollutants dispersion is presented.
- The application of model is connected with safety in road transport.
- Numerical simulations are performed for a case of smoke emission from a tanker fire.
- The results of simulation of smoke propagation in a built-up area are presented.
- The GIS is used to provide data for pre- and post-processing purposes.

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ABSTRACT

The paper presents the application of a Lagrangian particle model to problems connected with safety in road transport. Numerical simulations were performed for a hypothetical case of smoke emission from a tanker fire in a built-up area. Propagation of smoke was analysed for three wind directions.

A diagnostic model was used to determine the air velocity field, whereas the dispersion of pollutants was analysed by means of a Lagrangian particle model (Brzozowska, 2013). The Idrisi Andes geographic information system was used to provide data on landforms and on their aerodynamic roughness.

The presented results of computations and their analysis exemplify a possible application of the Lagrangian particle model: evaluation of mean (averaged over time) concentrations of pollutants and their distribution in the considered area (especially important due to the protection of people, animals and plants) and simulation of the propagation of harmful compounds in time as well as performing computations for cases of the potential effects of road incidents.

1. Introduction

Modelling the dispersion of pollutants belongs to a group of fundamental problems that are connected with evaluating the impact transport has on the environment. Although evaluation for longer periods of time and on larger scales (meso- and macro-) is relatively easy, in individual road accidents assessment of their effects proves to be difficult. This includes incidents resulting in the sudden release of pollutants.

A tanker fire in a tunnel is a particularly important problem that has been discussed in a number of scientific papers (Beard and Carvel, 2005; Caliendo et al., 2012; Colella et al., 2010; Hu et al., 2008; Miles and Smithies, 2006; Xiaojun, 2008; PIARC, 1999). According to PIARC (1999), in this case models of the CFD class are predominantly used, as in: Caliendo et al. (2012), Beard and Carvel (2005), Hu et al. (2008), Miles and Smithies (2006), and Xiaojun, (2008); less often zone models (Hua et al., 2005; Jain et al., 2008; Xiaojun, 2008; Yao et al., 1999) and one-dimensional models play an auxiliary role (Colella et al., 2010).

It should be noted that road accidents and vehicle fires, including vehicles that transport fuel, do not only take place in tunnels, but also elsewhere. Fires occurring in close proximity to buildings are especially dangerous — this is the case that this article aims to analyse.

Basically, there are two types of models that are used to model dispersion of smoke originating from a fire: microscale ones — such as the aforementioned CFD models (Novozhilov, 2001; Viskanta, 2008), which are predominantly used in problems related to fires in tunnels and closed spaces (e.g. a garage or an atrium (Qin et al., 2009)), and also in other cases when phenomena that spatially occur in the microscale (such as the fire of a fuel tank (Argyropoulos et al., 2010; Markatos et al., 2009)) must be taken into account; and mesoscale as well as macroscale ones, which are used most often to analyse forest fires (Lavrov et al., 2006; Mell et al., 2010). The following types may be distinguished in the group of mesoscale and macroscale models: empirical and theoretical (a comparison of models for the case of modelling dispersion of a smoke plume originating from a fire is presented in Fisher et al. (2001)), statistical (Yang et al., 2004) and numerical models in Euler (Vautard et al., 2007) or Lagrange (Stohl et al., 2005) coordinates.

Another division of models of fires is possible: into probabilistic models (event trees, statistical models, Monte Carlo simulations)

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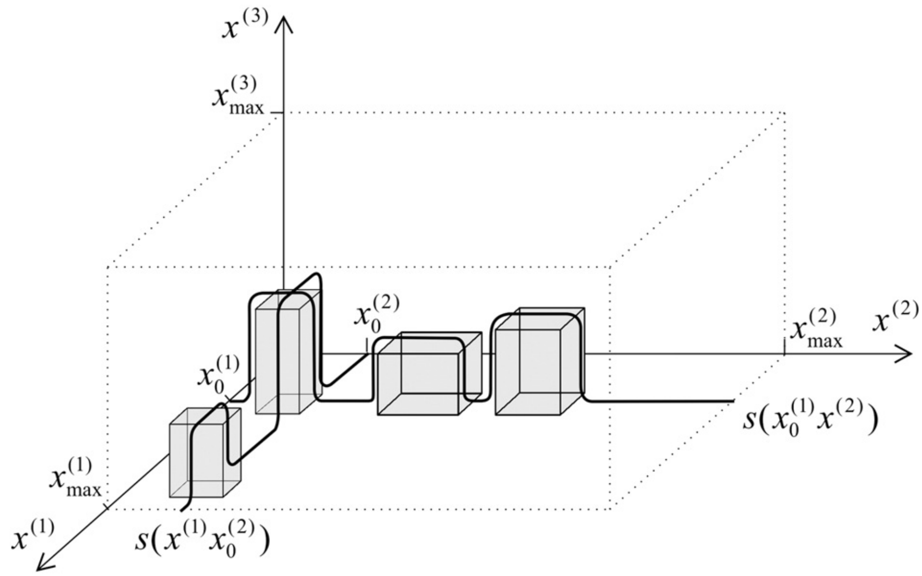

Fig. 1. Example of approximation of land surface with buildings by using the continuous function *s* (Brzozowska, 2013).

and deterministic models (zone models, discrete ones (field models, CFD)).

A taxonomy of models used in simulations of forest fires and their analysis can also be found in Pastor et al. (2003).

Modelling propagation of smoke originating from fires in urban canyons and in close proximity to buildings is a problem that is rather seldom discussed. Nevertheless, there are papers (Hu et al., 2009, 2011; Liu et al., 2011) worth mentioning in which the problem of smoke propagation from a building on fire into the street is analysed by using either (Hu et al., 2009, 2011) LES or experimental data (Liu et al., 2011) for computer simulation.

Geographic Information Systems (GIS) are used in modelling the dispersion of pollutants in the mesoscale and macroscale (Pastor et al., 2003). They may prove useful in preprocessing or postprocessing.

The current paper uses a Lagrangian numerical model combined with a diagnostic model of the air velocity field (Brzozowska, 2013). Problems related to transfer of heat were neglected in modelling the dispersion of smoke caused by an accident and the ignition of a tanker on a

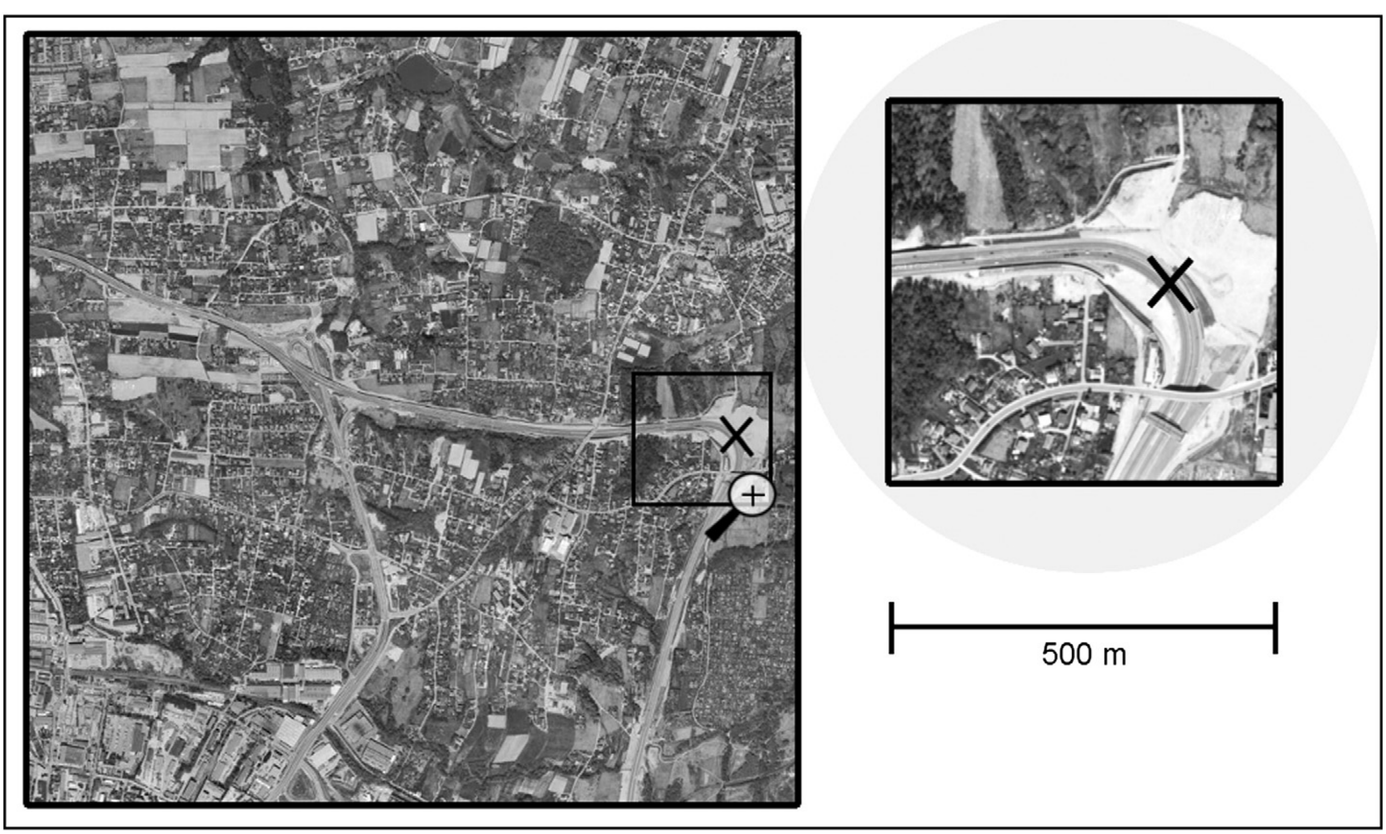

Fig. 2. Map of the modelled area and the location of the accident (marked with a cross).