Challenges and strategies of transportation modelling and simulation under extreme conditions

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Abstract: Recent natural and man-made hazards such as 9/11, the Asian tsunami, and Hurricane Katrina have raised worldwide concerns. To facilitate the efforts of emergency management, this paper discusses the role of transportation modelling and simulation in these efforts, identifies the challenges faced by transportation modelling and simulation under extreme conditions, and proposes strategies to address some of the challenges. More specifically, the challenges are (a) simultaneous requirements on scale and detail, (b) lack of tools to model traffic operation under extreme conditions, and (c) lack of knowledge and data about extreme conditions. In response to the first challenge, a dynamic multi-scale resolution framework is proposed to achieve the two competing goals, i.e., modelling large-scale networks yet achieving fine details of traffic operations. In response to the second challenge, a nanoscopic approach is conceptually proposed to provide the finest details of traffic operations. A conceptual case study is presented to illustrate a possible application of the above simulation framework.

Keywords: emergency management; extreme conditions; transportation; modelling and simulation; multi-resolution simulation; nanoscopic simulation.


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1 An overview of the problem

Recent natural and man-made hazards such as 9/11, the Asian tsunami, and Hurricane Katrina have raised worldwide concerns. If we broaden our perspective and include other non-recurrent, high-impact events such as earthquakes, floods, wars, nuclear threats, and chemical spills, we notice that the ensued extreme conditions characterise these emergencies in which real world systems operate drastically different from usual.
Extreme conditions may occur at any time and across boundaries. In the USA, attention to and research on extreme conditions evolved with time. Before 1990s, the emphasis was on nuclear threats and spills (Smith et al., 2002; Xia et al., 2005; Murray-Tuite and Mahmassani, 2005). In the years that followed, hurricanes became the major concern. In addition to the deadly and costly hurricanes such as Floyd, Allison, Charley, and Ivan, the theme was strengthened by the Tsunami in Southeast Asia and the recent Katrina at New Orleans. National Oceanic & Atmospheric Administration (NOAA, 2005) hosts a collection of reports covering various aspects of hurricane management including planning, assessment, and mitigation. Since the turn of this century, especially after the tragedy of 11 September 2001, the theme has been intermingled with a strong emphasis on homeland security. Consequently, requirements and demands on emergency management involving preparedness, prevention, protection, response, and recovery have been increasingly intense.

Extreme conditions are rare and high-impact events and, thus, are difficult to manage. The difficulties arise from the following:

- Extreme conditions are rare and, as a result, there is a lack of data to help analyse the mechanisms of the emergencies and the responses of the real world systems.
- Extreme conditions are non-recurrent, so management strategies developed in response to these extreme conditions may hardly be used in practice, and thus it is difficult to evaluate their effectiveness.
- Extreme conditions are disruptive and destructive, so it might be prohibitive to physically replicate these conditions for learning and training purposes.

As a low-cost, safe, non-disruptive, reproducible, and testable means of problem solving, modelling and simulation is particularly attractive in addressing problems under extreme conditions. Past research has documented applications of modelling and simulation in the following aspects of emergency management: understanding hazards (Cohen and Morrison, 2004; Woo, 2004), identifying potential problems and developing strategies (Albores and Shaw, 2005), improving system operation and coordination (Loper and Presnell, 2005; Robinson and Brown, 2005), emergency personnel training (Jain and McLean, 2005; Sanders and Lake, 2005), and developing and assessing evacuation plans (Sheffi et al., 1982; FEMA, 1984; KLD, 1984; Hobeika and Jamei, 1985; Southworth, 1991; Hobeika and Kim, 1998; PBS&J, 2000; Mei, 2002; ORNL, 2003).

Modelling and simulation covers a wide area and has been applied in various disciplines. Rather than opening a broad discussion in general, this paper focuses on the role of transportation modelling and simulation in emergency management. More specifically, the paper identifies a few key challenges faced by transportation modelling and simulation in dealing with extreme conditions. In response, some modelling and simulation strategies are developed to address these challenges.

2 The role of transportation modelling and simulation

One of the most important aspects underlying emergency management is transportation. Efficient transportation system operations are essential to ensure safe evacuation of people and goods as well as support response operations (USDOT, 2005). However, difficulties arisen toward achieving the above goals include:
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- the concentration of populations on available transportation networks
- the simultaneous requirements on evacuation access and responder logistics
- deviation from evacuation plans and normal driving behaviour
- the transportation system itself may be under attack.

Given the complex and magnitude of the problem, even modest improvements in the performance of the transportation system can lead to considerable benefits (Kwon and Pitt, 2005; Yuan and Han, 2005). To facilitate such an effort, transportation modelling and simulation offers the opportunity to study traffic operation under extreme conditions via the execution of experiments in a controlled environment without any disruption of actual traffic systems. Historically, modelling and simulation of transportation systems under extreme conditions has been centred on emergency evacuation plans (Wolshon et al., 2002; Urbina and Wolshon, 2003; Sisiopiku et al., 2004; Liu et al., 2005). Specific research problems explored included evacuation demands/participation rates (Lewis, 1985; Southworth, 1991; Peeta and Mahmassani, 1995; Barrett et al., 2000; Franzese and Han, 2001; Mei, 2002; Fu, 2004; Chiu et al., 2005; Alsnih et al., 2005), when to start an evacuation and clearance time or population removed as a function of time (Urbanik, 1986), evacuation routes and alternatives, optimising evacuation traffic, traffic control strategies to assist the optimisation, evacuation plan evaluation, vulnerability of transportation systems (Smith et al., 2002; Xia et al., 2005; Murray-Tuite and Mahmassani, 2005), and strategies to deal with vulnerable transportation systems.

3 Challenges in transportation modelling and simulation

To facilitate the development of future generation tools to assist better emergency management, it is important to understand the challenges faced by transportation modelling and simulation under extreme conditions. Among others, the following challenges stand out foremost: (a) simultaneous requirements on scale and detail, (b) lack of tools to model traffic operations under extreme conditions, (c) lack of knowledge and data about extreme conditions. These challenges are detailed in the paragraphs that follow.

3.1 Simultaneous requirements on scale and detail

In analysing transportation systems under extreme conditions, it is essential to have both capabilities of overseeing the full picture (e.g., a regional transportation network) and zooming in for local details (e.g., a corridor or an intersection). Anyone who is familiar with Google Maps or Google Earth develops a sense of the importance of having global information yet being able to zoom in and view local details. Transportation modelling and simulation tools developed in the past are mostly single-level resolution oriented in that they are suited for either solving large-scale transportation problems with coarse resolution or solving small-scale problems with fine details. Though these tools can provide partial solutions, efforts are needed to integrate them to provide a comprehensive analysis with both scale and detail because emergency management involves addressing multiple aspects of the emergency. To achieve both goals of scale
and detail, a framework is needed to allow a broad range of simulation systems to communicate, coordinate, and integrate. For example, a large-scale, high-level simulation process can be distributed to many small-scale, low-level simulation processes for a closer study and several local scenarios can be combined into one master scenario to show overall performance.

3.2 Lack of tools to model traffic operation under extreme conditions

Transportation system operation under extreme conditions involves moving a large population of indeterminate size on a road network with severely reduced capacity towards safer regions which cannot be easily determined either. However, conventional modelling and simulation tools are developed for use under peaceful settings and thus they are not suited for coping with such levels of uncertainties. Under extreme conditions, drivers are under panic and their driving behaviour changes drastically from usual. For example, safety as a prior goal may give its way to the need of getting out of the endangered site as quickly as possible. Traffic rules may not be observed and, as a result, unusual operations such as running red light, violating priority rules, and off-road operations are possible. Existing modelling and simulation tools are based on the assumption of driving in a safe world, so they have difficulty to replicate situations under extreme conditions. Moreover, panic behaviour is likely to result in more frequent accidents and crashes than usual. However, existing modelling and simulation tools are designed as ‘accident-free’ and this renders these tools less attractive in modelling and simulating transportation operation under extreme conditions.

3.3 Lack of knowledge and data about extreme conditions

It has been accepted by many that, under extreme conditions, driving behaviour is drastically different from usual, but little is known as to how different it is and how to quantify such change of driving behaviour. For example, research and documentation about drivers’ car-following preference under normal conditions appear quite abundant, but those under extreme conditions are rare. For another example, Matherly (2004) observed that, without external intervention, a transportation system that is ‘free-for-all’ is virtually guaranteed to result in a gridlock, but which factors contribute to the gridlock and how they drive the system into gridlock is unknown. On the other hand, we also lack the data to calibrate and validate emergency simulation models. We know that any modelling and simulation is a mathematical abstraction of part of the real world system. We also know that calibration and validation are critical to ensure that a model represents local conditions and approximates actual system behaviour. However, very rare do we have real data collected under extreme conditions to fulfil these needs.

4 Strategies for transportation modelling and simulation

Among the above three challenges, the last one requires systematic efforts and close collaboration among multiple institutions. Thus discussion of strategies for this challenge is out of the scope of this paper. In the sections that follow, strategies addressing the first two challenges are presented. More specifically, a dynamic multi-resolution simulation framework is proposed to address the first challenge and a nanoscopic transportation simulation approach is developed to address the second one.
4.1 The dynamic multi-scale resolution simulation framework

The past two decades have witnessed a major shift of modelling and simulation philosophy. Static, single-level resolution, and monolithic models are giving their ways to dynamic, multi-scale resolution, and distributed models (Corley and Lejerskar, 2003; Pollak et al., 2004). In the past, modelling and simulation are static in nature such that users prepare inputs, run simulation to a full stop, view the results, and revise inputs as necessary. As a result, one can only approximate the real world system coarsely step-by-step after each simulation run. A new approach is dynamic in nature such that users can insert new data while simulation is running and subsequent simulation can reflect the updates. In this way, one can approximate the real world system more accurately by more frequent incremental updates. Old paradigm of modelling and simulation works on a single-level resolution throughout the whole process. As a result, it is difficult to achieve the competing objectives – scale and detail – simultaneously. For example, macroscopic models achieve scale at the expense of detail, while microscopic models do the reverse. A new approach works on multiple levels of detail depending on needs. For example, it runs microscopic simulation at places which demand more details and runs macroscopic simulation elsewhere. By this way, one achieves both scale and detail in the same simulation process. Old simulation used a monolithic programme that takes care of every aspect of simulation by its own. As a result, it is difficult to take the advantage of other systems that provide complementary information and it is inconvenient to further process results of such a simulation. A new approach tries to achieve model and domain knowledge integration, to allow a broad range of simulation systems to share information (such as inputs, models, and results), and to facilitate the combination of distributed scenarios into one master scenario where the overall chain of events can be analysed and optimised. The above new modelling and simulation philosophy has been echoed by National Science Foundation (NSF) in its Dynamic Data Driven Applications Systems (DDDAS) endeavour (Douglas, 2005; NSF, 2005).

4.2 The simulation framework

Based on the new modelling and simulation philosophies discussed above, the dynamic multi-scale resolution simulation framework is sketched in Figure 1.

Figure 1 The dynamic multi-resolution simulation framework
At the core of the framework is a set of local simulation processes coordinated by a central simulation control. These simulation processes can be geographically distributed or centrally located but running in parallel. Each of the simulation processes takes care of part of an overall transportation system which is monitored globally by the central simulation control. The central simulation control communicates with, coordinates, and synchronises the local simulation processes which could possibly communicate with each other (as indicated by the dashed arrows). Each of the local simulation processes can be a single-level resolution simulation or a simulation involving multi-scale resolutions depending on needs. Available simulation levels of detail include macroscopic, mesoscopic, microscopic, and potentially nanoscopic. A local simulation process is able to zoom in to get finer levels of detail within the sub-network if necessary. For example, part of the sub-network running macroscopic simulation can be shifted to a microscopic simulation for more details. Within the microscopic simulation, a nanoscopic simulation may be used to examine the finest details at local spots such as intersections. No assumption is made on the hierarchical structure regarding how a simulation process can zoom in to the next level of detail unless implementation difficulties suggest otherwise.

Outside of the simulation framework are its inputs and outputs. The inputs can come from field sensors such as loop detectors and video cameras, information of which is fed in to the central simulation control or to a local simulation process. Other sources of inputs include ubiquitous environmental sensors, infrastructure management systems, live reports from the roads, and other sources of information. The outputs of the simulation framework include locations of bottlenecks, queue lengths, travel times, traffic flow parameters, incidents, alternative routes, clearance time, evacuation rate, etc. These types of information are very helpful for a variety of consumers such as emergency agencies, planners, trainers, first responders, and evacuees.

4.3 Levels of transportation modelling and simulation

The above framework mentioned a few options of levels of detail in transportation simulation without explanation which is the purpose of this subsection. Macroscopic transportation modelling and simulation treats a transportation network as a pipeline system and traffic as a one-dimensional compressible fluid (Lighthill and Whitham, 1955; Richards, 1956; Michalopoulos, 1984; Michalopoulos and Lin, 1986; Newell, 1993a; 1993b; 1993c; Daganzo, 1994; 1995a; 1995b; Ni and Leonard, 2005; Ni et al., 2005). Central to this approach is the law of vehicle conservation which simply states that, on a segment of highway, vehicles entered should be equal to vehicles exited plus any storage. Characterised by its lightweight, easy implementation, and computational efficiency, macroscopic simulation is ideal for modelling a large-scale transportation network with coarse resolution. Mesoscopic transportation simulation refines simulation resolution by applying Particle-Hopping and Cellular Automata to model vehicle movement (Van Aerde and Yager, 1988; Smith et al., 1995; Van Aerde, 1995; Morrison and Loose, 1995; LANL, 1999). In a partitioned time-space domain, driver-vehicle units hop from one cell to another governed by some local rules such as speed constraints. Further refinement in simulation resolution was achieved in microscopic simulation, a wealth of literature of which is available from NGSIM research project. Microscopic simulation improves over mesoscopic simulation by adding personalities to driver-vehicle units which moves continuously in time-space domain. The personalities are captured in three categories of logics governing vehicle movement: car-following,
lane-changing, and gap-acceptance. Though microscopic simulation stands for the state of the art and has been successfully applied in real world problem solving, this approach still suffers limited modelling details. For example, its vehicles are modelled as particles without mass and steering, its drivers do not control vehicles as what we do in real world, its vehicles never run into accidents, and its drivers never run out of roads. Actually, much of the above details are desirable in future generation simulation tools for studying transportation operation, especially under extreme conditions where traffic rules may disappear. This gives rise to some thoughts on advancing the frontier to the next level – nanoscopic transportation simulation (Ni, 2003) which is discussed in the next section.

To better illustrate the idea of different levels of modelling detail, the following analogy is made. Suppose one is observing traffic 10 000 m above the ground, traffic behaves as a compressible fluid whose states (speed, flow, density, etc.) propagate back and forth like waves. This is a scenario of macroscopic simulation. If one lowers to 3000 m, the sense of waves recedes and a scene of particles emerges. A vehicle behaves as a particle hopping from one cell to another constrained by some predetermined logics. This is a scenario of mesoscopic simulation. If one lowers even more to 1000 m, the scene is dominated by moving particles which interact with each other so as to maintain safe positions in the traffic stream. This is a scenario of microscopic simulation as well as the state of the art. Continuing with the above analogy, nanoscopic simulation provides a perspective as if one steps down to the ground and drives in the traffic stream. What one sees now is neither waves nor particles, but a complicated nanoscopic system consisting of drivers, vehicles, and environment (e.g., roadways, signs, signals, etc.). Drivers collect information and make control decisions in terms of steering, acceleration, and deceleration. Vehicles dynamically respond to drivers by executing the control decisions and moving in the environment. Feedback from vehicle dynamics, together with information from the environment, constitutes the basis for drivers to make control decisions in the next step and the above process goes on and on. Traffic operation is simply the movements and interactions of all vehicles in the system over time and space. This is a scenario of nanoscopic simulation.

4.4 Nanoscopic approach in transportation modelling and simulation

Extreme conditions are typically of high impact and short duration with situation changing rapidly. As a result, traffic pattern and driving behaviour are drastically different from normal conditions. Mechanisms that govern traffic operations under normal conditions such as collision avoidance and traffic rules may give their way to drivers’ desire of evacuation in the shortest possible time. As a result, more conflicts can occur between pedestrians and vehicles as well as between vehicles themselves. The goal of travellers is to search for whatever possible paths and spaces to get out of the endangered site. Conventional simulation models, including car-following, lane-changing, and gap-acceptance, may yield over-optimistic results under this scenario because drivers in these models always follow traffic rules and traffic always flows in an ordered fashion. Therefore, improvements of transportation simulation should allow modelling more details of driver decision-making and vehicle movement on road surfaces constrained by obstacles. The subsections that follow propose a conceptual framework, at a nanoscopic level, that brings transportation simulation closer to real world systems. More specifically, an Autonomous Intelligent Driver (AID) model is proposed to mimic
driver decision-making and control manoeuvre in real world systems, a Dynamic Interactive Vehicle (DIV) model is proposed to capture vehicle dynamic responses and allow vehicle movement on road surfaces, and, by integrating the above two, a driver-vehicle-environment closed-loop architecture is set up as the foundation of nanoscopic transportation simulation.

4.5 The autonomous intelligent driver model

In a traffic system, drivers are active components which make decisions, while vehicles are passive components which execute decisions. The interaction between a driver and his/her vehicle constitutes a basic unit in traffic stream. Therefore, a natural way to mimic real world systems closer is to model drivers and vehicles as separate models yet they interact. Drivers are driven by goals, act autonomously, and reason based on their knowledge – much like autonomous agents in the literature (Das, 1999; Erol et al., 2000; Ehlert and Rothkrantz, 2001; Dia, 2002; Kosonen, 2003). Figure 2 presents the structure of such an autonomous intelligent driver model.

Figure 2  The autonomous intelligent driver model

The autonomous intelligent driver model consists of three components: inputs, intelligent driver, and outputs. Inputs to the model are environment information and vehicle feedback. The environment loosely refers to the entire system including drivers, vehicles, pedestrians, roadway infrastructure, traffic control devices, roadsides, abutting lands, nearby business, etc. Vehicle feedback includes part of vehicle dynamic responses, such as vehicle speed, acceleration, and yaw velocity, perceived by the driver affecting his/her driving decision. As an intelligent agent, a driver is able to:

- respond in a timely fashion to changes in the environment
- exercises control over his/her own actions
- pursue a goal by which to drive his/her actions
- communicate with other agents
- change his/her behaviour based on previous experience.
With these considerations, the intelligent driver consists of the following components: a perception interface to fuzzified crispy information before it enters the driver, a reaction interface to defuzzify driver decisions to crispy information before it is executed by the vehicle, driver properties including driver’s goals and characteristics, a knowledge base including experiences and decision rules that govern driving behaviour, and an information dispatcher which is the central processing unit of the intelligent driver. Outputs of the driver model are driving decisions including steering, gas, and brake.

4.6 The dynamic interactive vehicle model

The dynamic interactive vehicle model improves over existing models by the incorporation of vehicle dynamic responses and lateral movement. Figure 3 illustrates the structure of the proposed vehicle model.

Figure 3 The dynamic vehicle model

The dynamic interactive vehicle model consists of inputs, dynamic vehicle, and outputs. Inputs of the dynamic vehicle come from two sources: inputs from the driver including steering, throttle position, and brake position and inputs from environment such as roadway surfaces, lanes, curves, and resistances. The dynamic vehicle consists of vehicle-specific information (i.e., vehicle properties such as mass, dimension, and engine power) and vehicle-generic information including a set of dynamic equations describing the dynamic performance of a class of vehicles, such as acceleration/deceleration and steering performance. Outputs of the dynamic vehicle are vehicle dynamic responses, of which longitudinal acceleration, lateral acceleration, and yaw velocity are of particular interest.

4.7 The nanoscopic simulation architecture

The above discussion presents an autonomous intelligent driver model and a dynamic interactive vehicle model. Working together, they form a driver-vehicle closed-loop system which constitutes a basic building block of roadway traffic. Many such blocks as well as roadways, traffic control devices, and other transportation system components constitute a general environment in which the driver-vehicle systems operate. The interactions among drivers, vehicles, and environment are summarised in the nanoscopic transportation modelling and simulation architecture shown in Figure 4.
Figure 4  The nanoscopic transportation modelling and simulation architecture

In this architecture, the driver receives information from the environment such as roadways, traffic control devices, and the presence of other vehicles. The driver also receives information from his/her own vehicle such as speed, acceleration, and yaw velocity. These sources of information, together with driver properties (such as characteristics and goals), are used to determine driving strategies (such as steering and gas/brake). The driving strategies are fed forward to the vehicle which also receives roadway information from the environment. These sources of information, together with vehicle properties, determine the vehicle’s dynamic responses based on vehicle dynamic equations. Moving longitudinally and laterally, the vehicle constitute part of the environment. Part of vehicle dynamic responses such as speed, acceleration, and yaw velocity are fed back to the driver for determining driving strategies in the next step. Therefore, the architecture creates an environment, in which each vehicle is an autonomous agent which is driven by goals and is able to achieve the goals by moving through the environment. Thus traffic operation is simply the movements and interactions of all vehicles in the environment.

5  A conceptual case study

A conceptual case study is presented in this section to illustrate a possible application of the dynamic multi-scale resolution simulation framework. At 2:00 p.m., Mr. Smith is monitoring traffic operation at Metro Atlanta regional transportation management centre. Field data come in from video cameras that are deployed throughout the regional transportation network as illustrated in the background map of Figure 5 (some of the images come from Georgia Navigator). Based on inputs from the cameras, a traffic simulation is running at macroscopic level to provide a region-wide overview of traffic operation. At 2:15 p.m., Mr. Smith receives a phone call reporting a chemical spill somewhere in downtown Atlanta (roughly the centre circled by I-285). A plume has formed and is spreading outward. One minute later, state emergency management agency calls in asking Mr. Smith to provide traffic information to assist evacuation. Of critical importance is clearance time, i.e., the time needed to evacuate the population. Mr. Smith
quickly inputs evacuation population to the simulation which suggests a rough estimate of clearance time of 8–20 hours. To get a more realistic estimate, Mr. Smith identifies a few critical corridors, one of which is downtown connector which is the segment of freeway near the magnifier at the centre of Figure 5. An unusual congestion pattern triggers a mesoscopic simulation for this corridor, illustrated as the local map at the top left corner of Figure 5. Traffic inputs to the mesoscopic simulation are provided at the boundaries by the macroscopic simulation. With more details fed back from the mesoscopic simulation, the macroscopic simulation is able to fine tune the clearance time and narrow the estimate down to 10–16 hours. As more information comes in, an accident is verified between 14th and 17th streets, indicated by the magnifier in the top left local map. Mr. Smith instructs the central simulation control to zoom in even more and run a microscopic simulation for the segment. The bottom right image of Figure 5 illustrates how a microscopic simulation looks like (this image is for illustration purpose only and may not correspond to a real scene of the accident). Again, the mesoscopic simulation supplies traffic inputs to the microscopic which, in return, feeds back to fine tune the mesoscopic simulation. Considering that the complication of emergency and accident may give rise to off-road operation and the loss of traffic rule, a more detailed simulation may provide an accurate estimate of bottleneck capacity. Therefore, part of the microscopic simulation is examined closer by a nanoscopic simulation. This is illustrated as the top right image of Figure 5 and the image is analogous to the perspective from some one physically in the traffic, as circled in the bottom right image. With all the details fed back progressively from nanoscopic to microscopic to mesoscopic to macroscopic simulations, the estimated clearance time would be around 12 hours assuming everything else is fine. Mr. Smith now has better information to advise the state emergency agency regarding clearance time and other traffic operation questions for the later to make decisions.

Figure 5 Illustration of a conceptual case study
6 Summary

This paper summarised recent interests in emergency management and how modelling and simulation in general helped in this regard. Of particular interest is the role of transportation modelling and simulation in emergency management. Past research has shown that transportation modelling and simulation was particularly helpful in answering questions related to evacuation – the movement of large population during a short period in a congested transportation system.

Three challenges are identified for future generation transportation modelling and simulation to better assist emergency management. These challenges are:

1. simultaneous requirements on scale and detail
2. lack of tools to model traffic operation under extreme conditions
3. lack of knowledge and data about extreme conditions.

Obviously, the last challenge requires systematic data collection efforts and inter-institutional collaboration, and hence is out of the scope of this paper. The paper focuses on the first two challenges. A dynamic multi-scale resolution simulation framework is proposed in response to the first challenge. The simulation framework is dynamic because it is able to approximate the real world system incrementally based on real-time field observations. The simulation framework is also able to execute simulation at multiple levels of detail simultaneously with low-detail simulation providing system-wide overview and high-detail simulation providing local details. Thus the framework is able to resolve the competing goals of scale and detail as frequently desired in emergency management. In response to the second challenge, a nanoscopic approach for transportation modelling and simulation is proposed. This approach aims at bringing simulation closer to the real world by mimicking real world driving experience. More specifically, an autonomous intelligent driver model is proposed to collect and process information and output control strategies in terms of gas, brake, and steering. A dynamic interactive vehicle model is proposed to execute control instructions, make dynamic response, and generate movement on road surfaces. Feedback of vehicle dynamics, together with environment information such as roadways and other vehicles, constitute part of the input to the driver model for making decision in the next step. Thus nanoscopic transportation simulation is built on the integrated closed-loop system involving drivers, vehicles, and the environment. This nanoscopic approach is promising in providing insights into traffic operation under extreme conditions (such as the absence of traffic rules, off-road operations, and traffic accidents) and assists better decision-making in emergency management.

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References


Note

1 http://ngsim.camsys.com/