MODELLING FOR ESTIMATING IMPACT ON ROAD TRANSPORTATION OF REGIONAL EMERGENCIES & DISASTERS

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ABSTRACT

The present study is focused on the use of Simulation as support for evaluating crisis over wide areas.
Authors' main objective is to demonstrate as Modeling & Simulation can be an effective support tool in order to face crisis involving complex systems, such as transportation, and integrating many aspects ((i.e. logistics, human flows, emergency conditions) in a dynamically changing scenario.

INTRODUCTION

September 11 and March 11 terrorist attacks in USA and Europe showed how the impact of indirect consequences rising after an unexpected event, are really devastating, even more than the attack itself.
For this reason, many countries are becoming sensitive about such specific issue, the homeland security.
Nowadays a significant lack in models able to support decision within this context remain. The reason why is mostly related to the fact that the impact of big crisis usually involves many different systems, such as communications, transportation, finance and affect areas so wide to be defined global crisis.

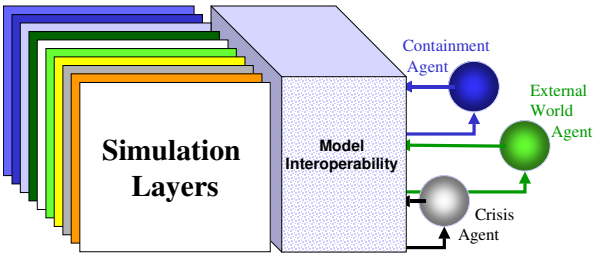

Figure 1: Homeland Security Multi-layer Modeling

In order to succeed in being able to quantify the consequences and to compare different solutions, policies and decisions, M&S is fundamental.
The present research is devoted to demonstrate that a modular approach can be used for analyzing this kind of context by multi-layer modeling. It allows to face wide problems, such as "Katrina" Hurricane. In fact, the presented demonstrator reproduce the impact of an hurricane on road transportation system, over a region large as a state.
The results obtained are used as reference for further development in the multi-layer approach.

A NEW APPROACH

Many sectors take advantages from the Multi-layer technique, above all communication networks, where it is often necessary to combine different infrastructures and solutions. The researchers focused the present study on application of such technique to homeland security scenario simulation, never leaving out of consideration the necessity to face several challenges in modeling (see figure 1).
Critical aspects can be summarized as follows:

Challenges in Crisis Simulation	*Homeland Modeling*
- Strong influence of human behavior - Reduced statistical data base - Complex crisis behavior - Heavy stochastic components	- Very large systems - Very complex systems - Many interaction among Objects

Challenges related to the Homeland Modeling are synthesized in figure 2:

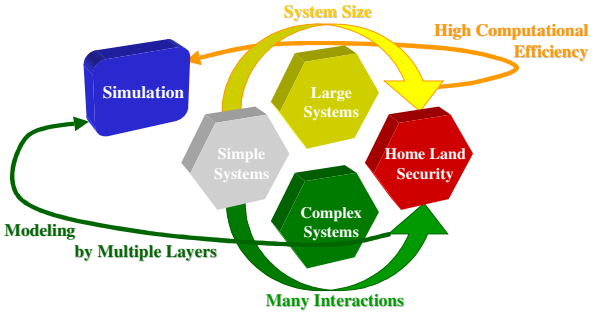

Figure 2: Homeland Modeling and related challenges.

Due to these considerations, the authors decided to create models for each single layers and then to proceed into the integration of different layers for estimating the interference among all the different factors.
Also, it is necessary to develop simulation models that can process large numbers of entities and parameters in reasonable time, for such a reason "size" is one of the critical issues.

THE SCENARIO

The proposed scenario reproduce an unexpected event such as an hurricane, the crisis occurred in Louisiana State gave to the authors the opportunity to tested their approach over a real case, a reproduction of the whole State. The scenario was named Katrina Style.
There is no doubt that such new criteria was very challenging, so the researchers decided to face, as first step, the creation of a single layer, road transportation, and to reuse eventually other models.

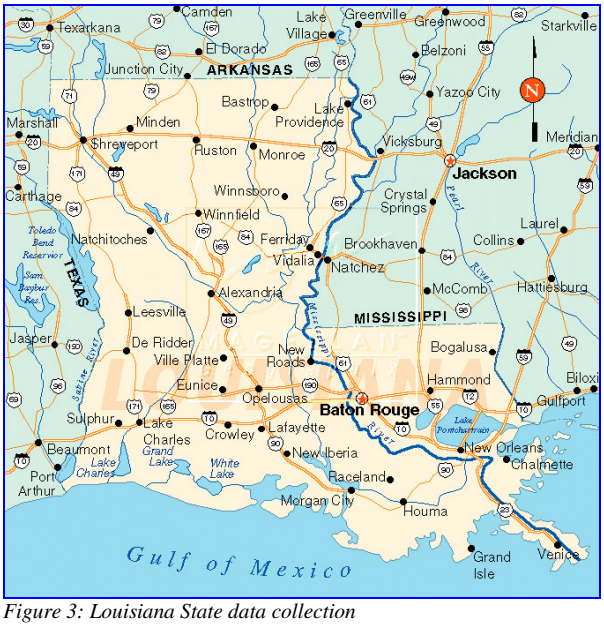

Figure 3: Louisiana State data collection

After that, it was decided to integrate the layer with some very basic models reproducing other phenomena:

- Traffic flows
- Air transportation
- Road transportation

Considering the extremely critical weather conditions, the airport activity was stopped and the people flows redirected to the road transportation system.
Due to this fact, the flows are dynamically affected by other factors: during the simulation such factors act and make the scenario variable just like the real one. In fact, Katrina simulator is devoted to analyze a specific point, the impact of a crisis on a transportation system and such a scope does not requires complex infrastructures modeling or data collection, the basic information was obtained through the web (i.e. maps from web sites as shown in figure 3).

WHAT IS TRAMAS?

By tailoring a simulation models that was developed by the authors for logistics and road transportation analysis, it was possible to face the Katrina scenario. Such a model (TRAMAS - Transportation Management and Simulation) is able to reproduce operations on a wide area,
TRAMAS database includes extended representation of roads, sites, cities etc., in its typical application in logistics sector, the number of vehicles is usually limited: in fact in complex logistics networks it is really unusual to overpass 500 trucks to be simulated concurrently.

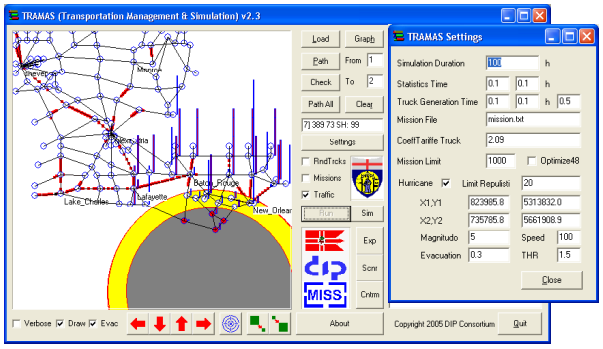

Figure 4: TRAMAS Simulator Graphic Interface evaluating Hurricane Impact on the State

TRAMAS is a micro-traffic model based on discrete event stochastic simulation.
In Katrina Style reproducing all the vehicles running over a state road network was needed, for this reason the authors worked on the model in order to improve its efficiency, making it able to "manage" millions entities.
In particular, the key source databases used by TRAMAS includes:

	DATA
TRAMAS	- Accommodations & Shelters - Additional Flows - Fees - Nodes Database - Roads Network - Special Missions - Sites Profiles - Source Destination Flows - Supply Chain Requests/Sources - Towns - Traffic Profiles - Vehicle Database

At this stage, it was necessary to map all the traffic flows, cargo and passengers among cities and major nodes within and out of the State included. The regular flows are usually affected by the timeframe, during the day and over the week this flows changes in intensity and direction based on traffic profile.
TRAMAS re-calculates the path for all the traffic flows and active entities on going concurrently on the simulation and this in correspondence of each critical event. In particular, the overall model includes all major roads:
- highways
- interstate
- state roads

The characteristics on traffic profiles and town was introduced in TRAMAS; therefore the model for reproducing the hurricane behavior was quite simplified: it regulates the crisis moving over the map and its evolution, both in term of dimensions or intensity.
Montecarlo techniques provided the authors with the possibility to reproduce dynamic changes on the basis of a stochastic evolution: the hurricane affects several conditions such as: speed over the roads, closing of the roads, closing of other transportation infrastructure, evacuation. The simulator dynamically check areas where airports, ports and roads have to be closed because of the hurricane.
Due to the strong impact of the weather conditions, people look for alternative escape route; such behavior causes the saturation of different available directions as presented in figure 4.
The evacuated people look for a close temporary destination (or in the boundary States) checking possible solutions (i.e. accommodations in safe places, shelters etc.).
The simulation also reproduce the longer traveling for refugees, caused by the saturation of the alternatives, in terms of locations.
Criteria for the evacuation (i.e. safe alert range) are defined as parameters in order to check different policies, at the same time different strategies can be evaluated (considering local special shelter preparation versus camp out of the state as shown in figure 5).
The results of the simulation are processed also by integrating the results with GIS (Geographic Information Systems). In this case this activity was just devoted to test joint capabilities by combining different approaches.


Fig.5: Shelters in Louisiana State

Due to these reason the Google Earth ™ GIS has been integrated, so shelters and sites with higher concentration of refugees, are exported to Google Earth ™ by TRAMAS and presented graphically over the map as shown in figure 6. In December 2005, during the development phase, special map database related to Katrina was available from Google Earth ™.
The experimental results allowe to complete tests on the relation between alert range for evacuation and the mean time requested to reach the destination (this from refugees' point of view)
The performed experimental analysis is basic, due to the characteristic of demonstration that marks Katrina Style, however the model demonstrated a big potential as decision support system to be applied in a crisis scenario.

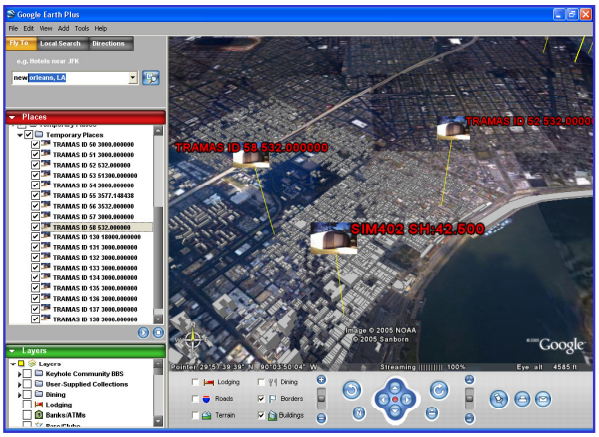

Figure 6: Integration TRAMAS™ Simulation and Google Earth™ GIS

CONCLUSIONS

This paper proposes a methodological approach for modeling complex realities by layers. Nowadays Simulation allows to dynamically proceed using different layers, providing the possibility to reproduce very large systems with complex relation keeping "control" over the model.

This research represents the first step to highlight the possibility to face the problem of a single layer applied to systems reproducing a wide region in details.

The case of road transportation is a challenge considering this large context: the possibility to evaluate the impact of a crisis affecting a whole state allows to test the efficiency and the potential of the model. "Katrina Style" scenario shows that this approach and the achieved results represent a very encouraging opportunity. In fact, homeland security is related to scenarios so wide that it is very critical to be able to estimate their impact on a large number of sub-systems, as well as on a wide area. The proposed approach seems to be an effective way to solve the M&S issues.

The authors are currently working forward for creating other layers to be integrated in different scenarios, but even if at this first stage, they consider as lesson learned through this demonstration that strong experience in modeling plays a fundamental role in order to be able to guarantee the implementation efficiency requested by wide area simulator.

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