On estimate of risk associated with urban road traffic

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Abstract: The recent road safety studies demonstrate that the risk associated with urban road traffic must represent an additional criterion in selection of the best planning alternatives. The settled goal is the a-priori minimization of road accidents number for each studied alternative of urban planning. Therefore supplementary research is necessary to develop models and tools to estimate traffic risk for different scenarios of urban areas development and traffic pattern. The paper presents the model developed with geographic information system (GIS) facilities for estimate of risk associated with urban road traffic in Bucharest. The digital model of the Bucharest city area is used to locate and analyze the road accidents and to identify the road infrastructures features and urban areas with traffic risk.

Key-Words: road traffic risk, road traffic safety, safety performance functions, geographic information system

1 Introduction

The contemporary post-industrial society is characterized by a new fundamental feature. While the main problems of the industrial society were the production and resources distribution, then the core concern of the present society is the risk repartition. This fact is demonstrated by the structure of political and social dynamics [1].

The risk is the result of the human activities. It generates effects which multiply themselves as number but especially as consequences [6]. The prevention principles promoted by the society and the authorities point to maintain the difficult equilibrium between policy and technological progress generated by scientific knowledge. The sustainable development intends to globalize the efforts against increasing of ecological and sociological risks.

The risk associated with urban road traffic as component of the global risks generated by people is intensely included in present and future policies, through the society reactions materialized in actions for reducing of number and consequences of road accidents.

Due to the social costs of road accidents, the authorities take account of the risk related to traffic as additional criteria in selection of the most appropriate urban planning alternative. Therefore a supplementary effort from specialists is needed to provide tools for a-priori estimates of risk for any analyzed alternative. This paper presents a model developed with geographic information system (GIS) facilities for estimate of risk associated to the road traffic in urban congested areas.

Firstly we have to underline the difference between the risk of road traffic and the frequently used term of “road traffic safety”. In case of risk associated with road traffic we consider the probability of accidents occurring with consequences on users and surrounding area, while in case of road safety we consider the frame of measures applied by authorities to reduce the frequency and the graveness of accidents.

2 Road traffic risk – specific features

In comparison with natural, industrial, economic or social risk, the risk associated with urban road traffic has specific spatiotemporal peculiarities. In case of road traffic the relation space-time is neither homogeneous nor isotropic. Its morphological features are given by differentiated configuration and structure. The space is not limited to material concrete components (residences, infrastructures, commercial areas etc.), but it includes multiple dynamic and fluctuant relations (social, economic, technological, natural, administrative, historical etc.) witch connect the space components through material, energy and information flows, decisive for people mobility needs.

Analyzed from phenomenological point of view, the urban area, where the road traffic risk appears,

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becomes a complex spatial system. Four classes of system inputs are significant for risk situation: objects (urban functional entities), actors, spatial structures and temporal structures. The four classes of inputs correspond to the four essential questions presented in Figure 1. The first two classes have conceptual and thematic character and the last two contain fundamental references for definition of the first two, not only from semantic and functional point of view but rather for precise location in space and time.

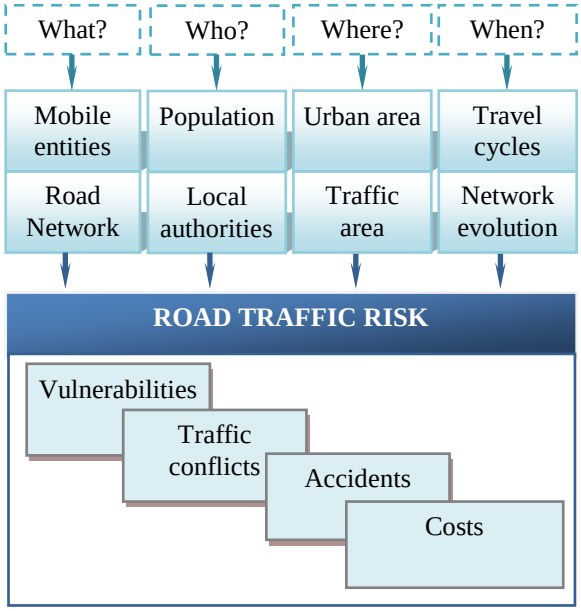

Fig.1 Structure of risk situation

The contents of each class are the following:

- The class "objects" defines various types of components, phenomena and processes, considered as susceptible objects to intervene in risk situation; e.g. mobile entities (vehicles, bicyclists, and pedestrians), infrastructures, residential areas etc.
- The class "actors" defines different persons, groups or organizations capable to influence the system, namely authorities, urban administrative institutions, population (taking into account the general character of road network and the public feature of the urban area);
- The class "spatial structures" consider the location of different elements and spatial processes connected to risk situation (defined by topological and geometrical configuration);
- The class "temporal structures" includes the set of elements explaining the temporal character of the system, namely the positioning in time of system entities, activities time/idle time, daily and seasonal travel intensity etc.

Generally, the first two classes – objects and actors – allow to identify and to record the system components. The last two classes - spatial structures and temporal structures – describe the place and time of interactions between elements by discrete modeling of geographical space (entities, administrative areas, functional areas etc.) and/or time modeling (time, period etc.) appropriate to each scale of analyze.

The interactions between classes generate traffic flows characterized by uncertainty on risk of accidents occurring. This risk could be defined only in relation with spatial and temporal environments. Therefore we use the term of "risk situation".

3 Using GIS in traffic risk estimation

The research on the binomial risk - safety for case of road traffic leads to the following four steps [5], [11]:

- Evaluate the accident causes (risk);
- Determine the probabilities of risk appearance;
- Estimate the consequences (injuries);
- Identify the correspondence between the injuries and the efforts to prevent or the capabilities of recovering/reparation.

In order to estimate the risk associated with road traffic, especially for the first three mentioned steps, complex and multiple spatial and temporal locations of numerous classes of objects and actors are necessary. A large set of attributes and interactions has to be defined and quantified for accurate risk assessment. Taking into account the complexity and the volume of the necessary data, the use of GIS facilities are incontestably required in any model of binomial risk - road safety.

This section outlines the structure of the model developed to estimate of risk associated to road traffic in Bucharest (Figure 2). The presented results of the model are obtained in the frame of the project "Research on estimation and enhancement of intrinsic safety performances for urban traffic networks". Using GIS procedures [2], [8] we developed geographical databases for modeling the urban road network, the urban area and for describing the spatial structures necessary in risk estimation (Figure 3). Starting from the digitized physical urban road network the appropriate macroscopic digital network is modeled.

The macroscopic digital network model is defined by nodes (which may correspond to

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physical intersection or point where local traffic is assigned), connectors of urban zones centroids and links (which may correspond to section of the major and arterial roads).

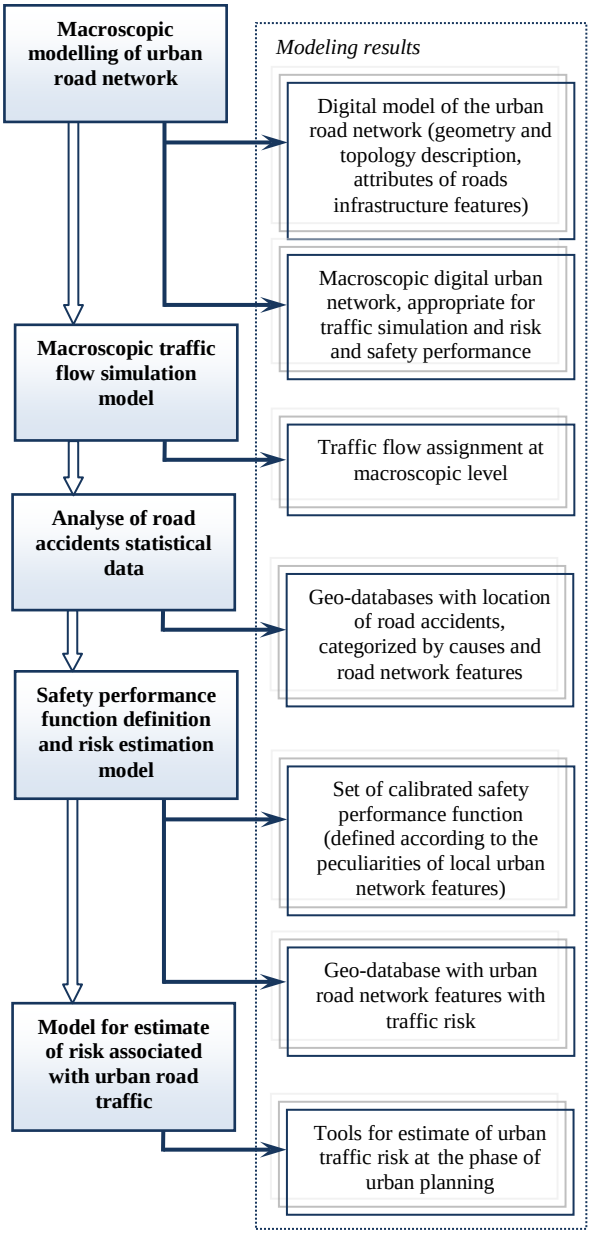

Fig.2 Structure of the model for estimate of the risk associated to road traffic in Bucharest

Each feature of the macroscopic digital network has assigned a code formed by digits which give information about type and category of road infrastructure, number and width of lanes, signalization, category and configuration of transit lines and stops, configuration of pedestrian crossing, median islands, adjacent street parking system. The geo-database with the macroscopic road network model is the base of the traffic flow simulation model.

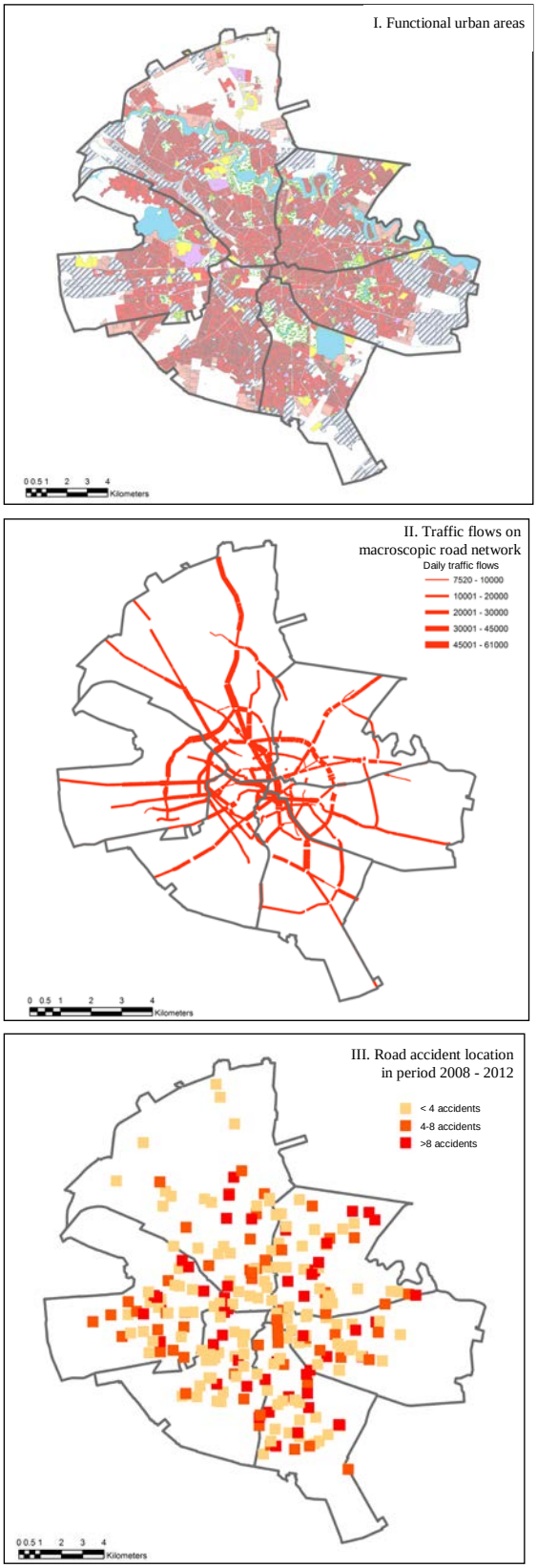

Fig.3 Geographical databases used for modeling the urban area

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The traffic flows assigned on the macroscopic road network features (Figure 3.II) are subsequently used to calibrate the functions for estimate of traffic risk.

Statistical series of road accidents from Bucharest in period 2008 – 2012 are analyzed and located and included in geographical databases (Figure 3.III). Selection by causes of road accident are performed (Figure 4) and then the attributes of the macroscopic urban road network features where road accident are located are used to obtain series of data necessary to define and calibrate the safety performance function [4], [7], [10].

For each selected macroscopic urban road network feature class, on basis of traffic flows intensity, urban and road infrastructure characteristics (given by digits code) and accidents statistics, the appropriate form of safety performance function is defined and calibrated [9]. Until the present phase of research the available data allowed us to define two categories of functions:

- Functions applied on the section between intersections (mid-block);
- Functions developed for estimating the accidents number in major intersections, where flows from major and arterial streets interact.

The parameters of the functions depend significantly on configuration of the intersection and section, type of vehicles, functionality of urban area etc. Hence the functions have to be defined and calibrated for different classes of network features and different traffic conditions. Correct defining of the functions for each urban road feature category is a complex issue and depends in large measure on data availability.

In our study the choice of risk variables [3], [4] was performed based on analysis of traffic flows at macroscopic level and available statistics of road accidents. We estimated the traffic risk for three categories of attributes (Figure 5):

- Urban functions of zones and location of economical, administrative and social objective which generate significant flows (vehicles and pedestrian);
- Intensity of motorized vehicles flows;
- Transit facilities and configuration of the pedestrian access to transit system (complex intersection with bus and tram stops, areas with bus stops with or without median islands, configuration of pedestrian crossings etc.).

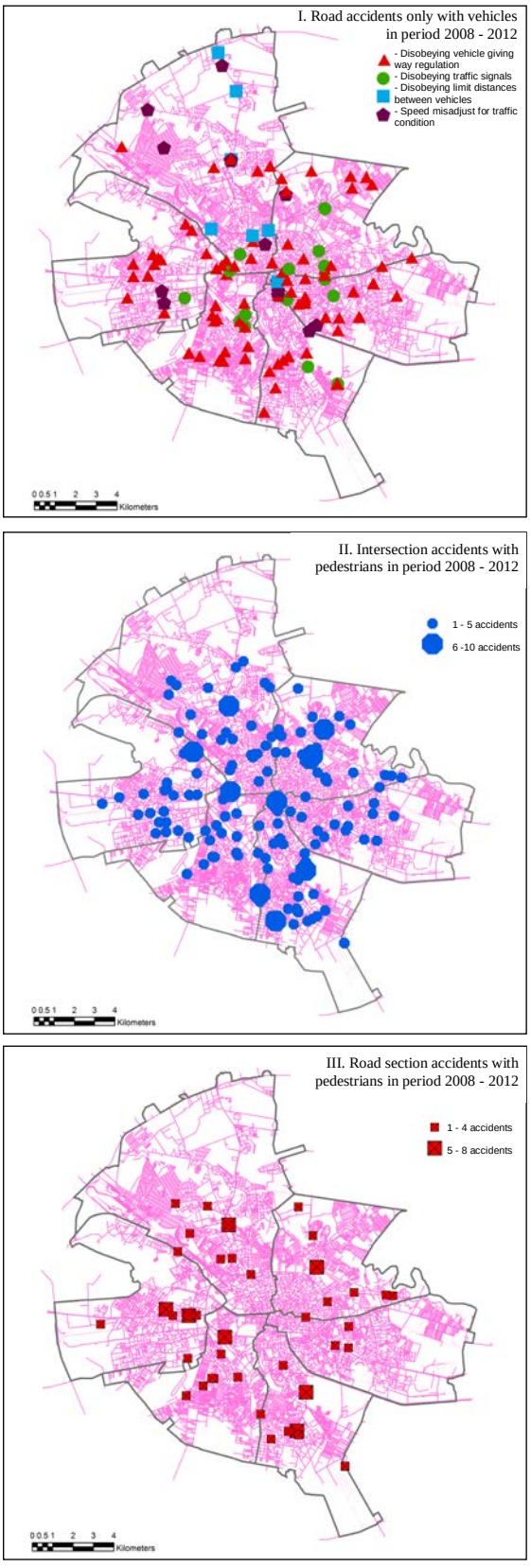

Fig.4 Analysis of road accidents by location and causes

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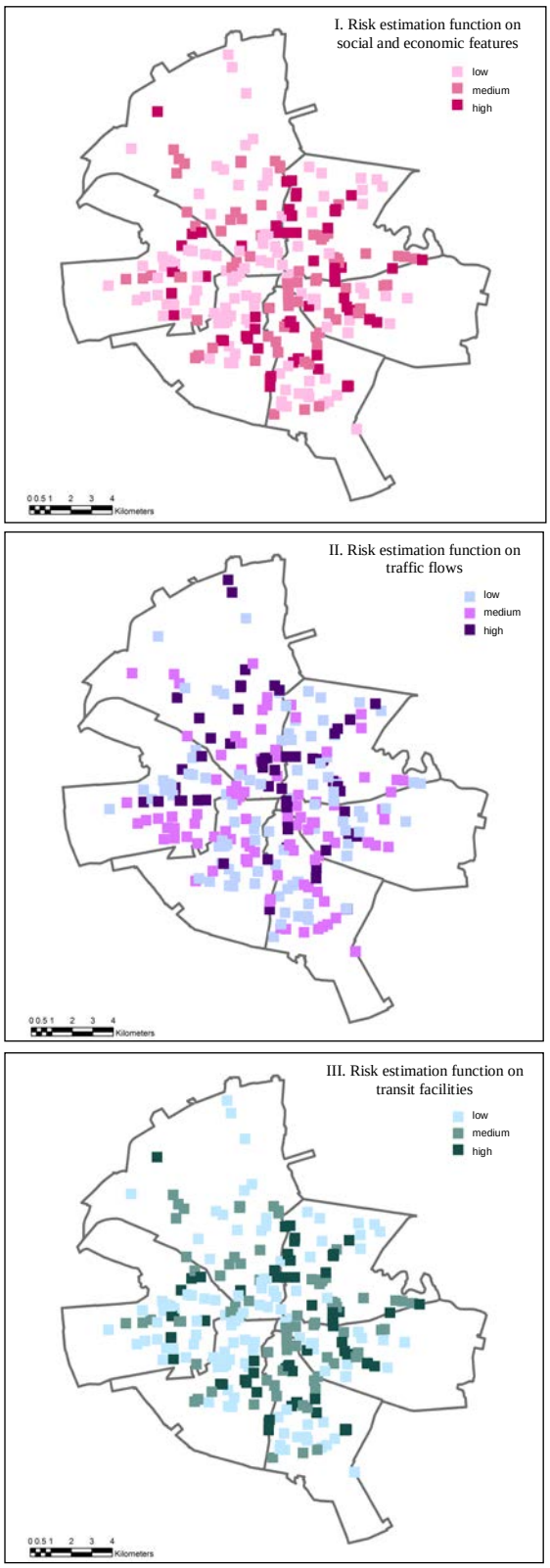

Fig.5 Estimate traffic risk function of different categories of attributes

Overlaying the areas characterized by risk situation for each of the three classes of attributes and defining a composite risk indicator for all variables, the areas with vulnerabilities for different categories of users and periods may be identified. This is the purpose for our further research. Considerable effort is necessary to fill the necessary attributes and especially to calibrate the risk indicator.

4 Conclusion

Road traffic safety represents a central concern in policies for land use and urban planning. Therefore the research on estimate of risk associated with road traffic has to examine larger domains of investigation and analysis. Geographical databases with complex structure are necessary to model the multiple spatiotemporal connections of urban structures and the needs of mobility reflected in binomial risk - safety. The results of the model developed to estimate of traffic risk presented in this paper demonstrate the utility and the advantages of using GIS facilities in risk analysis.

The model will be base for simulation tools developed in order to analyze different scenarios and traffic flows patterns, to estimate of traffic risk at the planning and designing phase and to identify appropriate solutions for traffic risk reducing.

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