URBAN COMPLEXITY AND THE MEASUREMENT OF RISK

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Résumé

La recherche analyse la notion de risque et développe un possible outil pour étudier les systèmes urbains. L'évaluation et la gestion des risques territoriaux ont été approfondis dans le détail par beaucoup de contributions, qui concernent le rôle de l'aménagement territorial dans les stratégies de prévention. Dans une structure urbaine l'approche est différente dès lors que l'événement dommageable n'est pas accidentel mais structurel et le risque strictement lié au comportement des systèmes sociaux. Dans ce papier le sujet a été considéré d'un point de vue analytique, dans l'intention de développer un outil d'investigation capable de tenir compte de l'aspect multidimensionnel des phénomènes qui produisent le risque et de la nature complexe du risque même. L'analyse du risque peut raisonnablement appartenir au débat qui concerne la vulnérabilité, du moment que des aspects tels que prévention et sécurité en milieu urbain sont absolument importants. Le papier propose une réponse à la question induite par ces principaux aspects du risque, en essayant de dépasser l'approche traditionnelle de l'analyse du risque fondé sur les logiques additives et compensatoires. Sont proposées deux applications : une investigation micro-échelle visant à la détermination des relations entre morphologie urbaine et pollution de l'air causée par l'automobile et une étude à l'échelle urbaine pour la construction d'une structure analytico-descriptive des conditions de risque engendrées par la présence simultanée de différents facteurs critiques.

Abstract

This research moves from the concept of risk and develops a possible tool for analysing urban systems. The evaluation and the management of territorial risks were dealt with in great detail in many important contributions, especially with regard to the role of territorial planning in prevention strategies. Within an urban framework the approach is different as the damaging event is not incidental but structural and the risk is strictly inherent to the behaviour of the social systems. In this discussion, the subject has been considered from an analytical viewpoint, in the attempt to develop a survey tool that takes into account the multidimensional aspect of the phenomena that generates risk and the complex nature of the risk itself. The risk analysis can justifiably belong to the debate about sustainability, since aspects such as prevention and safety in an urban environment are of absolute importance. The paper attempts to provide an answer to the questions induced by these main aspects of risk, trying to go beyond the traditional risk analysis approach based on compensating and additive logic. Two applications are proposed: a micro-scale survey aimed at determining the relationships between urban morphology and atmospheric pollution from automobile traffic and an urban-scale study for the construction of an analytical-descriptive framework of the risk conditions generated by the simultaneous presence of various critical factors.

Mots-Clés

Capacité de transport, multidimensionnalité, risque urbain, vulnérabilité

Key-Words

Carrying capacity, multidimensionality, urban risk, sustainability, vulnerability

1. Urban risk

The research subject is to deepen the concept of risk as a possible tool for analysing urban systems. According to the definition developed by United Nation Disasters Research Office [21] risk is the co-evolution between the stress exerted on a system and its vulnerability. In urban systems risk indicates the status and the transformations of the relationships between individuals and space that surrounds them and expresses the union between sources of risk and vulnerable elements [4]. The urban system is given by the spatial concentration of people, activities, material and intangible flows, and the social risks, that are strictly related to such a system, can be defined as the *dangers*, common to many individuals, for which processes are triggered to determine the minimum levels of acceptability. The stabilisation mechanisms of the uncertainty in the social systems consider risk to be a structural characteristic, a *normal* condition of a complex system, where normal refers to the linear and non-linear forms of interaction, resulting from processes inherent to the same systems [14]. Thus, risk is interpreted as an amplification of the uncertainty innate to each stabilised social structure.

Within a strictly urban framework the approach to the evaluation and the management of territorial risks assumes particular characteristics. The concept of *risk assessment* was dealt with in great detail in various contributions [9], especially with regard to the role of territorial planning in prevention strategies but in urban systems the risk is not related to a rare event or in any case something attributable to cause and effect, but is inherent to the behaviour of the system. The damaging event is not incidental but structural and it is generated by the relationships that are structured within such a system. Like any territorial system, even the urban one has levels of vulnerability and fragility elements determined by exogenous and endogenous factors [18]. However, in this case, we must re-conceptualise the meaning of variables such as resistance and stress. It is important to be able to return the risk in terms of area, since the territorial nature of the phenomenon requires a synthetic representative criterion that takes into account the survey scale but does not ignore the intrinsic nature of the information about the risk.

Like every territorial system, the vulnerability level of the urban system is characterised by both geographic and systematic factors [18] that assume the determination of the elements of fragility.

The greatest difficulties inherent to the urban risk analysis involve the problems of identifying and representing the *risk area*. In fact, the perception of risk and the concept of social safety often do not depend on the objective and measured reality and are not strictly related to the predetermined parameters of risk acceptability.

The concept of risk in urban systems assumes some interesting levels of analysis and in-depth study, each of which refers to the importance of having a tool that can represent and present the risk in the way it is analysed and measured:

– the presence of an objective risk and a subjective risk highlights the importance of identifying, representing and communicating the risk; in social phenomena, the emotive attitude of the collective whole does not always match the real magnitude of risk;

– the perception of danger and the perception of safety by human beings are part of a cultural coding that makes it possible to develop strategies to respond to situations involving uncertainty;

– the principle of precaution and the prevention policies include the definition of guidelines that identify thresholds of acceptability and commonly accepted objectives.

Therefore, the risk study can be tackled starting from each of its different aspects:

– awareness and analysis,

– individual behaviours and perception,

– decisional, management and prevention aspects.

In this discussion, the subject has been considered from an analytical viewpoint, in an attempt to develop a survey tool that takes into account the dimensional aspect of the phenomena that generate risk and the complex nature of the risk itself.

The risk analysis can justifiably find space and significance within the debate about sustainability, since aspects such as prevention and safety in an urban environment are of absolute importance. The problem relative to the measurement and representation of risk paves the way toward the possibility of defining an *urban performance* indicator that can be compared to the sustainability objectives.

2. Risk measurement hypothesis

Risk is defined as a rational and emotive evaluation that a society has with respect to a given event, a perception related to the local culture, mass media, management policies, etc. [14]. The state of risk occurs when, given a system and a stress, it is uncertain that the resistance of the system is greater than the stress to which it is subjected [10]. Stress and resistance can be indicated otherwise with the terms *hazard* and *vulnerability*, more frequently used in the international literature, focusing attention however on the difference between the environments of pertinence of resistance and *vulnerability*: resistance measures the field of stress within which the system does not suffer specific damage, while *vulnerability* considers the field in which the system manifests that damage. The theory of vulnerability involves the identification of a critical damage threshold, above which the system is incapable of supporting specific stress and thus is no longer capable of resisting a given stress level.

Resistance and stress are probabilistic parameters that can be represented as random density variables with a known probability [10]. The state of risk occurs when the two *probability density functions* overlap, defining an area that identifies the current risk.

Before formalising the measurement of risk, some classical concepts should be briefly described: danger, probability and gravity. Danger is the tendency of a system to generate dangerous events, probability measures the « chances » that the danger has to materialise and gravity measures the impact of such materialisation [4].

Risk is the combined measurement of the danger and can be expressed as the product of the probability of an event and the gravity (magnitude) of such an event [22]:

$$R_t = P_e \, x \, M_c \qquad (1)$$

where R_t = total risk, P_e = probability of the event, M_c = magnitude of the consequences.

The data can be represented in terms of a risk curve [22], tracing the so-called *Farmer diagram* (bearing the name of the English expert who created it), that expresses the probability of an event occurring (P_e) with a certain magnitude (M_c) (fig. 1). It indicates how the probability and magnitude variables can have different reliability weights, overcoming the imprecision generated by the impossibility of comparing events which, with risk being equal, are due to quite different values of P and M.

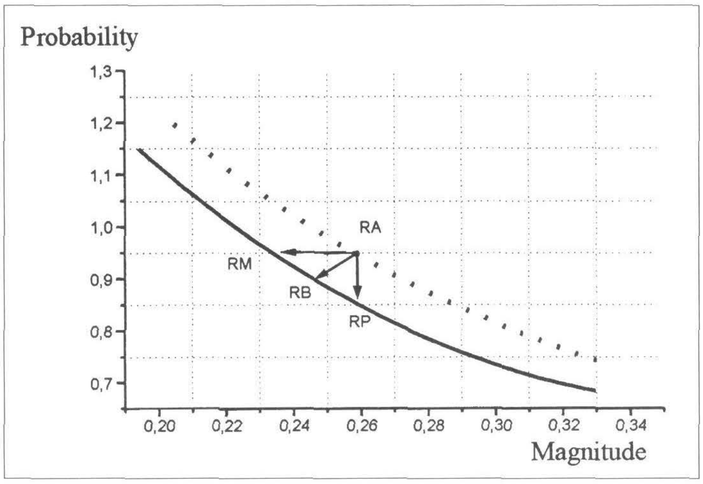

Figure 1 - Farmer diagram, risk curve

The definitions of *probability* and *magnitude* and the attribution of the relative weights are very important, so that any iso-risk conditions can be highlighted.

To evaluate the probability, the method adopted is derived from the statistical analysis of the survey system, and is strictly related to the variables involved and their interaction. As concerns the magnitude, the situation is more complex due to the numerous factors that are involved with the identification of a reference damage that is commonly acceptable.

Therefore, in the quantitative phase of the risk evaluation, it is indispensable to define the *acceptability threshold*. The problem is to find a reference to use as the means of comparison to evaluate the dangerousness given by the risk indices obtained.

The following paragraph proposes two applications for a possible risk evaluation in the urban area:

– a micro-scale survey aimed at determining the relationships between urban morphology and atmospheric pollution from automobile traffic;

– an urban-scale study for the construction of an analytical-descriptive framework of the risk conditions generated by the simultaneous presence of various critical factors.

The methodology developed concerns an urban system for which there are reference indicators and spatially distributed observations. The determination of risk starts from the identification of the stress to which the system is subjected, in relation to the resistance/vulnerability of that system.

In both cases the discriminating element, as well as the key for deciphering the graphs obtained, is the level of acceptability that identifies the vulnerability threshold of the system and therefore the magnitude. For some variables, such as pollution, it is plausible to define exogenous general limit values determined from measurements regarding human health (see for example the information from the World Health Organization), or, for indicators that express supply of services and urban functions, it is possible to calculate thresholds and use potentials. There is greater complexity in the social indicators, for which not only the objectivity of the data obtained is important but above all the perception of such data by the public is a substantial factor. A phenomenon distributed in space suggests feelings and behaviours that are different from another one concentrated in special areas of the city. Here is adopted a self-referencing criteria of the variables that puts the system in direct relationship with itself. This evident peculiarities and areal differences strictly related to the contextual reality.

It is possible to make a cross-section per spatial unit including all the values assumed by the various indicators. The real values and the acceptability threshold of each variable are compared in figure 2. The risk area is represented by the point where the threshold is exceeded by each indicator. By attributing a score value, the sum of the magnitudes present, to each spatial unit, we obtain an index of overall risk relative to the group of indicators considered. When two or more areas reach the same total score, an iso-risk condition occurs. The comparison between the various situations may generate a low, but diffused magnitude or a high magnitude caused by just a few factors. The iso-risk areas are an important opportunity to deepen the actual concept of risk. It is possible that with scores being equal, one area may have only a few critical factors with high magnitudes while another has more critical factors with limited magnitudes and thus a risk index of a distributed apprehension whose risk is in fact related to the multiple aspects of the damage. Both cases are identified by the same risk but the effects are quite different.

One possible and interesting line of research involves a study of the synergetic effects between risk factors. The importance given by the interactive complexity that is generated in the urban system requires further investigation concerning the linear and non-linear relations between the variables. The multi-dimensional aspects of the risk phenomena should be studied with tools that not only can identify the damage as the sum of magnitudes, but also the possible effects generated by the simultaneous presence of some factors rather than others.

Such relationships are difficult to perceive with traditional statistical methods, in which the very restrictive hypotheses are unable to produce complex relationships between the data. Instead, it would be interesting to process by applying instruments such as neural networks, which not only make it possible to understand the association between variables, but also to extrapolate possible scenarios according to various hypotheses.

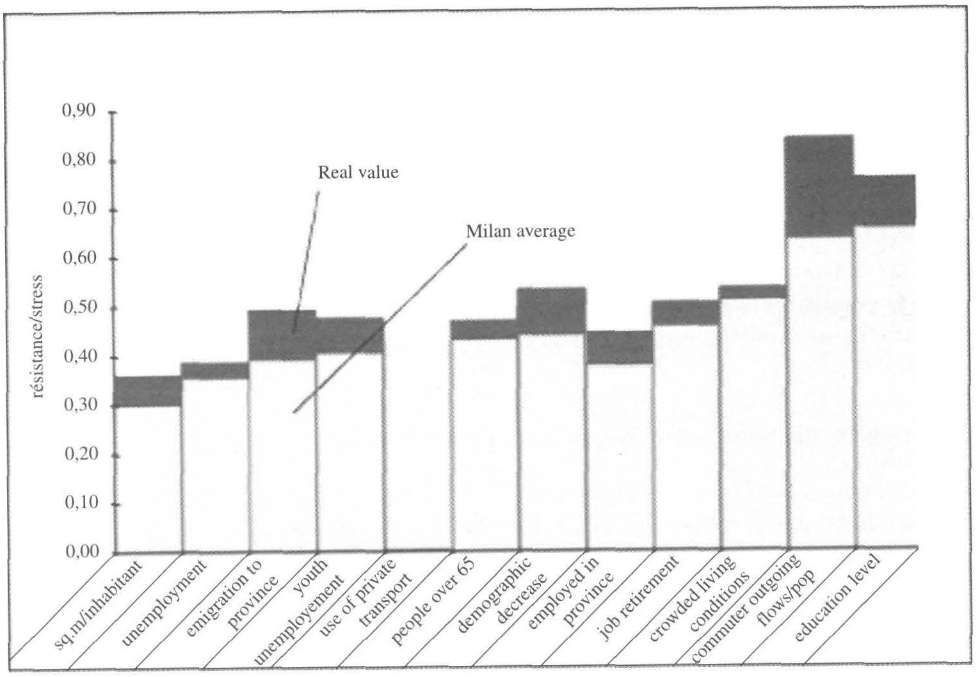

Figure 2 - Socio-economical system, risk area, Porta Genova Station

3. Application : repercussions of the concept of risk in an urban environment

3.1. Urban morphology and air pollution

This phase of the research involves the application of the risk measurement method on a micro-scale. Urban risk is determined for a damaging event with the purpose of investigating the possible relationship between the urban built form and environmental quality, given by the presence of air pollution.

The variables that are considered in the analysis are: mobility given by the vehicle traffic flows, urban morphology, with the size characteristics of the street section, and air pollution, here expressed by the concentrations of carbon monoxide (in the following paragraph we will see why the research focuses on this pollutant).

We would like to synthetically represent average conditions in a certain area, that take into account the physical characteristics of the street and traffic flows. The purpose is to be able to construct an urban risk map, in which the areal conditions of the urban framework are clearly visible and easy to identify. Naturally, the problem could be tackled by measuring and reading pollution levels for each street and maintaining their subdivision also in the representation phase, but a similar approach would limit the possibility of having an overall testing instrument of the urban risk. The clarity of the results depends on the need to be able to evaluate the problems that emerge, in an integral manner, also in terms of urban sustainability, according to which particular importance is given to the global systematic meaning of the phenomena. We cannot limit ourselves to a specific analysis and tests, because such an excessively close-up view would compromise the possibility of constructing a general and systematic overview of the problem considered.

To define a risk area and measure its magnitude, it is necessary, as we have already extensively described, to identify an acceptability threshold of the values obtained, to which to compare the real measurements. Thanks to the well-known relationship between intensity of vehicle flows and pollutant concentrations, it is possible to develop a method to determine the critical threshold strictly related to the imposition of air pollutant concentration level limits. As we will see, it is possible to establish critical flows beyond which the situation may be considered to be at risk. Such flows are the result of the admissible and pre-defined pollutant levels and the morphological characteristics of the street section. This leads us to consider the possibility of recognising a carrying capacity of the urban structure, given by its capacity to contain and sustain the stress induced by factors that have recognisable and comparable effects in relation to physical variables. In general, in an urban environment, the concept deviates excessively from that considered by classical ecology. In the city, resource self-purification and regeneration processes are not possible. The urban ecosystem, as a dissipative system, is unable to restore the resources and maintain the non-renewable qualities [1]. However, the carrying capacity can be defined where it makes sense to talk about the capacity to react to the pressure exerted by negative externalities. For air pollution concentration, the street morphology determines the possibility of dissipating the substances emitted by vehicles and thus defines a resistance and permeability capacity to stress imposed by traffic flows.

3.1.1. The analysis method and synthesis processing operations

The application intends on providing a method for completing the maps that can restore the risk/safety conditions of the streets analysed in terms of air pollution due to vehicle traffic.

It is known that the contaminants emitted into the atmosphere undergo different physical, chemical and chemical-physical processes. An analysis of the pollution from mobile sources indicates that carbon monoxide is considered the primary compound linked to traffic in any socio-environmental situation, and is considered active in proximity to the street level [22]. The concentration of carbon monoxide can be calculated by using local diffusion micro-models. In addition to traffic flow characteristics, these instruments also take into account the topographic and spatial features of the micro-environment in which the source has an effect. Many streets in urban centres have a canyon effect on the pollutant concentration. This occurs when the direction of the wind above the buildings is perpendicular to the traffic direction. The attained concentration levels depend on the wind speed, background concentration of air contaminants, traffic, dimension of the streets and height of the buildings facing the street. It is known that the presence of buildings greatly modifies the wind field, a fundamental vector for dissipating pollutants. At the street level, the movement of air is established by the direction of the street axis and sometimes by traffic. Wind with a general circulation makes a significant contribution only on long streets that have the same direction [16].

Starting from a simple model, an urban risk indicator is developed to calculate the local concentrations of carbon monoxide. The primary purpose of the indicator is to emphasise the ratio between air pollution and urban morphological characteristics.

The intensity of the concentrations expresses the relationships between the geometric and physical variables that define the calculation model of the local concentrations. The reverse link between the variables makes possible to identify critical flows obtained from the imposition of specific polluting concentration values. A comparison between the critical flows and the real flows provides information about the urban risk for each street analysed.

The survey was carried out over a sample area in Milan, selected by evaluating the representative criteria of the urban context and the availability of the necessary data. In general, the results can be represented by illustrating the overall situation of the area highlighting the risk level (fig. 3).

The analysis can be extended to the entire urban area until obtaining an overall vision of the risk of pollution from carbon monoxide. By comparing the risk levels, the various morphological arrangements of the urban framework and the intensity of the traffic flows, an attempt could be made to theorise initial overall evaluations regarding the role that the form of the urban structure has in determining the incident stress.

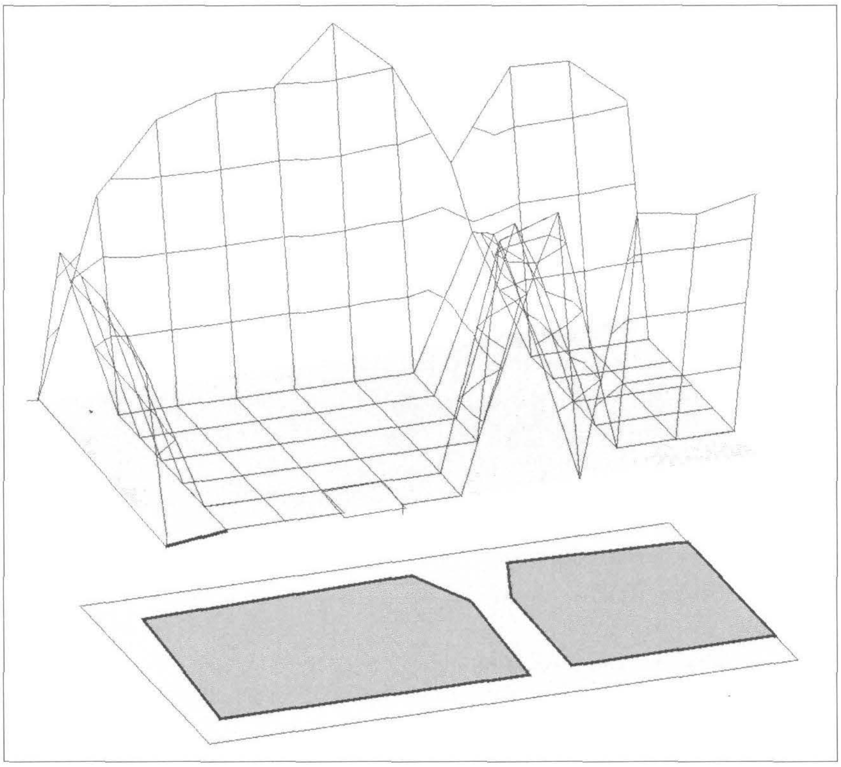

Figure 3 - Air pollution risk level, overall situation of the sample area

3.1.2. Results

This experiment proposed a method for analysing urban risk through a flexible and easy-to-use tool with which to be able to visualise the connections and interdependencies between the urban morphological layout, form of the construct and magnitude of the traffic flows in the formation of the risk of pollution from carbon monoxide.

Considering how it was treated in this situation, risk is a real sustainability indicator. Its characteristics, to describe the phenomenon in question and to provide information concerning the contextual situation, lay the foundations for constructing a descriptive/informative support from which to develop possible planning intervention policies.

Figure 3 represents the distribution of risk levels in the area being examined. The sampling was carried out considering a semi-central area of Milan, between main streets with high traffic intensity. The structure of the street network can be immediately recognised, especially in relation to the role that the various types of streets have in relation to the vehicle traffic flows. Almost all the outlying streets and the major axis have higher risk levels, while the minor network, that distributes local traffic, does not seem to be affected by any significant stress. In reality, based on an in-depth survey suggested by some observations by World health organisation [24], it was found that by increasing the pollutant exposure time, specific concentrations not considered dangerous over a period of 1 hour become hazardous after 3 hours of exposure.

In general, risk reduction is an indisputable environmental and social objective, and there is unanimous consensus at least concerning its theoretical/conceptual assumptions. Regardless of the direction in which the survey is carried out, it is of absolute importance to make the dangerousness of a specific event in an area as visible and understandable as possible.

This type of application made it possible to give meaning to the concept of carrying capacity of the urban system. For some variables related to physical factors, such as pollutant concentrations, the urban structure has the capacity to react and to limit the pressure exerted by risk factors and thus make it possible to identify maximum carrying capacities.

This report does not deal with the issues relative to the intervention strategies. However, it is important to emphasise the possibility of using a method to analyse and to visualise the risk to further investigate the construction of future scenarios, starting from choices aimed at reducing the risk level in the urban area. Being able to visualise possible alternative developments of the decision makes it possible to express evaluations regarding the choices to be made on the basis of effects that can be measured dynamically over the long term.

3.2. Evaluation of urban risk toward sustainability

The main objective of this phase of the research is the construction of urban sustainability maps of Milan, through which to identify the risk situations and opportunities structured according to characteristics and problems that emerged at an urban and micro-urban scale.

With respect to the numerous definitions of sustainability proposed at an international level (Bruntland Report, 1987; World Conservation Union, UN 1991; EEC Green Paper on the urban environment, 1991), the recent work formulated by ICLEI (International Council of Local Environmental Initiatives, 1994) appears to offer greater operating repercussions, suggesting the multi-dimensional aspect of the interpretative approach (descriptive and design-oriented), that can highlight the significant relationships between different systems, whose interaction qualifies and makes the notions and actions of sustainability more objective.

The methodology adopted arises from the definition of sustainability as a positive co-evolution between various systems :

- social (the social subjects examined in relation to quality of life, i.e. social interaction, opportunities involving living quality, jobs, culture leisure time, personal assistance, buying power);
- economic (level of richness, concentration and dynamics of companies, real estate market, accessibility to means of transport, opportunities for transformation and investment);
- physical/environmental (quality of the air, water, ground, green areas and regeneration capacity and environmental protection).

Only positive interactions between the three subsystems represent the pre-conditions that are essential for the life and development of the city. On the contrary, the undesired effects of diseconomies of scale produce negative externalities of urban degradation, social marginalization and pollution.

The survey scale assumed by the research is purposefully aimed at the micro-scale and concerns the Municipality of Milan which is spatially divided into 144 zones. This choice may be criticized.

The sustainability of development occurs at each territorial level with specific problematic connotations and requires adequate and specific policies. Thus, sustainability is a trans-scalar objective by definition.

In fact, it is evident that the city, as a dissipative structure [17] exists since it activates a complex system of interactions with its hinterland: the dependencies regarding energy, green areas, labour force and, on the opposite side, the impact of pollution, wastes, tourism and leisure time, are known factors of this dependency.

At a national or international level, other interrelations and scale effects can be identified which lead to other decisions that are essential for sustainability: the choices on energy technologies, the laws on control of polluting sources, the policies about transport and mobility, the fiscal policies on energy consumptions.

Thus, sustainability is an objective that necessarily implies different space-time scales for which however the micro-scale expresses problems and opportunities with respect to which the planning policies may play an important role.

The city is in fact an articulated and interconnected system where areas that are spatially differentiated carry out different and complementary functions. The identities of neighbourhoods, the socio-economic characters of the inhabitants, the economic/productive tradition and the spatial structure and location of the sites and the networks make the interactions between the three subsystems produce different and unpredictable results. Each area has its problems and its opportunities to utilise in a single and specific path toward sustainability.

Thus, focusing research on the micro-scale is motivated in the assumption that local planning policies can, with a network of specific interventions, improve the quality of life and the attractiveness of Milan with regard to the hinterland and the international cities with which it competes.

3.2.1. The analysis method and overall processing

The progressive approach to attain the research objective was consolidated in the application of selected indicators on the scattered territorial areas, in order to validate them. This made it possible, based on a geographic reference system, to determine the sustainability situation by themes/systems.

The systematic methodology at the base of the research, that focuses on the most significant relationships between the various subsystems that constitute the urban structure and make it operational, made it possible to suggest both the initial forms of sustainability indicators as well as the contributions of each category responsible for environmental degradation. The purpose was to indicate the local opportunity and risk conditions to be assumed for the subsequent territorial reorganisation hypotheses.

Because of the plurality of the indicators selected, a methodology was required that would make it possible to organise a summary overview, while minimising the loss of specific information that each indicator expresses. An approach often implemented at an international level adds the different types of what are mainly economic indicators, such as the NDP (Net Domestic Product), with other social well-being indicators, into a single super sustainability indicator. According to this prospect, it is expected to obtain the whole index as the sum of the various parts with which the problem was divided for operational reasons. In addition, in this way it is hypothesised that the single parties do not undergo any changes because of being withdrawn from the whole.

This different methodology, though it does provide a summary and simplified overview of the situation being studied, would not permit, considering the spatial detail of our survey scale, to perceive the interrelationships between the various phenomena and in fact would reduce the prospects about the difficult emergencies of each territorial situation.

Therefore, it seemed appropriate to initiate a process of gradual construction of an overview, highlighting the themes and associating to each of them a set of indicators according to an analytical and interpretative key aimed at identifying the simultaneous presence of various critical factors.

The following factors were considered: the professional cultural level, the issue concerning emigration and suburbanisation, the job marginalisation phenomenon, (commuting and accessibility), the problem of crime and social inconvenience, (living quality), the presence of qualified urban activities, (social and basic commercial, areas for young people, environmental quality) and finally the transformation opportunities.

The areas subject to the greatest risk were selected on the basis of the simultaneous presence of critical factors, identified according to the values of the pertinent indicators, higher than a certain threshold (median, quartile or decile of the distribution of values).

3.2.2. Results

The work carried out made it possible to create an analytical-descriptive overview of the risk and opportunity conditions in Milan based on a definition of urban sustainability related to the interaction between social system, economic system and physical-environmental system.

Thanks to the use of main parameters or indicators that correspond to the precise choice of making a close connection with possible sustainability strategies, it was possible to go beyond a simple static-analytical view of the Milanese environment and to lay the foundations for suggesting significant policies and actions to pursue the sustainability objective. The results obtained to this point can be used to express evaluations regarding the areal conditions of Milan through special indicators chosen to understand the problems and the meaning of the interactions that occur on a micro-scale.

The representation through risk/opportunity maps can be used to highlight the issues strictly related to the urban system, emphasising the important aspect related to the multidimensional nature of the phenomena.

Risk was analysed defining a series of key critical factors and evaluating their simultaneous presence based on a threshold approach. Thus, the risk situation is present where the factors selected attain values that exceed the limit imposed by the pre-defined threshold. The disaggregation in different factors allow to evidence the qualitative variety of urban sustainability.

Generally speaking the peripheral areas are critical by different points of view and, as expected the center performs better with respect to sustainability. Nevertheless a more accurate analysis in each interaction gives important indications on the spatial pattern of urban risk.

The socio-economic risk (fig. 4) affects not only the most peripheral areas but some semicentral zones with complex interactions of many punctual factors (poverty, commuting, employment marginalisation).

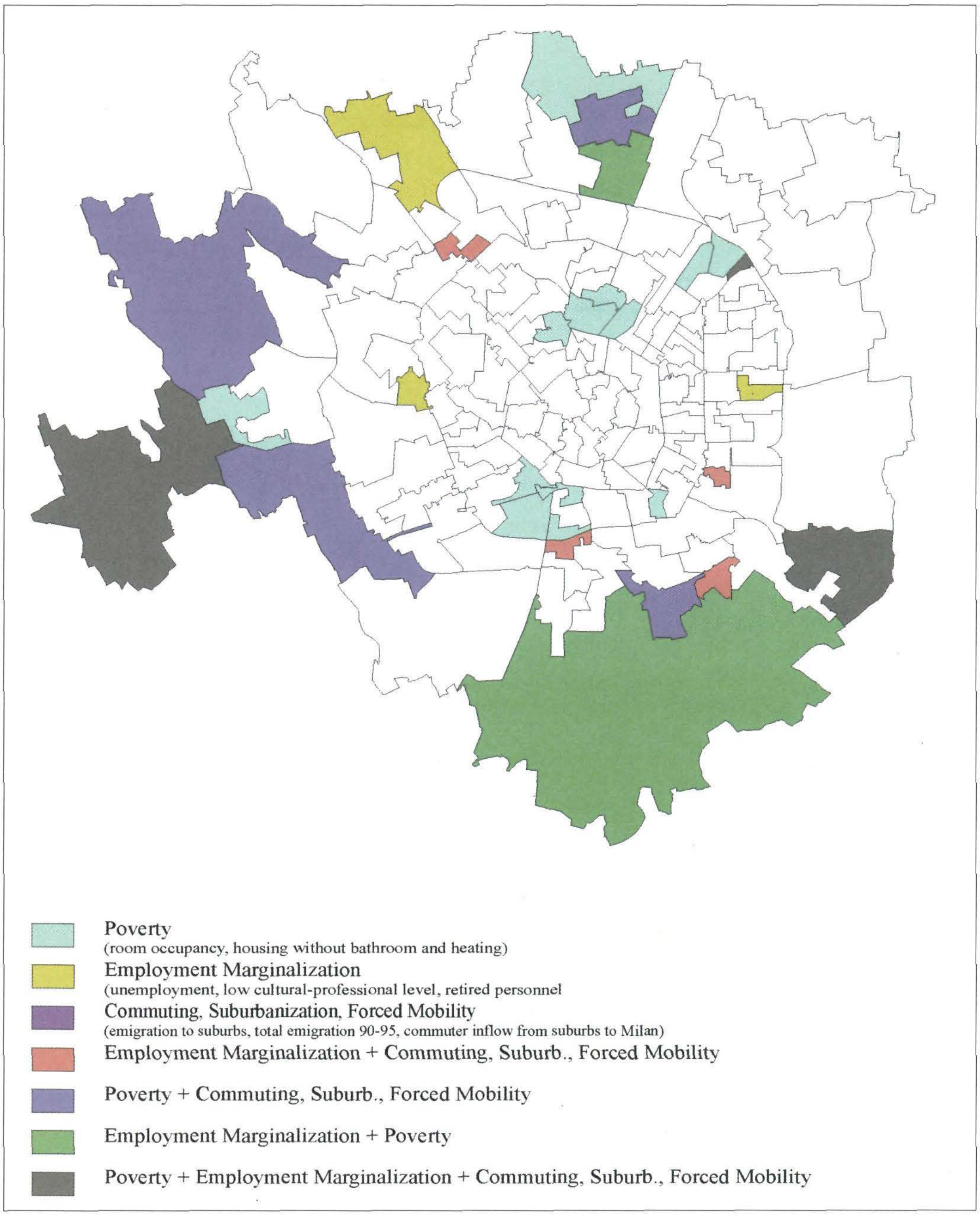

Figure 4 - Milan - social-economic system: risk conditions

The economic-environmental risk is more expanded since it is produced by diffuse phenomena like air pollution, poor accessibility to public transport, housing stock decay and scarce economic vitality. Finally the map of socio-environmental risk affects not only the border areas but also semicentral and central areas due to criminality and pollution.

The opportunities are concentrated in the center and point out the residential high standard of living vocation of the north-west sector, opposed to the vital mix of housing and jobs in the east semi-central areas which seem to present good opportunities of revitalisation near the railway stations where there is availability of derelict lands, although the good accessibility is often associated with social instability and a poor housing quality.

This method does not effectively quantify the risk, but highlights its complex and composite nature, and presents it as a systematic phenomenon, generated by relationships and bonds of influence between various variables. On this basis it is possible to carry out qualitative evaluations and to identify what they are and which characteristics have risks (and the opportunities) on a micro-urban scale. The study might give rise to a proposed set of strategies for sustainability aimed at some objectives for the city of Milan, including the liveability of its inhabitants and the maintenance-improvement of its position in the network of European cities.

4. Conclusions

This analysis made it possible to define an urban risk study methodology that allows for developments and applications on different scales. The two proposed applications, though very different in terms of the scale and the nature of the survey, do implement a common risk analysis method that, starting from the attempt to respond to some basic enquiries about the problem, define a concrete tool for visualising and evaluating the current risk.

As already extensively discussed in the introduction, risk in the urban system has peculiar characteristics that allow it to be recognised as a complex phenomenon that is strictly related to the nature of the socio-economic systems. We already noted the risk in an urban environment is not an incidental event, definable by identifying a cause, or a set of causes, and evaluating the consequent effect. Instead, it is structured within the relationships and bonds that are generated in the city, a spatial concentration of human activities and flows that do not involve only linear types of phenomena.

Treating risk as an urban phenomenon means to consider some fundamental issues and to give concrete and articulated answers that take into account the complex nature of the processes in action in the social systems.

Of the various aspects of urban risk involving the most basic questions, two are particularly important because of their capacity to stimulate reflection and in-depth thought and because of their strict dependency on the possibility of effective risk representation:

– the multidimensional aspect of the phenomenon within the complexity of the urban system;

– the definition of a threshold of vulnerability of the system and acceptability of the risk.

The research attempted to provide an answer to the questions induced by these two aspects, trying wherever possible to go beyond the traditional risk analysis approach in which compensating and additive logic is often applied. Urbanisation produces risks (and naturally opportunities) related to the physical framework of the city and to its social and economic structures. The dimensional aspect of the phenomenon is a significant part of the risk evaluation problem. Urban risk has such a complex nature that it cannot be perceived by applying processes of monetisation and compensating logic, as cost-benefit and multicriteria analysis, and additive synthesis. The various aspects that comprise the phenomenon not only acquire different weights, but denote the risk, differentiating perception thresholds and types of intervention. The risk factors become such at the moment in which a critical mass is generated that is imposed as the stress on the system. In addition, the process of forming the risk has non-linear characteristics that must not be neglected during the information synthesis phase, otherwise we will lose the importance of the various aspects that comprise the nature of such a phenomenon. To this regard, it would be interesting to test a new approach for processing data based on a connection-oriented cognitive method, such as using neural networks, with the purpose of investigating the relational structure among urban indicators. Thus, the objective of further research would be to introduce the application of analysis instruments that are capable of analysing the synergetic effects between risk factors and to further investigate the non-linear connections of influence among the variables.

Finally, it is important to emphasise how in this work the possibility arises of dealing with the issue of carrying capacity also in relation to urban systems, though limited to some variables. The topic, as is known, requires much caution. The dissipative nature of the city does not permit a generalised extension of the problem, but where the risk factors depend on recognised physical variables, more in-depth investigations and specific studies would be worthwhile. If there is a threshold, beyond which the urban system carrying capacity is overloaded relative to a specific aspect, then intervention strategies and policies can be theorised that focus directly on reducing the risk levels.

Réferences bibliographiques

[1] ALBERTI M., BETTINI V., 1996 : Sistemi urbani e indicatori di sostenibilità, in V. Bettini *Elementi di ecologia urbana*, Turin, Einaudi

[2] AMENDOLA A., FUNTOWICZ S., 1994 : Comunicazione del rischio. Attività di supporto alla Comunità Europea, *Rischio. Gestione del rischio. Comunicazione del rischio*, n° 4, p. 8

[3] CAMAGNI R. (Ed.), 1996 : *Economia e pianificazione della città sostenibile*, Bologne, Il Mulino

[4] CNRS - Centre National de la Recherche Scientifique, 1997 : *La lettre du PIR Villes - Dynamiques urbaines, Programme Villes, Lettres des programmes de recherche du CNRS*, n° 7

[5] DIAPPI L., BOLCHI P., CAMPEOL A., FRANZINI L., 1998 : La costruzione di una mappa di sostenibilità ambientale a Milano : le condizioni di rischio, in R. Capello & A. Hoffmann *Sviluppo urbano e sviluppo rurale tra globalizzazione e sostenibilità*, Milan, Franco Angeli

[6] DOUGLAS M., WILDAVSKY A., 1982 : *Risk and Culture : An Essay on the Selection of Technological and Environmental Dangers*, Berkeley, University of California Press

[7] EUROPEAN COMMISSION, 1990 : *Green paper on the urban environment*, Brussels-Luxembourg, UE

[8] EUROPEAN COMMISSION, 1994 : *European sustainable cities*, Luxembourg, UE

[9] FAIRMAN R., MEAD C.D. & WILLIAMS W.P., 1998 : *Environmental Risk Assessment. Approaches, Experiences and Information Sources*, Copenhagen, European Environment Agency

[10] GRANDORI GUAGENTI E. & BRAMBILLA M., 1986 : *Rischio e soglia di rischio accettabile nei problemi di pianificazione ambientale*, Milan, CLUP

[11] GUAGENTI GRANDORI E., 1982 : Modelli stocastici nella riduzione del rischio sismico, *Rendiconti del Seminario Matematico e Fisico di Milano*, 52, pp. 283-97

[12] INTERNATIONAL COUNCIL FOR LOCAL ENVIRONMENTAL INITIATIVES, 1993 : *The Local Agenda 21 Initiative*, Toronto, ICLEI

[13] IUNC, UNEP & WWF, 1991 : *Caring for the Earth*, Gland, Switzerland

[14] MARINELLI A., 1993 : *La costruzione del rischio : modelli e paradigmi interpretativi nelle scienze sociali*, Milan, Franco Angeli

[15] MILLER A., 1985 : Technologic thinking : its impact on environmental management, *Environmental Management*, 9 (3)

[16] PAGLIARI M., 1989 : Il clima e l'inquinamento urbano, *Terra*, (6), pp. 39-42

[17] PRIGOGINE I. & STENGERS I., 1993 : *La nuova alleanza : metamorfosi della scienza*, Turin, Einaudi

[18] SANTOIANNI F., 1996 : *Rischio e vulnerabilità : disastri e territorio*, Naples, CUEN

[19] UNITÀ SOCIO SANITARIA LOCALE 75/III, 1992 : *Studio modellistico sull'inquinamento atmosferico da traffico e da riscaldamento nell'area metropolitana milanese*, Milan, USSL & Province of Milan

[20] UNITÀ SOCIO SANITARIA LOCALE 75/III, 1993 : *Studio per la valutazione della qualità dell'aria nella provincia di Milano*, Milan, USSL & Province of Milan

[21] UNITED NATIONS DISASTERS RESEARCH OFFICE, 1979 : *Natural disasters and vulnerability analysis*, Geneva, UNDRO

[22] VISMARA R., 1988 : *Ecologia applicata*, Milan, Hoepli

[23] WORLD COMMISSION ON ENVIRONMENT AND DEVELOPMENT, 1987 : *Our Common Future*, Oxford, Oxford University Press

[24] WORLD HEALTH ORGANIZATION REGIONAL OFFICE FOR EUROPE, 1997 : *WHO Guidelines for Air Quality*, Geneva, WHO