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THE RISK EVALUATION IN URBAN SUSTAINABILITY: A THRESHOLD METHODOLOGY AND A NEURAL NETWORK INVESTIGATION

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Abstract

This paper focuses on the concept of a *sustainable city* and its theoretical implications for the urban system. Urban sustainability is based on positive interactions among three different urban sub-systems: *social*, *economic* and *physical*, where social well-being coexists with economic development and environmental quality.

This utopian scenario doesn't appear. Affluent economy is often associated with poverty and criminality, labour variety and urban efficiency coexist with pollution and congestion.

The research subject is the analysis of local risk and opportunity conditions, based on the application of a special definition of risk elaborated and made operative with the production of a set of maps representing the multidimensional facets of spatial organisation in urban sustainability.

The interactions among the economic/social and environmental systems are complex and unpredictable and present the opportunity for a new methodology of scientific investigation: the connectionistic approach, processed by Self-Reflexive Neural Networks (SRNN). These Networks are a useful instrument of investigation and analogic questioning of the Data Base. Once the SRNN has learned the structure of the weights from the DB, by querying the network with the maximization or minimization of specific groups of attributes, it is possible to read the related properties and to rank the areas.

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.

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1. Introduction: research subject and survey scale

The research subject is the analysis of local risk and opportunity conditions, based on the application of a special definition of sustainable development elaborated and made operative within the environment of the same research project.

The notion of sustainable development developed by the most highly accredited sources at an international level (Bruntland Report 1987; World Conservation Union UN 1991; ICLEI 1993, Green Paper on the Urban Environment - EEC 1991) goes far beyond the concept of environmental protection, since it implies that considerations must be made for future generations and for the long-term health and integrity of the environment. It includes attention to the quality of life (and not only an increase in income), equality between persons in the present (intra-generational equality), inter-generational equality (the inhabitants of the future deserve an environment with the same if not better quality than what we enjoy today) as well as the social and ethical dimensions of human well-being. It also implies that each additional development can occur only if it does not exceed the load capacity of the natural systems. Thus, it is evident how dealing with the difficulties of sustainable development involves new problems to be solved, and last but not least the problem regarding an effective integration of urban policies within a multi-disciplinary context.

Within this context, the term *sustainability*, refers to problems over an immense scale, from vast regions to the entire globe, focusing aspects relative to consumer processes and degradation of non-renewable resources, and to the equilibrium of natural ecosystems, on the models of life and consumption in their entirety, to economic/productive macro-transformations.

In a pure ecological perspective, the city, as an artificial system, would be unsustainable by definition and would orient the sustainability policies mainly in the direction of minimising the impact in the natural environment.

In effect, the cities, in their entirety, in terms of dimensions, number of inhabitants and high levels of pro capita consumption, are among the entities with the greatest responsibility for the current world-wide environmental compatibility crisis. But the city has, and historically has had, a major role in promoting human well-being and in offering a quality of life that is different and specific related to urban values: variety of lifestyles and social contacts, diversification of the job market, promotion of innovations, variety of cultural options, presence of rare and qualified urban functions.

The demographic density that characterises the cities can be used to provide society with a large variety and choice of jobs, goods, services and recreational activities, and to carry out a substantial share of movements by means of public transport, to provide more efficient environmental services (such as waste re-use and recycling) and to promote architectural and planning solutions that are more rational in terms of energy consumption.

Only by considering the urban values as *resources* capable of promoting human well-being is it possible to identify a more complex concept of sustainability whose objective is based on a series of factors for which only some involve the physical-ecological quality of the urban environment.

This issue therefore cannot be dealt with without involving the interactions between the *social system* (quality of life, social interaction, job, cultural and leisure time opportunities), the *economic system* (level of richness, diversification of the job market, efficiency of services and infrastructures, income and energy costs, investment opportunities) and the *physical-environmental system* (settlement morphology, climatic conditions, residential quality, parks and gardens, production technologies, energy consumption and disposal, communication technologies, road and transport networks).

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* (Prigogine and Stengers 1975) 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 consumption.

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.

2. The potential of the city and its limits

As already stated, to offer a good quality of life and environmental compatibility, the city must allow its inhabitants to live in a sustainable manner: the concept of availability of sustainable living models includes the environmental quality, the quality of life and the future success of the city.

Thus, the cities and the urban living model are potentially advantageous it terms of environmental compatibility. This may create evident perplexities for the case of Milan.

The reasons for the failure may be better understood by considering (eco) system types of approaches which should make it possible to understand and consolidate the environment compatibility potential, as an alternative to analytical and managerial methods, of a sectorial and non-integrated nature. For example:

- The areas with high urban density, which permit essential scale economies of collective transport, functional specialisation and variety of activities, often are not supported by a good accessibility and therefore do not fully utilise their urban development potential. The building decay that often occurs in these situations, might however offer good opportunities for renewal and revitalisation, if appropriately supported by transport policies.
- On the contrary, peripheral areas, which lack a functional character and are in marginal situations from a social viewpoint, have good accessibility which in itself is unable however to activate any process of revitalisation on the vast derelict lands available to them.
- In a dynamic setting the process of decentralisation of inhabitants and firms affects urban sustainability in two folds: first, by creating high land consumption at low density with an additional burden in terms of urbanisation and transport costs and second by reducing the density and therefore the precondition of urban quality. If the conservation of the city's scale economies is a priority sustainability objective, the renewals in particular of the semi-central areas, which are primarily interested by deconcentration, are fundamental strategic factor.
- The advantages of economic development contrast with the drawbacks of crime, poverty and marginalisation.
- Finally the ecological-environmental issue contrasts with a rather unfavourable weather-climatic condition, an urban presence of green areas that is utterly unsatisfactory to create bio-mass and bio-diversity, and the features of urban morphology, that presents evident problems in ventilating and dispersing the pollution.

In summary, based on all the various considerations, it is found that the city, along with objective weaknesses and vulnerable points, also has important positive factors which can be implemented quite efficiently within a prospect of sustainability.

3. The Methodology

The definition of sustainability as a positive co-evolution between the three systems: social, economic and physical/environmental, leads to the methodology adopted that is based on an analysis of the areal conditions through appropriate indicators selected to encompass the problems and the sign of the interactions.

The operational task of the research, which lies in the construction of maps of risks and opportunities at local scale, led us to develop the concept of risk taking in to account his multidimensionality and the consequent probabilistic formalization of this term.

In fact an urban area should be considered at risk if various negative factors affect her sustainability (i.e. criminality, low cultural level, youth unemployment, low housing quality). These elements are often related and point out various areas with similar emergency problem;

The complex structure of these recurrent relationships among indicators may be organized or synthesized by an "a priori" identification of factors of risk and the consequent choice of a set of indicators. An other direction should consist in exploring "a posteriori", through a suitable methodology able to investigate the complex relationships among Data, the connected phenomena and therefore the groups of indicators to be interpreted and processed.

At this stage of the research, due to the lack of experiences in this topic, the research has moved in two different directions: the first with the identification of 10 macro-factors of risks, organized in the groups and with the consequent construction of six maps of risks and opportunities, and the second through a Neural Network investigation which has pointed out the underlying relationships among indicators. Both the directions have been explored and the results are presented in this paper.

3.1.The data Base set up

Since the concept adopted for urban sustainability lies on the interactions among the social, economic and physical urban system, each of those should be represented by a suitable set of indicators. And therefore:

- *Social system*: the first group of indicators is used to estimate how the quality of human life is supported by the functional-environmental structure, that offers local opportunities for social interaction, cultural and leisure activities, but also risks of social and environmental degradation;
- *Economic system*: the second group concerns the complex relationships between residence, job, professionalism, culture and income of the population;
- *Environmental system*: the third group is designed to measure the economic vitality of the city, the efficiency of the urban structure, the transformation and investment opportunities to promote the economic development thus fostering social well being, the negative externalities include the risks of economic stagnation, reduction of investments and built stock decay.

Externality	Social-Environmental System	Social-Economic System	Economic-Environmental System
Positive	• **Occasions for Social Life and Leisure Time** (places for young people, clubs and assoc., public green areas, sports) • **Quality of Transport** • **Qualified Urban Activities** (business centres, cinemas, restaurants) • **Social and Basic Commercial Services** (schools, assistance for the elderly, supermarkets)	• **High Cultural and Professional Level** (university and high-school graduates, male and female activity rate) • **High Residential Quality** (sq.m./inhabitant, executives and business men, domestic help) • **Local Work and Study Opportunities** (self-contained commuter flows, commuter inflows, commuter flows within 30')	• **Economic Vitality** (functional mix of services to enterprises and pop.) • **Quality of Communication Networks** (accessibility by public transport, airports, motorways) • **Urban Environment Quality** (green areas, high real estate values) • **Renewal Opportunities** (derelict lands, high urban density)
Negative	• **Crime** (drug dealing, prostitution, thefts, murders, purse-snatching and pick-pocketing) • **Under-equipped Urban Areas** (retailing mix) • **Pollution** (air, water, soil)	• **Employment Marginalisation** (unemployment, low cultural-professional level, retired personnel) • **Commuting, Sub-urbanisation and Forced Mobility** (emigrates to suburbs, employed in suburbs, demogr. decrease, outflows) • **Living Inconveniences** (room occupancy, sq.m./inhabitant)	• **Pollution** (air, water, soil) • **Economic Stagnation** (poor mix of services to enterprises and pop.) • **Built Stock Decay** (dwellings without indoor bathrooms and heating, low real estate values)

Tab.1 Indicators of environmental sustainability risk in Milan

The work, which is still in the completion phase, was carried out according to a sequence of articulated phases. An initial systematic collection of the informative material produced by various sources was used to describe the physical-ecological environment and the socio-economic structure of the area which was the subject of the survey.

The construction of indicators, many of which of the original source of the work group, made it possible to create theme maps relative to the various selected indicators.

Then, a method was developed to process the information regarding environmental issues which made it possible to establish significant relationships between the physical characteristics of the city from an ecological resource point of view (water, air, green areas, etc.) and the organisation of the urban structure. A similar

database, which is updated over time, might offer an "observatory of the interdependencies" in order to monitor the actions foreseen by the competent institutions regarding planning and environmental issues, as well as to evaluate the compatibility with the context of foreseen urban projects.

Then, a representation of the “risk or opportunity” of environmental sustainability was tested with reference to three subsystems, to be compared to the choices currently in effect by the public administration and based on which to consider the planning forecasts as well as the short and medium-term urbanisation programs.

Finally, a methodology to calculate urban risk was developed to define a classification of areas identified by points, obtaining a summary framework with references of the situation in Milan in terms of the qualitative-quantitative distribution of the risk in its entirety.

Preparing the processes of the latter phase should make it possible for the competent organisms and institutions to define actions/projects to re-qualify the urban environment that are aimed toward sustainability, identified on the basis of precise evaluations in order of intervention priorities.

3. Risk Analysis and Mapping

The identification of factors of risk and consequently of the indicators to be jointly considered, started from an evaluation of the multiple facets by which the factor arises. Twelve factors have been identified:

1. Cultural and Professional Level
2. Suburbanization
3. Employment Marginalization
4. Commuting and Accessibility
5. Crime and Poverty
6. Living Quality
7. Qualified Urban Activities
8. Social and Basic Commercial Services
9. Occasions for Social Life and Leisure Time
10. Economic Vitality
11. Ecological Quality
12. Renewal Opportunities

3.1 The concept of risk and his measurement

The risk state occurs when, given a system and a stress, there is uncertainty that the resistance of the system is greater than the stress to which it is subjected. Stress and resistance can also be indicated with other terms, for which the most significant used by the international literature are *hazard* and *vulnerability*. However, there is a difference between resistance and vulnerability: resistance measures the field of stress within which the system

does not sustain a specific damage, while vulnerability considers the field in which the system exhibits such damage. High resistance therefore implies poor vulnerability.

Resistance and stress are probability parameters that can be represented as random variables with a known probability density (*probability density function*). The state of risk occurs when the two probability density functions overlap, defining an area that returns the current risk measurement and therefore the probability of a specific damage.

The risk concept analysis involves two important evaluations: *exposure* to the risk and its repetition over time. Exposure involves an in-depth focus on the social, economic and physical-environmental aspects that form the system. Instead, the time repetitiveness requires a stochastic model that can express, in real terms, the modality with which the damaging situation arises. Therefore, the risk can be expressed as the product of probability (frequency) of an event and undesirable consequences having a certain dimensional entity (magnitude):

$$R_t = P_e \times M_c \tag{1}$$

where

R_t = total risk
P_e = probability of the event
M_c = undesirable consequences (magnitude)

The attribution of the relative weights to the *probability* and *magnitude* variables is very important to ensure that any iso-risk conditions can be evaluated. To this regard, the data can be represented in terms of a risk curve, that express the probability of an event occurring (P_e) with a certain magnitude (M_c).

To deal with the application issue of the risk concept, we must first define the system on which to carry out the analysis. In our case, the three subsystems considered to this point (socio-environmental, socio-economic, economic-environmental) must be analysed with particular reference to their negative externalities.

The risk state is created by the interaction among the variables that form the structure of each subsystem. Stress and resistance emerge from the behaviour of the subsystems, are determined by the synergetic action that occurs within them and are realised within the links of influence. Once the risk levels to be examined are quantified, the condition exists to support a planning activity that develops response strategies in a situation of widespread uncertainty, recognised as being impossible to eliminate and connatural with the “urban nature”. Thus, it is possible to understand the importance that may be attributed to the development of future scenarios visualised in risk maps.

In an urban environment, where the damaging event has structural rather than incidental features, it is indispensable to consider the main properties of risk: the type of exposure to risk factors and the environment characterised by the resistance and stress parameters. To evaluate the consequences of a specific phenomenon and to begin programming, the measurements must have a common reference. For us, this is given by the subsystem being examined in which the risk factors are the "negative" indicators and the statistical areas the resistance/stress fields.

In relation to the analytical formulation (1), the probability is represented by the number of risk factors and the magnitude by exceeding the critical threshold (e.g. Milan average) of the value assumed by each factor/indicator. This makes it possible, for each statistical area, to evaluate the probability of damage occurring relative to its different levels of manifestation and the entity of the current risk.

For each system, points are attributed to the areas given by the sum of the magnitudes present. The probability is constant since the number of risk factors in the system does not change. The iso-risk condition occurs when two or more areas reach the same number of points. Their comparison may indicate situations with low but widespread magnitude and risk equal to situations involving high magnitude but resulting from only a few factors.

The iso-risk areas offer the opportunity to focus on such a risk concept. When an equal point total (risk) occurs, the consequence is a comparison between the critical situations.

With equal points, an area may have only two critical factors with high magnitudes and another area with several critical factors but with limited magnitude. Both cases have the same risk but the effects are certainly quite different.

The nature of the critical factors is very important. Given the probability as the number of negative externalities considered (indicators), the magnitude may be widespread without however ever reaching significant levels. Here, the risk does not have a specific nature. It is an index of a widespread malaise whose risk level is related to the multiple facets of the damage. Otherwise, if the magnitude is zero or almost zero for some factors and high for others, then its peculiar aspects will emerge. The critical factors may belong to the same group (e.g. low real estate values and built stock decay) with damage and with effects of a defined or definable nature. Furthermore, in the same system, they may have a different nature (e.g. air pollution and deficiency in services to enterprises). In such a case, the synergetic effect produced must be considered, the extent of which is related to the type of interaction and correlation among the critical factors.

The importance of the synergy between factors is not limited, however, to iso-risk situations, but extends throughout the risk/opportunity analysis as it is considered in this framework.

In its entirety, the discussion about risk up to the determination of the points for each single area can be reconsidered and applied to the calculation of opportunities. Since resources are involved, the magnitude

naturally is not considered as damage as a result of a specific event, but as an expected consequence induced by a positive externality.

3.2. Results

The maps obtained by the procedures are shown in fig.1, 2 and 3. 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 affects not only the most peripheral areas but some semi-central zones with complex interactions of many punctual factors (poverty, commuting, employment marginalization).

The economic-environmental risk is more expanded since is produced by diffuse phenomena like air pollution, poor accessibility by public transport, built stock decay and scarce economic vitality.

Finally the map of social-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 revitalization near the railway stations where the availability of derelict lands and the good accessibility are associated with social instability and a poor housing quality.

4. The Neural Networks investigation

Over the last few years, artificial neural network models have generated increasing interest in urban and regional analyses. The idea of training the system to carry out operational capabilities independently as an adaptive response to an information environment is a fundamentally new approach to information processing. Openshaw (1992 and 1993), White (1989), Fischer and Gopal (1992) were pioneering scholars who realised the potential of neurocomputing in Regional Science. Recent contributions have pointed out the potential of some Auto-Associated Neural Networks when used as a Data Base analogic questioning instrument (McClelland 1981; Rumelhart et al.1986; Buscema 1994a).

During the learning phase, these Networks behave as normal pattern encoders, while during the recall phase they use specific algorithms which are different from the algorithms used during the learning phase. The algorithms allow the Auto-Associated Neural Networks to *adjust* their own answer in a certain number of steps, which is not pre-determined; moreover, during the *answer process*, they dynamically re-structure their target. For this reason they have been called Self-Reflexive Neural Networks (Buscema 1995).

Figure 1a - social-economic system: opportunities

Figure 1b - social-economic system: risk

Figure 2a - social-environmental system: opportunities

Figure 2b - social-environmental system: risk

Figure 3a - economic-environmental system: opportunities

Figure 3b - economic-environmental system: risk

The Self-Reflexive Neural Networks (SRNN) have been shown to be highly efficient in determining the fuzzy similarities among different Records in any Data Base (DB) and the relationship of gradual solidarity and gradual incompatibility among the different Variables. Therefore, the Self-Reflexive Neural Networks can be used as *prototypical* generators, as the means of discovering *ethnotypologies* and as simulators of *possible scenarios* in any Data Base.

Once the network has learned, it can be queried, and questions asked that we may define as: *prototypical, virtual, and impossible.*

The first question tries to identify the common relationships among variables which highlight one or more prototypes. By activating two or more properties from the DB the SRNN activates the subjects and the other connected properties which better represent those properties imposed externally. The second question searches a set of properties which are not found in any subject of the DB. This does not mean that in the future it will not be possible to add other subjects to the DB that would have those same features. In some respects this is a more interesting and useful approach to query a SRNN. In fact, we can envisage an imaginary city, which corresponds to some ideal targets (i.e. an ecological city with low pollution and high cultural facilities) and evaluate the related consequences. With the third question the network is queried about properties which cannot belong to any of the DB subjects at the same time. Nevertheless, according to the fuzzy set theory, it is possible to conceive of a subject that in some respect belongs to both types, as a fuzzy intersection of two incompatible sets of the classical set theory. This approach seems promising and may lead to insights about the relationships among urban assets while stressing the underlying common structure.

4.1. Self-Reflexive Neural Networks

There are many algorithms and many topologies by which to optimise the learning connections matrix of Auto-Associated Neural Networks. There are also different algorithms to dynamically question Auto-Associated Neural Networks that have already been trained.

Here we want to show one type of Auto-Associated Neural Network, called the recirculation neural networks, which answer dynamically during the recall phase. Since they are also able to re-structure their own target during the answering process, they have also been called Self-Reflexive Neural Networks (Buscema 1995).

4.11. Recirculation Neural Networks

These Networks are already known in literature (Hinton and McClelland 1988). The Recirculation Neural Network model that we created consists of a 2-layer architecture, with 3 operating steps and is very special. In fact, we must distinguish between *visible* and *hidden* Input and Output units as well as between *hypothetical* and *real*.

4.12 Recirculation learning

We define the Input vector a_i^R as *Real Visible Input*. Starting from a_i^R it is possible to perform a *first step* to calculate a *Real Hidden Output* a_o^R. In a second step, retroacting from the Output to the Input, and starting from a_o^R, it is possible to calculate a *Hypothetical Visible Input*, a_i^I. In a third step, starting from a_i^I, it is possible to calculate a *Hypothetical Hidden Output* a_o^I.

Therefore, the signal in a Recirculation Neural Network is transferred in 3 steps

- t_1: *Real Visible Input* (a_i^R) *Real Hidden Output* (a_o^R)
- t_2: *Real Hidden Output* (a_o^R) *Hypothetical Visible Input* (a_i^I)
- t_3: *Hypothetical Visible Input* (a_i^I) *Hypothetical Hidden Output* (a_o^I).

Learning occurs when the Hypothetical Visible Input (a_o^I) reproduces each Real Visible Input a_i^R; this means that the 2 Hidden unit vectors, a_i^R and a_o^R, have created their own internal representation of the Input vector a_i^R:

The weights matrix of a Recirculation Neural Network consists of *maximum gradient* connections between the Input and the Output layer. Therefore, if there are *N* Input Nodes a_i^R in a Recirculation Neural Network, the weights matrix W_{Oi} will be made up of N^2 connections. The learning algorithm of the Recirculation Neural Network occurs in 2 steps; each time the signal is filtered by the Real Input (a_i^R) to the Hypothetical Output (a_o^I), 2 corrections are made on the same weights matrix: the first one considering the difference between the Real Input and the Hypothetical one, the second one calculating the difference between the Real and the Hypothetical Output. In this way, the Recirculation Neural Network converges after a very low number of cycles. The transferring equations of the signal are the following:

(1) $$a_o^R = f\left(\sum_i W_{oi} \cdot a_i^R + \theta_o\right) = f\left(Net_o^R\right) = \frac{1}{1 + Exp\left(-Net_o^R\right)} \;;$$

(2) $$Net_i^I = \sum_o W_{io} \cdot a_o^R \;;$$

(3) $a_i^I = R \cdot a_i^R + (1-R) \cdot Net_i^I$; $0 < R < 1$

(4) $Net_o^I = \sum_i W_{oi} \cdot a_i^I + \theta_o$;

(5) $a_o^I = R \cdot a_o^R + (1-R) \cdot \frac{1}{1 + Exp\left(-Net_o^I\right)}$.

In our experimentation we have chosen $R = 0.75$.

The learning algorithm consists of two equations; each of them corrects the same W weights matrix:

(6) $\Delta W_{io} = Rate \cdot a_o^R \cdot \left(a_i^R - a_i^I\right)$; $0 < 1$.

(7) $\Delta W_{oi} = Rate \cdot a_i^I \cdot \left(a_o^R - a_o^I\right)$;

(8) $\Delta \theta_o = Rate \cdot \left(a_o^R - a_o^I\right)$.

4.13 The Recall phase of the Recirculation Neural Network: the Re-entry

With regard to this we have developed a technique called the *Re-entry* (Buscema 1994b).

We consider the answer of a Network during the questioning phase as "*an information Input Re-entry process*" in Output, for a number of steps independently decided by the same Network, according to the type of Input that the Network is processing. We called this the *Re-entry* technique. This mechanism is used to state 2 important methodological concepts and creates a practical advantage. The first point of the method is the following: when reacting to a stimulus, the Network not only has to handle the information internally, but it also has to *perceive* its own handling of the information. This means the information produced by the new Input stimulus *must be allowed to circulate* internally, until such information has been integrated (deformed) with the previous information that the Network has codified in its own weights. This *Re-entry* mechanism is internal to the Network and it is impossible to know how many Re-entries a Network will need in order to stabilize its own Output answer for any Input. The algorithm of any Re-entry is very simple: it consists in "re-introducing" the Output just generated by the Network as a new Input until the Output which is generated each time stops changing:

WHILE

(9) $(U_{O(n-1)} \neq U_{O(n)})$

DO

(10) $U_{i(n+1)} = U_{O(n)}$

where:

U_O = Output vector

U_i = Input vector

n = answering cycle

It is as if the actual Output of the previous cycle is the target desired by the Network. In the case this has not occurred, we carry on with the *forcing in* of the Output obtained in the Input of the following cycle. This simple mechanism allows the Network *to process the interpretation* that it is providing to the external stimuli and to stabilize its own answer just when it has "digested" the external Input through a re-evaluation of its own activity. The Re-entry configures a *meta activity* of the Network, a *higher control* activity on its own activities. In this sense the name Re-entry is not a bad analogy with the concept of Re-entry drawn by Edelman in his Neural Groups Selection theory (Edelman 1992). The second point of the method is perspective. With the Re-entry it is possible to imagine a learning activity and an answering activity of the Network that learns, evaluates, deforms and answers to the Input stimuli that continuously activate it. There is also a practical advantage in using the Re-entry when questioning a Network: Network *forces its interpretation* against an unknown Input as much as it can. This allows it to read the Gestalt of many stimuli against which those Networks, which are not given the Re-entry, confuse or banalize their answer.

In a Recirculation Neural Network the Re-entry technique is particularly useful and simple: during the questioning phase the Real Input consists of the type of question that we want to ask to the Data Base. Therefore, the Real Input vector is first transformed into Real Output and then into Hypothetical Input, through the transferring equations that were already described. At this point, we measure the distance between the two Input vectors (Real and Hypothetical) and if this is higher than a certain tolerance value (close to zero) the Hypothetical Input values are *forced in* again in the Real Input for a second cycle. Also in this case the number of cycles which are necessary to stabilize the system is independently decided by the Recirculation Neural Network. During the learning phase the Recirculation Neural Network, through its own weights matrix, draws the *hypersurface* defined by all the Variables present in the Data Base.

During the questioning phase, the Re-entry used this hypersurface *to deform* the new Input in the Input vector which is nearest to those one already defined by the weights matrix.

Therefore, the stabilisation process of Recirculation Neural Network occurs through a *minimisation* of the internal energy of the Network, starting from the perturbation that the Network has undergone in the Input. It is also possible, in this case, to adjust the Records of the Data Base as an additional layer of the Nodes of the Recirculation Neural Network during the questioning phase. This means that we create a new weights matrix, with the same technique described for the Constraint Satisfaction Neural Network, between the layer of the Hypothetical Input that represent the Variable of the Data Base and the new layer of Nodes-Records.

4.14 The ways of questioning a Data Base

The Recirculation Neural Networks represent one interesting way to question a Data Base in an analogic manner. We could say that they function as a Structural Query Language with fuzzy borders. These Networks can be used to create:

- *Dynamic simulations of scenarios*: how the entire Data Base would structure itself again if certain variables assumed specific values, in a stable or temporary way.
- *Associating Process based on meaning*: which are the prototypical meanings of a group of variables in a specific data base and how a group of contradictory variables can work together.

Compared with other associative networks, such as Constraint Satisfaction Networks (McClelland and Rumelhart 1988, Buscema 1994c), these Recirculation Networks have a very different way of dealing with and trying to resolve these problems. The Recirculation is a *co-operative* kind of Neural Network: all its units cooperate during the answering process to *minimize* the perturbation produced by the "question" asked of the Data Base. The answering process stabilizes on a value that is the result of a *complex negotiation* among its weights and its Nodes to resolve a conflict and to maintain a *homeostasis*: this is its value but also its limit. Nevertheless, its sequential dynamics are still important and complex, since they are very similar to the associating dynamics of human memory.

4.15. Network query: some experimental results

In order to identify the common relationships between variables it is possible to query the network asking prototype-like questions. In our case, activating the variables contained in the database, the SRN activate the areas and those variables connected to them that best represent the properties imposed by the external world.

In the query phase some indicators were examined that are considered important in the study of urban phenomena. The results of the experiment are reported below.

Case 1: (Population density = +1)

The areas with the highest population density are also the most residential, with many privately-owned dwellings, with the presence of diploma holders and university graduates, with a high rate of male activity, high real estate values, where public transport is used and where sometimes the crowding index is high.

In essence, there is a spatial pattern that highlights some semi-central areas (with higher point values) in which accessibility conditions are often limited by the non-passage of the subway. The fact that public transport is still used emphasises the conflict that sometimes arises between supply and demand of urban services.

Case 2: (Crime index = +1)

A high crime rate is related to positive externalities such as a residential sector, diploma holders, male activity rate, accessibility, real estate values and use of public transport, and to negative externalities such as emigration to the suburbs and commuter traffic.

Among the 72 areas included in the survey it is interesting to note how the highest point values are attributed to the areas surrounding the Centrale Station, in which there is a concentration of location advantages and the greatest number of minor criminal activities.

Case 3: (Accessibility = +1)

In relation to accessibility, the variables activated include the presence of university graduates as well as executives and businessmen, and the real estate values of offices. This demonstrates the strong correlation between high cultural/professional level, good accessibility and choices for locating enterprises which, as we will see further on, is based on an attractive urban context especially in terms of quality.

Case 4: (Real estate values = -1, derelict lands = -1, housing without bathroom and heating = +1, use of private vehicle = +1) fig. 4

Activating these variables the related properties highlight some simultaneous elements of conflict especially in the semi-central areas. In fact, there are evident signs of urban degradation such as a high crime rate, constant emigration to the suburbs and, to a certain extent, a strong presence in the population of people over 65 years of age, but simultaneously there are also good correlations with the presence of university graduates, executives and businessmen and with the male activity rate. All this confirms the fact that more or less localized and specific degradation phenomena often co-exist with certain elements of urban attractiveness. To this regard it is significant that the areas adjacent to stations have the highest point totals.

Case 5: (Population density = +1, accessibility = +1) fig. 5

In general, the result of such a query is a good and sometimes excellent urban quality. The variables activated include the presence of diploma holders and university graduates, the high percentage of privately-owned housing, the male activity rate, real estate values and the use of public transport, while the only negative externality is the room occupancy index. Once again a “mixed” condition is expressed that identifies degradation phenomena in the areas with strong attractiveness.

Case 6: (Real estate values = +1)

Activating the variable relative to the real estate values it is interesting to dwell on the different behaviour assumed by the three types considered here: housing, stores and offices.

Population density	0.34
Residential index	0.64
Population prevailing age	0.50
Privately-owned dwellings	0.12
University graduates	0.97
Diploma holders	0.38
Adults with secondary school degree	0.10
Adults with primary school degree	0.04
Male activity rate	0.77
Female activity rate	0.61
Executives and businessmen	0.76
Employed as domestic help	0.33
Unemployment under 30 years of age	0.02
Employed in suburbs	0.18
Emigration to suburbs	0.03
Emigration to region	0.71
Room occupancy	0.09
Demographic decrease	0.01
People over 65 years of age	0.73
Dwelling for sq. km.	0.35
sq. m. /inhabitant	0.68
Public green areas	0.00
Accessibility	0.03
Crime index	0.94
Housing rents	-0.73
Stores rents	-0.75
Offices rents	-0.75
Derelict lands surface	-0.75
Entering commuters/population	0.02
Exiting commuters/population	0.61
Use of public transport	0.32
Housing without bathroom	0.97
Housing without heating	0.90
Not available housing	0.38
Buildings mean age	0.05
Use of private transport	0.77

Figure 4 - Activation (or inhibition) of the outlined variable and the consequent prototypical profile on the other nodes. On the left the activated areal units

Population density	0.92
Residential index	0.62
Population prevailing age	0.20
Privately-owned dwellings	0.85
University graduates	0.79
Diploma holders	0.95
Adults with secondary school degree	0.17
Adults with primary school degree	0.09
Male activity rate	0.90
Female activity rate	0.09
Executives and businessmen	0.27
Employed as domestic help	0.05
Unemployment under 30 years of age	0.21
Employed in suburbs	0.09
Emigration to suburbs	0.08
Emigration to region	0.27
Room occupancy	0.73
Demographic decrease	0.06
People over 65 years of age	0.13
Dwelling for sq. km.	0.45
sq. m. /inhabitant	0.13
Public green areas	0.01
Accessibility	0.99
Crime index	0.27
Housing rents	0.94
Stores rents	0.31
Offices rents	0.93
Derelict lands surface	0.00
Entering commuters/population	0.03
Exiting commuters/population	0.60
Use of public transport	0.90
Housing without bathroom	0.04
Housing without heating	0.13
Not available housing	0.13
Buildings mean age	0.06
Use of private transport	0.08

Figure 5 - Activation of the outlined variable and the consequent prototypical profile on the other nodes. On the left the activated areal units

The value of housing is related to accessibility, the use of public transport, the value of offices, the male activity rate, the presence of diploma holders and university graduates, the percentage of privately-owned housing as well as the room occupancy index. This outlines a situation in which there are areas of the historical centre together with the semi-central areas with the greatest residential characteristic, flanking the areas near the Centrale Station where there is high accessibility and signs of degradation represented by the room occupancy index.

The value of stores is correlated not only with a good urban quality expressed by the real estate values of other categories, but also the residential characteristic, while the value of offices is related to the presence of public green areas and to the accessibility as peculiar conditions for a good quality of the urban environment.

5. Conclusions

The analysis performed made it possible to identify the opportunities and the risks on a micro-urban scale and to lay the foundations for the development of a set of strategies for sustainability that focus on at least two objectives for Milan: the liveability of its inhabitants and the maintenance-improvement of its position in the network of European cities.

After completing the analysis, that may offer the opportunity, on a micro-planning scale, to develop a series of specific initiatives, it would seem however that territorial policy guidelines emerge on an urban level that can be structured according to some priority strategic elements, that can be summarised in attributing:

- *accessibility to the dense points of the urban structure*: the scale and agglomeration economies assume high settlement densities together with high accessibility. In a similar fashion, the sites equipped with greater urban vitality, such as commercial backbones or the areas with a high functional mix, are adequately supported by safety and environmental quality policies. For example, the commercial axes , which is the focal point of the north-west sector, has no subway accessibility. Similarly, the numerous projects in the Bicocca area conflict with an evident lack of rapid access ways. For what concerns the leisure time and fun sites, there is a progressive concentration of areas from C.so Como-Brera to Navigli that are not supported by efficient accessibility;
- *polarising functions and high settlement densities* where accessibility is present. Many outlying areas have enhanced accessibility due to the presence of subway lines. Within a reticular logic structure that can restore the equilibrium to the divergence in quality and functional mix among the various parts of the city, urban service functions for the population and companies could be located in proximity to subway stations, thus revitalising the context. To this regard, the Polytechnic has had important experience at Bovisa that in a few years has already created a considerable side-business network and greatly improved the safety problem;

- *improvement of environmental quality* whose degradation is not only a damage for the inhabitants but also greatly inhibits its development since today it is also a fundamental factor that dissuades many economic activities from locating there. The new orientations of ecological urban planning (such as those adopted in Berlin and Munich) with the design of ecological corridors that fortify the city and connect the few adequately sized green areas, improve the conservation of the bio-mass and the bio-diversity.

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