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Is relocation a good answer to prevent risk?

Criteria to help decision makers choose candidates for relocation in areas exposed to high hydrogeological hazards

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Abstract

Purpose – The purpose of this paper is to illustrate the results of a research mandated by the regional government of Lombardia, Italy. The results identify the criteria used to decide in what situations the relocation from areas subject to high levels of hydrogeological hazards is a viable preventive strategy.

Design/methodology/approach – In the first part, the state-of-the-art regarding voluntary relocation from hazardous areas supported by governmental funding and incentives has been described, showing that very few examples are available for reference. Therefore, lessons learned from involuntary relocation have been considered – especially regarding specific strategies that must be designed to address societal needs. In the second part of the article, the criteria developed, to help decision makers decide when and if relocation may be considered a preventive option, are described in detail. Finally, it shows what results have been obtained by applying the criteria to the case of the Lombardia region.

Findings – Four sets of criteria were proposed, shaped according to different geographical scales and to different demands, recognizing that relocation is a rather extreme solution that must be carefully evaluated and proposed to interested parties and citizens. Those criteria have been applied to assess some specific cases in the Lombardia region, and to identify potential candidates for relocation in the whole region, by querying a complex database that was prepared – integrating layers representing hydrogeological hazards on one side, and exposed settlements on the other.

Practical implications – Until now, most of the laws to prevent risks have imposed limitations to building and development in hazardous areas, while rarely focusing on existing settlements. The experience described in this article concerns a region that has decided to design a specific law to promote preventive relocation in the most critical situations, where structural measures have failed a number of times, and losses are frequent and large.

Originality/value – The criteria proposed in this paper provide a method and a tool for deciding in what cases and circumstances relocation can be considered a viable preventive option to lessen the risk in particularly critical zones, exposed to high hydrogeological hazards. In doing so, it shows that relocation can be considered not as an "emergency" and episodic measure, but rather as a part of a more comprehensive policy, in which candidates for relocation can be determined on a regional scale respecting basic social, political and economic conditions.

Keywords Earth sciences, Hazards, Groundwater, Risk management, Cost/benefit analysis, Italy

Paper type Research paper

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Framing relocation within prevention measures

The search for an ideal place free from any kind of hazard to site a town or a new urban development has more to do with utopia than to reality, especially in our times, as the dramatic increase in population has pressured urbanization of large areas regardless of their being apt or not for settlement:

> The work of urbanization goes on but we are unwilling to face its implications and, less and less does the traditional view that the city appears and grows in response to favourable geographic conditions, describe the realities of modern urban growth (Brogan, 1963, p. 161).

Therefore, the question is not so much to look for the best possible places to develop but, rather, to differentiate between places with respect to the hazard and to the quality of construction and settlement organization. Suitable settlement sites are not chosen following a yes/no scheme; instead the larger the number of available risk categories the wiser and the more informed will be the decision.

What can be held true, however, is that radically wrong choices, that privileged the most dangerous sites and the worst building techniques constitute a heritage difficult to bear for future generations, because once developed urban areas will last longer than any individual construction. The urbanization process tends to be definitive and in general terms irreversible.

This is the main reason why information regarding the most critical areas should anticipate and guide planning choices not in the search for areas absolutely free from risk, but for less dangerous places, where mitigation and protection practices can significantly reduce the expected damage to people and goods.

Stressing this point again and again is important because, despite of the advancement in legislation and normative rules, urban development is still driven more by real estate market pressures than by safety considerations.

Those preliminary remarks needed to be made to introduce relocation as a mean for preventing risks; while governments are starting considering this a viable solution at least in certain zones, wrong siting decisions are still being made, creating the ground for very high collective costs: the cost of today's urbanization, the cost of tomorrow's first attempt to mitigate risk once a disaster occurs, and finally the cost of relocation.

A question that must be asked is when relocation has been put forward as a viable prevention solution to avoid future losses. Before answering, however, the term relocation itself should be precisely defined, as it may evoke at least four different processes.

Mass population movements have occurred in the past in Western countries and still occur, especially in Asia, to create large infrastructures, especially dikes. People are forced to leave their houses and settlements in the name of public interest; they may or may not be compensated for their tremendous loss depending on the political regime and law system of the country where the infrastructure is being built.

The World Bank refers to this type of relocation as involuntary and in order to sustain the project it requires the participation of the people paying the highest price, by being forced to leave their home and change their lives. In its documents the World Bank stresses the difference between public consultancy and participation: the first is aimed to communicate choices and verify the degree of acceptance, while participation refers to:

> [. . .] a voluntary process according to which the population, including some marginal groups, meet with authorities to share, negotiate and control decisions in the development of a project and in its subsequent implementation (The World Bank, 1993).

It is felt by the authors that those recommendations perfectly fit also to voluntary relocation, when, as in the cases considered in the present research, people decide to move in order to avoid future losses due to natural hazards.

A second type of forced relocation, though not motivated by a human siting decision, may occur during a prolonged emergency, as it can be the case of a long volcanic crisis or a bradyseism. In those circumstances, the emergency lasts long enough to permit taking decisions regarding semi-permanent or permanent evacuation in safer areas that will be proposed to the affected people as a good permanent solution to avoid the hazard threat in the future.

An example in Italy is provided by the quarter of Monteruscello, that was built to host permanently people moved from Pozzuoli, hit by a prolonged bradyseism phenomenon in the year 1970 (Signorelli, 1996; Giglia, 1998).

A more recent case reported internationally concerns the Ayta tribe in the Philippines, forced to move from the Pinatubo slopes during the 1991 eruption.

In both cases, relocation brought significant problems to people, especially because the design of the new settlements failed to take into account their needs, both from an architectural/urban planning point-of-view and as far as the economic and social relations they had developed within their origin sites were concerned.

A third way to intend relocation is "reconstruction in another place". This choice may mature in the aftermath of a very severe disaster, when in any case full reconstruction must be engaged and the decision to rebuild in the same area or in a safer one must be at least taken into consideration. History offers examples of reiterate reconstruction in areas that had proved to be unsafe as well as cases in which it was decided to move and abandon the origin site. This means the decision is neither automatic nor it depends only on the level of destruction nor on the correlation between the latter and local geological conditions. Rather, it is the result of complex interconnected political, economical and social factors.

According to the last meaning that has been considered in this research, relocation is a pure prevention tool, to be used *ex-ante*. Examples of this type of relocation have not been found, either in literature or in more recent experiences; generally relocation is always considered only in the aftermath of an event. What is changing nowadays is the acceptance of this measure also in the face of minor or relatively minor degree of damage, where it could be still possible to repair. Although taken in the aftermath of an event, then, this kind of relocation can be considered preventive, as it aims at reducing the potential for damage in the future, also in cases that could be repaired at costs equivalent if not cheaper than relocation.

Examples of this strategy can be found internationally as well as in Italy.

Up to now the more relevant experience in terms of implied quantities comes from the USA: after the 1993 flood it was decided to devote 15 per cent of reconstruction funds to relocation projects, managed by Fema, the same agency holding the national insurance flood program. In the last years, 10,000 properties have been moved from the most dangerous areas: the majority being dwellings, with a relatively small number of businesses and public facilities, especially schools.

As it constitutes a very recent experience, research and studies considering sociological, economical and planning consequences are not available yet, so that the only documents to rely on in the attempt to understand this rather new and interesting form of prevention are those available in the internet.

Relocation as a prevention tool in Italy

In Italy relocation has been introduced in a national law in the aftermath of the tragic Sarno mudflow, killing almost 200 people in May 1998 in the area of the Pizzo d'Alvano mountain in the Campania region. The first article of the law states that special plans should be drawn by watershed authorities to determine:

> [...] the infrastructures and the buildings at the highest risk. Regions should establish incentives to help private owners in implementing structural measures when possible and to relocate businesses and dwellings out of the most dangerous zones.

A specific article addresses industrial areas and industrial plants, that should be moved away with the highest priority.

To be honest, it was not the first time a national law promoted relocation as a prevention tool: in 1908 the law 445 had been passed (and is still valid), mentioning in the IV section the need for "consolidating landslides and moving settlements in new areas". In the annex to the law there was a list of settlements that should have been moved to achieve safety. Despite of the fact that very few if not any settlement has been actually relocated according to the law, it is still useful to consider it both in terms of the reasons for its failure and as for the main result it achieved, that is the complete halt to any building or even retrofitting initiative. Once a settlement was listed in the annex no further development or even building retrofitting was permitted, but, as complete relocation was not actually achieved, the only real result of the law has been worsening the vulnerability of existing and still occupied constructions.

If the existence of such a law is not enough to guarantee the compliance with its content, especially when a delicate issue like relocation is dealt with, it is nevertheless a pre-condition of whatever attempt to utilize relocation as a prevention measure. A law in this regard must state precisely who has the right to apply for public funding, what are the procedures and how the public administration will lead the whole process.

In this regard, after the catastrophic floods that hit Italy in the years 2000 and 2002, the two regions of Emilia Romagna and Val d'Aosta have passed laws regulating relocation.

The Emilia Romagna's regional law number 25/2001 is restricted to the buildings damaged the year before; it specifies how the residential surface must be calculated in order to get public funding, corresponding to the amount granted for public residential housing and to a reduced amount for vacation dwellings. Furthermore, the laws addresses the procedures to be followed by municipalities applying for funding in order to demolish abandoned buildings in hazardous areas and possibly to re-naturalize them.

The law passed by the Regione Val d'Aosta (n. 11/2002) is a general law connected to the land use regional planning act (11/1998) which strongly promotes natural hazards prevention. As a consequence of this link to the urban planning act, this new law provides careful indications regarding the areas where resettlement should take

place, by giving incentives to people who will decide to live in already existing buildings, possibly in historic centers.

Besides those two regional laws, two other Italian relocation cases have been considered in the research: the resolution of the Campania region 2145/2003 and the strategic plan for the Malpensa airport area.

By providing incentives for people (particularly renters) to relocate, the Regione Campania aims at reducing the population density in the so-called red zones of the Vesuvio, the most dangerous settlements in case of a volcanic eruption. The idea here is to reduce the alert time needed for evacuating from the present two weeks to one week, thus, diminishing also the probability of a false alarm.

In the Malpensa case, three small settlements close to the landing and taking off routes have been offered incentives to move away.

The Malpensa case and the Emilia Romagna were studied also with respect to the first results of the relocation program, which, though not exhaustive, provide interesting elements for further analysis.

In both cases, with the exception of three municipalities in Emilia Romagna, people were offered public funds to move away and find another house to live. This means that public resources have been spent in the private real estate market, without any attempt to control the resettlement choices of inhabitants. This has at least two important drawbacks. The first is that reiterated wrong location choices cannot be completely excluded, as people were not guided in the choice of their new house, secondly this procedure, if extended to a larger number of cases, may produce further agricultural soil consumption and urban sprawl. The idea here is not to oblige people resettle in predetermined zones, rather to offer an alternative within the original area. Involved citizens will probably appreciate this opportunity, provided that new quarters are designed taking into account their needs and demands. Corroborating this statement are the first surveys conducted on the resettlement decisions in the Malpensa case, where most of the people have chosen to buy their new house within a short distance from the place they had moved from.

Proposed method to evaluate opportunities and constraints of the relocation measure

In the aftermath of the floods and landslides that hit various settlements in the Lombardia Region in November 2002, in areas that have been repeatedly damaged also in the previous events in 1999 and 2000, the regional government decided to initiate a process to develop legislation regulating relocation projects. In order to do this, it funded a research producing two results. The first is a GIS system comprising information on different hazards and hazard levels with maps representing different land uses in the whole region; the second is a set of criteria to support decisions regarding when and where relocation should be considered a viable option and incentives granted to people moving to safer areas. The latter will be discussed more extensively in this article, as the authors have contributed to their development within the working group.

The proposed criteria have been then partially applied to the entire Lombardia Region so as to provide the public administration with an idea of the quantities (territories and financial expenditure) that would be implied in such an extensive relocation program.

The proposed criteria can be grouped within three main conceptual categories:

(1) social acceptability;

(2) economic feasibility; and

(3) compatibility with existing land use trends and planning recommendations.

With respect to social acceptability, lessons learnt from past experiences, both successful and unsuccessful, have been capitalized, looking at Italian (Monteruscello and S. Antonio Morignone) and international cases (USA after the 1993 flood, Pinatubo eruption in the Philippines, New South Wales in Australia, see May *et al.*, 1996; the El Cajon dam in Honduras, see Loker, 1998).

The recommendations of the World Bank commented above have been also considered as well as the extensive literature and experience developed within community projects and the tools most likely to succeed in public involvement in urban plans and projects (see the historical Arnstein, 1969 and the more recent example proposed by the WHO project, Barton and Tsourou, 2000).

As far as the economic feasibility is concerned, a cost-benefit approach has been looked for, looking at the investment return of relocation projects on one hand and at the economic costs and social burdens on the other.

Cost benefit analyses have been defined as a set of techniques to guide public administrations to chose the best option among a variety of alternative solutions for a given problem (Nuti, 1987) and, more generally, as a way to rationalize decision making (Gerelli, 1987). The principle being that any human action brings consequences on public goods, some minor some others very relevant. Safety can be considered a public good, and therefore relocation is one of the possible alternative means to guarantee it for society. In any risk prevention project, costs and benefits to be considered are the following:

- Costs comprise direct and indirect expenses borne by various subjects to implement prevention measures (public subjects invest resources in order to implement structural as well as non structural measures, while private subjects can be asked to participate to the expense by improving their property, by paying taxes or buying insurance).
- Benefits equal the resources that will be saved and losses that will not be carried by society shall an extreme natural event occur.

A rather significant limitation to cost benefit analyses within the natural risk domain is due to the uncertainties regarding hazards' occurrence and severity (Mechler, 2003). Therefore the choice to be made is between "certain costs – both public and private – to be borne today" and "potential costs of tomorrow", that will be paid largely by governments.

Furthermore present and future costs are particularly difficult to compare as far as some intangible goods (like human life and well being; historic monuments and towns) are considered. In this regard, the reduction of potential future costs should be considered as an investment for the society as a whole and not just a matter of the concerned public administration.

Another key issue refers to the time when this investment is being made: several US case studies show that the economic efficacy obviously grows significantly if

prevention measures are taken before an extreme event rather than afterwards. This is particularly true considering not only direct expenses that will be saved, but also the potential systemic losses and damage in the long-run, that will be avoided.

In this respect, the capacity to estimate those damages is still very limited and discussions are still running about the notions of indirect and secondary damages (Van der Veen *et al.*, 2003). Nevertheless, first attempts to estimate such losses, considered in terms of damage amplification or negative ripple effects, have shown the important role they play not only for individual businesses but also at larger markets scale. A summary of relocation costs and benefits is as follows:

(1) *Relocation costs*:
- relocation feasibility studies;
- project design and expertise advice;
- public support activities (information, advice, consensus building);
- buildings acquisition;
- abandoned buildings demolition;
- renaturalization of abandoned areas;
- compensations for loss of environmental quality in resettlement sites; and
- general social and private costs related to changes.

(2) *Relocation benefits*:
- improvement of environmental quality in abandoned areas;
- reduction of rescue costs;
- reduction of other disaster mitigation expenses;
- reduction of reconstruction costs;
- reduction of systemic losses; and
- reduction of costs related to social discomfort caused by emergency.

Finally, it should be borne in mind that resources that will have to be spent in the urgency of a disaster will be diverted from other expense chapters or will be charged in form of financial liability to future generations. Especially in the first case (see Fema, 1996), not only emergency and reconstruction activities will have to rely on uncertain and short term resources, but also other programs, that had been already forecasted and financed, will have to be reconsidered and perhaps changed, with consequences that are hard to evaluate. The positive economic impact of prevention activities should be considered also in terms of advantages deriving from the possibility to program in advance and in a more satisfactory way expenses and investments.

Those positive effects should be carefully laid on the discussion table when relocation is at stake: despite of its immediate high economic and social costs, in fact, it produces long-term and lasting cost reduction. Exposed goods and activities are moved from the hazardous areas, freeing the latter for other more compatible uses and in some cases lessening the hazard potential itself.

The third assessment pivot is constituted by criteria that may be defined as "territorial" as they address both the areas to be abandoned and those in which relocation should take place.

It is essential in fact to analyze the characteristics of the areas subject to high hazard levels, to determine if they can be found or reconstituted in another site, or, on the contrary, if they are so unique that any attempt to recreate the same conditions elsewhere is going to end up in failure. Local characteristics of this type are particularly relevant for some economic activities, that are strongly linked to a given place and landscape, like for example tourism. In this case, relocation is obviously rather problematic. Another aspect that must be considered with respect to areas to be abandoned is that any future development should be prohibited and even more than that, they should be re-naturalized, so as to achieve greater environmental benefits from the relocation investment, in the form of improved water drainage capacity or of improved resistance of previously instable slopes.

As for the areas where to re-settle, they should be designed and planned in order to respond to moved people's needs and also to guarantee development in safer areas, minimising urban sprawl and negative environmental externalities. National and international examples that have been examined for this research are not satisfactory from this point-of-view, with few exceptions: incentives to relocate are just monetary compensation, without any attempt to control the design of resettlement zones.

Application of the criteria to three evaluation frameworks addressing different questions regarding relocation as a preventive tool

The criteria have been applied to three sets of evaluation frameworks, the first two distinguishing between a regional and local level.

At the regional scale parameters are assessed so as to derive an indication of the quantities involved in a potential relocation program, while locally parameters can be investigated with a greater detail and considering the actual geographic context. A combination of evaluations at local and regional scales provides a better guide to decide where and in what cases relocation can be considered as a prevention tool.

The three frameworks that have been introduced consider different perspectives:

(1) The first answers the question when and where relocation is desirable from the point-of-view of the regional government (see Table I).

(2) The second aims at understanding when and where relocation is most likely to succeed; budgetary limitations and public acceptance of relocation have been considered the key issues here (see Table II).

(3) The third addresses more specifically the need to judge a given relocation project, once it has been designed and proposed to the regional government for funding. It responds to the question: what are the features that make a "good" relocation project? While the first two sets of parameters can be treated both at a regional and local level, it is clear that this one can be assessed only locally, considering the specific context the relocation project has been prepared for (see Table III).

The first two evaluation frameworks do not necessarily lead to overlapping and coincident results, because they consider different stakeholders' view: on one side the public administration, who should consider both economic feasibility and public interest, on the other involved citizens, who may have diverging views on their interest to move from their homes and change their everyday landscape.

Criteria	Scale parameters	Highly desiderable when
Regional scale criteria:		
Profitability and time	Frequency	RP $< =$ 50 years of low magnitude events
Profitability	Events severity	High expected magnitude
Profitability and time	Existence of hazards that may be triggered by the event	Existence of hazardous plants in the area of 100 return period event Existence of hazardous plants exposed to high magnitude events
Profitability and time	Number of phenomena menacing the same area	More than three phenomena menacing the same area
Local scale criteria:		
Profitability related	Use of buildings typology	Permanent family house
	Comparison with other prevention measures	Other measures not feasible or producing insufficient results
	Cost-benefit comparison in 50 years (including direct and indirect costs)	Benefits $>$ Costs

Note: RP = Return period

Table I.
Criteria to assess the desirability of relocation

A clear example is provided by the couple of parameters: event frequency and event severity. A public administration will be extremely concerned by a severe and potentially highly destructive event, even if rather rare. In the case of the Vesuvio volcano, for example, the Campania region is willing to invest in order to lessen the population density in the most dangerous zones. On the other end, the same public administration will be willing to prevent also very frequent losses, that occur almost each year in the same areas: the cumulative expenditure due to repeated though minor events tends to be equally high to sustain.

When the attitude of the exposed population is considered, instead, one may find that people are willing to invest in prevention only if they experience frequently the hazard, while they are far less concerned by rare events, no matter how potentially disastrous they might be. This is a common finding in sociological, psychological as well as economic literature (Kunreuther, 2004; Slovic, 2000; Lupton, 1999).

Short description of the three evaluation frameworks to assess relocation opportunity and constraints

In the following section a brief description of the parameters that have been considered will be provided and the way they have been assessed applying the different criteria shortly discussed.

In Table I, where the desirability of relocation from the point-of-view of a public administrator is assessed, the following aspects have been considered, apart from the already discussed couple events frequency/severity:

- The third parameter looks at potential induced damages provoked by floods or landslides affecting hazardous installations located in floodplains or instable zones; in this case the high risk should be a sufficient argument for the public administration to decide relocation despite of possible oppositions.

Table II.
Criteria to assess the probability of success of relocation

Criteria	Scale parameters	High success potential	Low success potential
Regional scale criteria:			
Profitability	Expected event frequency	RP < = 20 years	RP > 100 years
Hazard related (dangerousness exposed activities vulnerability)	Expected damage to buildings (Di)	Di > = 40%	Di < 10%
	Reduction of transportation function	Unique infrastructure closed for > six months	More than two access ways; Unique way closed for < = six months
Economic sustainability	Enough funding available	Relatively small amount of areas to be relocated each time	Insufficient
Site dependency index function: land use and urban activities	Typology and functions of buildings	Residential	Sale activities
		Infrastructure Sport facility	Large commercial districts
	Built-up area age	Average age < 50 years	Historic centre Average age > = 50 years
Local scale criteria:			
Site dependency index function: production activities	Level of activity	Partially dismissed	Full activity
	Use of resources	General, not site dependent	Local and strategic for that specific place
	Workers	Living in areas distributed around the municipality	Living in the vicinity of the firm
	Type of machinery	Can be easily moved and recombined	Fixed installations difficult to move
	Cultural links	Not linked to local identity features	Typical production Historic tradition
	Recent investment	Scarce in the last five years	Significant in the last five years
	Accessibility factors	Not dependent upon specific networks	Dependent upon specific networks
	Comprised in local productive network	Not dependent upon local productive networks	Dependent upon local productive networks

Notes: RP = Return period; Di = Damage index

Table III. Framework to assess an individual project

Criteria	Local scale parameters	Positive evaluation	Need to improve	Negative evaluation
Local scale criteria:				
Profitability	Areas are relocated as extensively as possible	Yes, according to a specified program		No
Applicability	Resettlement areas clearly specified	Yes, including property transfer rights procedures	Yes, without a clear property rights transfer procedure	No
	Resettlements areas conditions	Urbanised and apt	To be urbanised	Not apt
	Relocation area destiny	Renaturalization forecasted	Only demolition of buildings	Not specified
	Project and use of abandoned areas	Renaturalization apt to uses congruent to dangerousness of abandoned areas	To be improved	Not specified
	Reorganisation of infrastructures and public facilities	Forecasted according to a specified program	To be improved	Not specified
Profitability of investments in time	Cost-benefit analysis in a time horizon of 50 years	B > C		C > B

- The fourth parameter looks at the co-existence of several threats in the same settlement: in case of more than two hazards menacing the same set of houses it may be reasonable to think about relocation and perhaps the latter is even cheaper than adopting a variety of structural measures.

At a local scale the following parameters can be assessed:

- The use of houses: if they are permanent or vacation residences, as the priority clearly goes to the first; this can be seen for example in the Emilia Romagna law, granting smaller subsidies to move vacation dwellings.
- The last two parameters aim at answering the fundamental question if the money is well spent: cost benefit analysis has been proposed as a tool to compare between relocation and other structural measures.

In Table II, parameters to judge the success potential of relocation projects are shown.

Starting from the third parameter (as the previous concern the event's frequency/severity couple), what is assessed is the availability of enough founding to complete the project. It may be desirable in some cases to relocate entire settlements, but this is not feasible economically even for a rather rich public administration, while a "spot" result, in which only some buildings are relocated, substantially will make the whole investment fruitless.

All the parameters considered below the fourth one address the key issue of what has been defined as "site dependency". They are aimed at "measuring" how strong are the links between settlements and activities to a given territory and to verify those cases in which they may hamper any relocation attempt. The concept of "site dependency index" has been developed to account for those relations, to be used both for assessing relocation feasibility and to guide administrations in the search of acceptable and suitable resettlements alternatives.

At the regional scale the settlement age and the concerned functions are appraised. The first parameter translates into a threshold the idea that historic centres are almost impossible to relocate, because of their intrinsic value, which cannot be transferred or rebuilt.

The other parameter expresses the recognition that some functions are more difficult to reconstitute elsewhere, like, in general terms, economic activities. Plants and machinery requirements, needed spaces, proximity to markets and resources, accessibility, links to other firms and services are some of the many parameters to be considered in the resettlement of an economic activity. The latter may be strongly connected to a given site in terms of cultural, historic, and social relations, that must be considered both in the attempt to assess potential damage in case of disaster and in any relocation project.

Most of the parameters defining the "site dependency" can be assessed only at a local scale, considering the specific characteristics of a settlement within its geographical context (see the remaining parameters at the local scale).

The third and last evaluation framework (Table III) should be used to assess a project once it has been submitted to the public administration for funding. Obviously, only the local scale is considered here. The main factors that should guide evaluators in their work are the following:

- They should examine if areas for re-settlement have been adequately assigned in the project, if they suit the needs of the people and activities to be moved (the first three parameters).
- They should look at the destiny of abandoned areas: if future construction has been clearly banished, if renaturalization is going to take place, and, finally, if public facilities and especially transportation have been moved accordingly to serve new axes of activity and new residences.
- Finally, a cost-benefit analysis should be provided, in order to demonstrate that the proposed relocation is going to lessen significantly the potential risk in the face of high public expenditure.

First applications

The first two frameworks have been applied to the entire Lombardia region to test the method, while projects were not available for testing the third one, as the regional government is still in the preliminary phase of considering the pros and cons of relocation.

A few words must be spent with regard to the GIS database that has been developed within the present research and used to test the criteria. For the first time, hazard information regarding all hydrogeological hazards affecting the whole Lombardia region has been overlaid to maps generally used for urban and regional planning purposes. This way, it is possible to have an exact notion of how many square meters of different land uses are exposed to what kind of hazard (landslides, avalanches, floods, etc.) and to what "level of hazard" (distinguished in low, moderate, high and very high). The system is far from being perfect, but it was the first time that technical and land use planning maps were overlaid in such a way that the final result could be queried to obtain new information. The creation of such database proved to be extremely useful not only for the "positive" results it produced, but also because it permitted highlighting some limitations in both systems of maps (land uses and hazards). With respect to the land use, for example, the database does not permit to distinguish among different types of economic activities, making it difficult to apply correctly the "site dependency index". On the other side, the hazard database does not distinguish between frequent and severe events, as "hazard levels" have been defined mixing the two parameters. According to what has been proposed in the evaluation procedure, instead, it would be of extreme importance to be able to assess separately the frequency/probability and the severity of a given phenomenon. However, in many cases this is simply impossible, or at least can be done only on a very experimental basis, not validated by the scientific community in the field of interest. This is the case of landslides, for which it is rather difficult to estimate probabilities and to identify parameters addressing only the "severity" of expected events.

Furthermore, the system has been conceived so as to "sum" different hazards in order to obtain a synthetic index for a given area. In the last years, the scientific community has come to the conclusion that instead of trying to combine different types of threats to build a multi-hazard map, more efforts should be put into the development of a "multi-risk" map, that is taking as a basis not the natural phenomena but the built environment exposed to various types of threat.

Despite those limitations, it seemed useful to use the GIS system to test the criteria and the evaluation procedure proposed in the research. First, it is strongly believed that

only by using the tool it is possible to suggest improvements; second, once the application has been carried out, it may lead to refinements regarding both the evaluation method and the mapping system driven by actual needs instead of following theoretical prescriptions. Hazard and risk mapping encounter inevitable obstacles due to the difficulties in making converge the needs of scientific advancement and practical applications aimed at political and administrative goals.

Nevertheless, the first results that have been obtained seem interesting, as they provide the public administration at least with an idea of quantities and extension of the built areas to be relocated, should this become a systematic strategy of the regional government.

Selected applications of the first two assessment frameworks in the Lombardia region

In the following section it has been chosen to illustrate the most meaningful results of the application of the first two frameworks that have been discussed in the previous chapter.

As for the first grid addressing the desirability of relocation, for example, a query was submitted to the system to estimate the situations where urbanized areas are exposed to more than one hydrogeological hazards (see Figure 1): in 490 municipalities urban areas are exposed to more than two threats; in 298 to more than three and in 78 to more than four hazards. Obviously, the more concerned are mountain provinces, with Sondrio leading the group with 40 municipalities, followed by Bergamo (21) and Brescia (12).

As far as the local scale is concerned, a simulation of cost benefit analysis has been simulated in a tourist municipality located in the Sondrio Province (see Tables IV and V). In this case, a small part of the community is exposed to avalanches; eight houses are directly located under the main channel, with an estimated return period of 30 years and 18 houses are more external, thus exposed to an avalanche with a 300 years return period.

Relocation has been judged desirable, especially for the houses comprised in the 30 years return period zone: in this case in fact the cost of relocation has been estimated around 1.280 Million Euros against the 1.778 Million Euros forecasted for the structural defence measure. To the latter the costs associated with the potential damage due to an exceptionally severe avalanche must be added, estimated here as corresponding to a reconstruction cost of 60 percent of the building value. This severe event cannot be excluded, as it already occurred in the past, and as the geologist himself suggested the more expensive and "safer" structural solution requiring 2.500 Million Euros. In the 300 years return period zone, the assessment is more controversial, as the relocation costs of around 5.720 Million Euros almost double the 2.500 Million Euros needed for the structural defence. If other costs were taken into account, comprising maintenance of the structural work and the possibility (though rather low) of failure of the latter, the total cost reaching 5.932 Million Euros would average the cost of relocation.

The relocation has been assessed potentially successful in this case. The site dependency index in fact is medium to low, as there are no economic activities to be moved, all houses are rather recent and alternative safer locations can be found within the municipality.

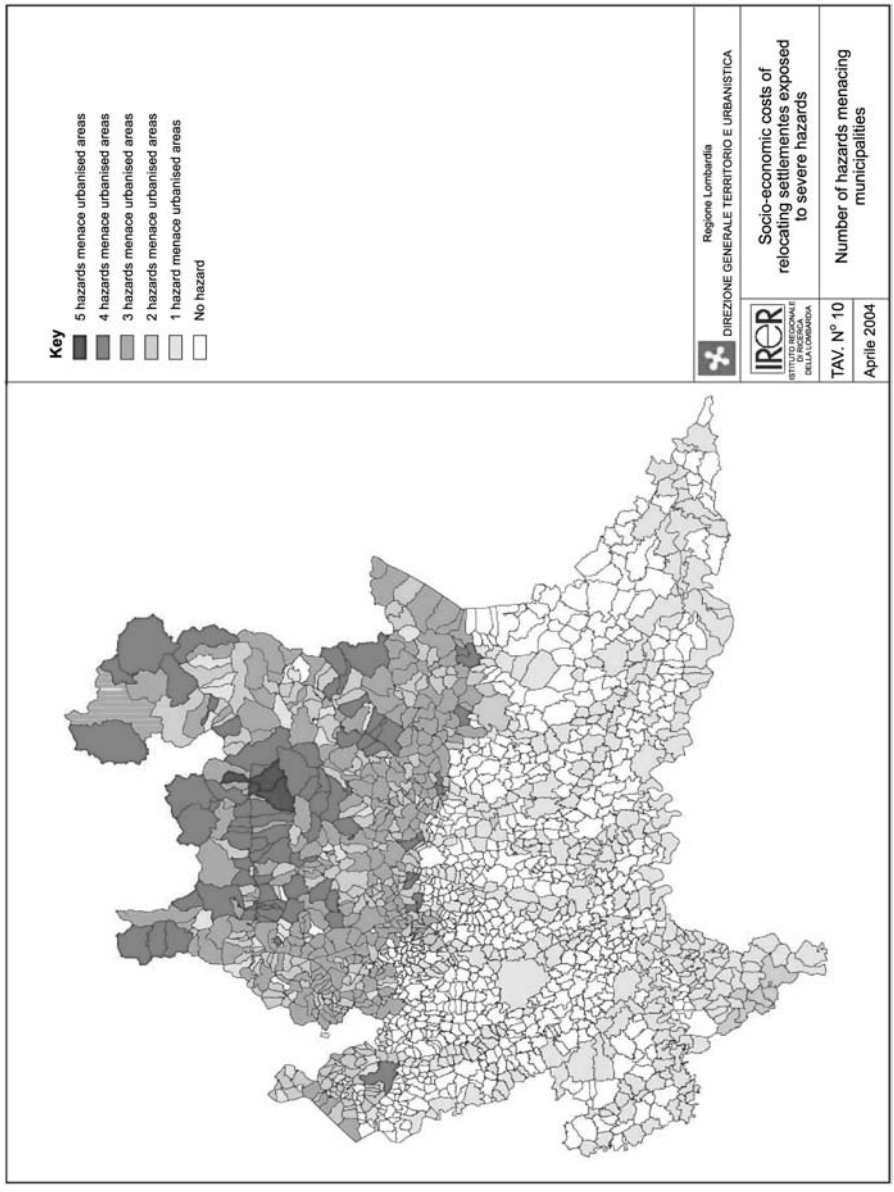

Figure 1.
Number of hazards menacing municipalities

Table IV.
Cost analysis of the relocation option for a municipality in the Sondrio Province

Costs	Relocation feasibility study	Administrative	Projects and experts advice	Building acquisition	Abandoned buildings demolition	Renaturalization
In theory	Measurable	Measurable	Measurable Reference: Emilia Romagna case	Measurable Reference: Malpensa case (market values) Emilia Romagna case (public housing)	Measurable Reference: Emilia Romagna case	Measurable
Case study			Cost = € 20/sm 8 houses = € 32,000 26 houses = € 104,000	Cost: € 800/sm holiday houses € 1,100/sm living dwellings (€ 200/sm individual houses) 8 houses = M€ 1,280 26 houses = M€ 5,720	Cost = € 100/sm 8 houses = € 160,000 26 houses = €520,000	

Table V. Benefit analysis of the relocation option for a municipality in the Sondrio Province

Benefits	Direct environmental benefits	Rescue and emergency costs reduction	Mitigation costs reduction	Reconstruction costs reduction	Systemic costs reduction	Costs related to social discomfort reduction
In theory	Difficult to monetize	Measurable	Measurable	Measurable, depends on considered RP over the event	Measurable, further research and studies are needed	Difficult to monetize
Case study			Estimated costs reduction for avalanche defence works: 1,778 M€ for RP = 30 years 2,500 M€ for RP = 300 years	Estimated costs reduction related to an event provoking 60% damage in 50 years: 8 houses[a] RP 30 years = € 768,000 26 houses[b] RP 300 years = M€ 3,432		

Notes: RP = Return period; [a]Directly located under the main channel with an estimated return period of 30 years; [b]More external, exposed to an avalanche with an estimated return period of 300 years

Going to the second framework, in order to evaluate at the regional scale those situations in which relocation is more likely to be successful, the system was queried so as to compare the expenditure needed to relocate those (few) situations where a large part of the settlement are at risk and the large number of dispersed houses each exposed to high levels of hazards. First, the extent of residential areas exposed to high hazard levels have been calculated for the whole region and the subset representing those municipalities where less than 1 percent of the total residential areas constituted by less than 10.000 sm has been extracted (see Figure 1). Both thresholds are important in fact: 1 percent of a very large area (of lets' say 1 Million sm) still represents a tough challenge for relocation, while the 1 percent with less than 10.000 sm reflects the rather sparse settlements made of individual houses and small villages that seem to be easier to move. Most of those situations comprise the urban sprawl of the last 20 or 30 years, driven, especially in mountain areas, by tourism and vacation housing.

Overall, 288 municipalities in Lombardia pertain to this category in the face of five municipalities where more than 40 percent of the total residential areas is exposed to highly critical hydrogeological threats. Facing budgetary limitations it makes sense to improve the situation of the first 288 municipalities rather than addressing the other five municipalities, despite of the fact, that, perhaps from another perspective, those are the most risky situations. Intervening on the large number, in fact, not only the risk is lessened but also the probable high costs needed to reach 288 different localities (even more, as the majority of houses at risk are rather dispersed as commented above) for rescue personnel is dramatically diminished, not to mention the environmental benefit of lessening the urban sprawl (which means also roads, pollution, etc.) (Figure 2).

To put forward this idea, the expenditure that would be needed to relocate residential areas in those two different situations were compared, taking as a reference the incentive per sm paid by the Regione Emilia Romagna in its relocation program. In order to relocate the most critical situations in the five municipalities with more than 40 percent of residential surface exposed to highest levels of hazard, the expenditure

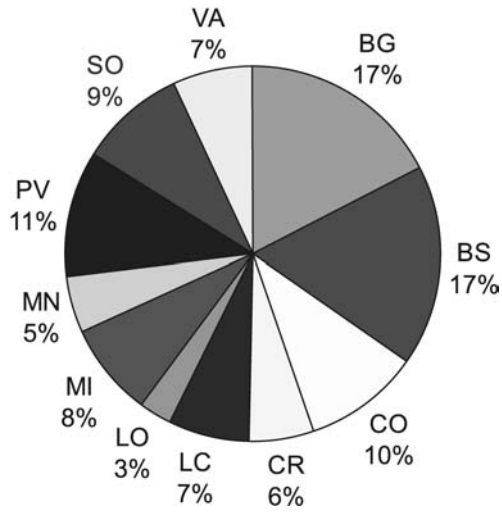

Figure 2.
Municipalities with less than 1 per cent of residential areas exposed to high levels of hazards

would be around 1.060 Million Euros, while 1.400 Million Euros would be needed to move the small residential quantities in the other 288 municipalities.

Different results are obtained if, instead of considering the incentives paid by the Emilia Romagna region, the Malpensa case were chosen as a reference, substantially funding relocation at market costs (respectively, 2,000 Million Euros for the five municipalities and 3,000 Million Euros for the 288).

Preliminary conclusions

Relocation is one of the most quoted measures considered for preventing risks in already built areas. As it often occurs when a general statement, apparently trivial, is analyzed in deeper detail, the research has led to recognize limitations and opportunities for its actual implementation. First, the difference between considering it a systematic and generalized tool has been discussed. While it can be considered in the first term, relocation cannot be called for whenever a settlement is exposed even to high levels of hazard. Moving people and activities is extremely costly from both social and economic perspectives and becomes almost impossible as the site dependency index rises because of the interdependence between urban functions and a given territory.

Therefore, a methodological procedure has been developed to assess at what conditions relocation can be a viable prevention measure to be adopted not in any circumstance but at least more systematically than it has been the case until now. In order to achieve this, it has been shown how important are economic and social considerations, as well as land use and urban planning issues, addressing both abandoned and resettlement areas.

The method has been applied then to a geographic information system developed for the Lombardia Region within this research, overlaying different land uses to diversified degrees of hydrogoelogical hazards. Those first applications highlighted the uncertainties and the room for arbitrary and subjective judgment that cannot be completely avoided, even though improvement of data and local analysis may help in enhancing the quality of results.

Many aspects can be further developed on the ground of this research; some will be addressed briefly here.

As for social aspects, it would be of extreme importance to fund studies addressing the short- as well as long-term consequences of relocation for people who experienced it in Italy and in other countries. All the criteria related to the social acceptability, the site dependency, the feasibility of this measure will benefit from those studies.

But also economic factors require further research; first it is necessary to improve our ability to estimate secondary and indirect damages in order to grasp the overall magnitude of a threatening event on one side and the costs associated with relocation on the other. It must be recognized that the ability to appraise enchained and systemic effects particularly on economic activities is still at an initial stage (see Van der Veen *et al.*, 2003).

With respect to urban planning and strategic development programs, a lot has to be done in order to integrate relocation within a more comprehensive vision of the future of some areas, especially mountain ones, exposed to several hazards at a time. Abandonment and resettlement should be considered as equally important to guarantee the efficacy of public expenditure and the conformity of siting decisions with other landscape and natural resources preservation requirements.

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