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TOOL–BOX AND INDICATORS FOR URBAN RISK CONTROL AND SAFE DEVELOPMENT

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ABSTRACT

Development and application of aggregate risk analysis for urban safe development are under consideration. Multipurpose and target disaster scenarios and maps of risk, as a complex apparatus for risk awareness and management, are step by step carried out and improved by means of methodical tools developed and implemented before.

Aggregate risk analysis and mapping were worked out in territorial (M 1:200000) scale and were used in such new important documents as risk maps, land use cadastre, passport of investment attractiveness of territories, passports of regional and municipal safety and for controlling the process of the safe urban development. Special indicators and corresponding criteria for monitoring of the sustainable safety progress were offered.

Criteria of permissible and acceptable risk and other fields of application of the risk analysis, which are accompanied with examples implemented into practice, are also under consideration.

Introduction

The objective process of growth of disasters must be met by rational counteraction being planned in advance and realized within the frames of disaster reduction policy and strategy accepted by the community. Special attention is to be paid to such objects of risk inside the human settlements as national and cultural heritage, hospitals, schools, lifelines and critical facilities. The development of urbanization and degradation of the environment accelerate the process of damage formation and growth of the disaster risk. In this connection there appears a necessity of preliminary aggregate risk analysis, assessment of this risk, its regard and measures directed on its regulation under the social and economic development and territorial planning. The rational land use, investment & housing policy and urban planning cadastre require an obligatory regard of natural and man-made risks which may appear in the process of construction development of new territories and exploitation of the existing built environment.

The final goals of the work done are:

a) providing the sustainable and safe development of urban and industrial areas first of all by urban planning and engineering means;
b) understanding of shaking, secondary and aggregate seismic risk and its preliminary and deliberate decrease up to the officially permissible level (PERIL); the following reduction up to acceptable (desirable) risk – aspiration risk level (ASPIRIL), are shown on Figure 1;

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c) providing the protection of the territory and population against probable emergencies; preparation for the damaging and destructive earthquakes, emergencies management and elimination of disasters by own (local and territorial) forces and means.

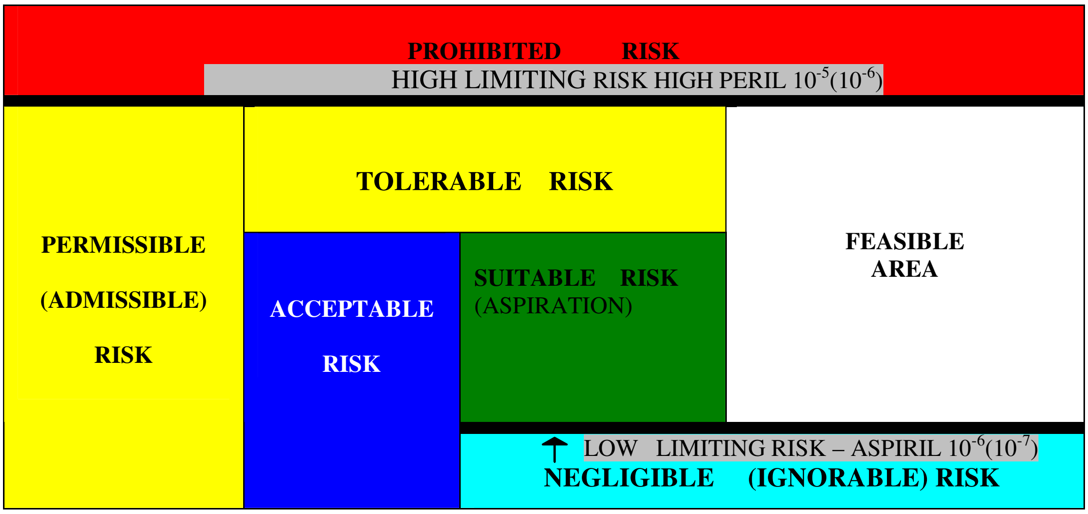

Figure 1. Aggregate urban risk allocation.

For the last 20 years the author has managed to develop (Klyatchko 1987– 2006), and implement the system of special approaches, criteria, methods and decisions which is a necessary and sufficient toolbox for analysis and control of the risk, the system being used at present.

On Necessity of Regarding the Risks in Urban Planning and Regional Development

The knowledge of natural and man-made risks, i.e. the probability of human losses and property damage is absolutely necessary when estimating the current state of the “life quality”. This knowledge is also necessary on all stages of progress of the “sustainable safety” of society that is one of the basic elements of “sustainable development”. The initial assessments of the natural and man-made risk are defined by construction and planning vulnerability of the built environment in existence and by probability of occurring of one or another dangerous natural and technogenic impacts. These initial values which are, as a rule, inadmissible for normal living of a human being and for keeping his environment are to be steadily and consequently decreased up to some PERIL ordered by code and adopted by community accordance with the real economic capacity, i.e. it is necessary to manage the risks that can be realized under the long-term social and economic development and territorial planning.

As the basic instruments, which are necessary for the functioning of the most spread mechanisms of managing the risk, the following can be named:
a) the maps of individual natural and industrial risk;
b) probable disaster scenarios (DISC) with indication of human losses and property damage and associated with the assessment of economic stability of the territory to withstand disasters of the size being expected ; one or few working DISC, which has to be taken into consideration, is especially clear up;
c) passports of safety of territories and cities (settlements);
d) regarding the risk- analysis in the land and urban planning cadastres;
e) development of insurance and reinsurance of risk analysis;
f) passports of investment attractiveness of the territory allotted for various purposes and kinds of built environment.

The Main Approaches, Methods and Assumptions under the Risk Analysis

The general expression - a formula of risk analysis, which defines deterministically the probable economic damage and social losses under the destabilizing impacts, has the form of complex matrix equations given below:

$$\mathbf{D} = \mathbf{A}_j \bullet \mathbf{W}_k \bullet \mathbf{V}_{jk} \bullet T_{st} \quad (1)$$

$$\mathbf{A}_j = \mathbf{H}_i \bullet \mathbf{U}_j \bullet \mathbf{I}_{ik}, \quad (2)$$

where:

D - complex matrix of damage, which consists of block matrices of social losses $\mathbf{D_1}$ and block matrices of economic damages;

$\mathbf{A}_j$ - matrix of damaging impacts;

$\mathbf{W}_k$ - complex matrix of social ($\mathbf{W}_{1k}$) and economic ($\mathbf{W}_{2k}$) values of objects at risk;

$\mathbf{V}_{jk}$ - complex matrix of human ($\mathbf{V}_{1jk}$) and economic ($\mathbf{V}_{2jk}$) vulnerabilities of objects at risk;

$\mathbf{H}_i$- matrix of hazards (perils, dangers);

$\mathbf{U}_j$ - matrix of damage formation factors, which are taken into account;

$\mathbf{I}_{ik}$ - matrix-indetificator of influence of damaging factor "j" on the object "k";

T_{st} . - time operator, where "s"- season number (1,2,3,4), and "t" is day time (1,2,…, 24).

Eqs. 1, 2 proceed from the methodical approaches suggested and developed (Klyatchko 1987, 1993) since 1987. Its suppose, that any urbanizes territory, city or settlement is considered as a social and economic system of urbanization which consists of "k" objects of risk having a definite social and economic value and characterized by come social and constructive ulnerability (vulnerabilities of built environment and of population). Urban system is exposed to "i" natural and secondary man-made hazards (threats) described by matrix $\mathbf{H}_i$ and realized by the concrete damage formation factors "j" with blocked into the matrix $\mathbf{U}_j$**.** For the engineering calculations the damaging loads and impacts on the urban system, which are represented by matrix $\mathbf{A}_j$ are used. The state of urban system (social and economic filling, value, vulnerability) can change at any time "t" and in any season "s" that is corrected by the time operator $T_{\mathbf{st}}$.

Developed Method of Logistic Estimation and System Analysis (MELESA) is necessary on each stage to complete the Egs.1,2 beginning from the database and to solve the problem. MELESA is based on the combination of:

- Theory of Fuzzy Sets or "Eroded Images";
- Reasonable Sufficiency;
- Economic Expediency;
- Optimized Choice;
- Risk Smoothing and Leveling (human losses minimizing) or Weak Points Protecting (property damage reduction)

The MELESA is used and developed in the CENDR since 1987, and its fruitful application was demonstrated in various seismically prone urban areas (Klyatchko 1987-2006). For example, it is impossible without using the MELESA to analyse the risk in area of low seismicity, where urbanization has never been before, where structural vulnerability of existing buildings is unknown and cannot be quickly tested, where modern strong motion observations are recently operated, where post – earthquake investigations are not completed or not corrected, etc., i.e. where the application of deterministic and probabilistic methods are unfit.

Application of the MELESA reflects in structural composition and in kind of collection of database required to carry out the risk-analysis. This database is a necessary, sufficient and authentic applied material for risk analysis - AMFORA, which consists of 2 parts:

a) The information and analytical database-DIABAS, including characteristics and peculiarities of the object of risk. DIABAS is the main dependable (linked to the object of risk) and specific component of the initial part of the AMFORA. The standard and main part of AMFORA is formed on the basis of studying of the so-called base objects for the analysis of the buildings.
b) The bank of knowledge and technical experience of the Earthquake-BANKNOTE, which were received on analogical territories (objects) and/or in analogical conditions. BANKNOTE is an independent, not linked to the object of risk, conditionally abstract, permanently developing part of AMFORA, with which the incomplete information of DIABAS can be added for the further elaboration of DISC, i.e. for assignment of impact, assessment of vulnerability and modeling the damage formation on the basis of similarity and analogies by the expert way.

Thus, procedure of database collection and geographic information system creation obey above-mentioned order, i.e. expression:

AMFORA = DIABAS+ BANKNOTE (3)

The more of BANKNOTEs you can search out worldwide, the better the risk analysis will be reached. That is why the unified of post-earthquake investigations, lessons learned from recent disasters, such international projects as “RADIUS” and the WHE (World Housing 2004) are so important.

When performing risk analysis on one or another territory the following approach is used:
1. Risk-analysis may be subdivided for four levels with corresponding maps of risk: national level (M 1:1000000), territorial level (M 1:200000), city (municipal) level (M 1:10000), object level (M 1:500 – 1:2000).

2. When making the risk analysis on the territorial level, the general population density on the territory being considered, mainly in the night time, as well as the schemes of the built environment of the territory differentiated by the construction types and number of stories, level of earthquake resistance and/or class of vulnerability with the use of macroseismic scales are used (MSK or MM scales are admissible).

3. Under the risk-analysis on the municipal level and when the work is performed on the topographic maps on the scale of 1:10000, the more accurate data on location of population in the buildings differentiated by the class of their vulnerability (according to EMS-98) are used. In doing so, it is desirable to take into account different vulnerability of population to seismic impacts (adults, children, aged, disabled, etc.) with regard of their psychophysical response and readiness to emergencies. The built environment is to be considered not by the “spots”, but in detail with examination of every building according to the data of inventory and certification, passports of reliability and safety and territorial catalogues of vulnerability of the built environment represented mostly by base objects for the analysis of the buildings. On the city level the complete set of the probable scenarios of disasters which includes the night (3 am), day (3 pm) and “transport” (7-8 am or pm) is to be drawn up (the secondary risks are taken into account).

4. The seismic impact is allowed to be assigned with the help of intensity of expected earthquake with the use of maps of seismic zonation with different detailed elaboration (general, detailed and microzonation). The seismic impact on the key objects of life support and management of the emergencies as well as on the large potentially risk-prone technological objects (PORTOs) is recommended to assign with the use of (Uzdin 1996). In scenarios of probable seismic events the well-known historical earthquake (scenarios-analogues) and designed (virtual) scenario events can be used. Under the detail risk-analysis it is recommended to use the specially elaborated scenarios of seismic events in which the information on for-shocks and after-shocks, the duration of impact, its spectral analysis, presence and characteristics of the vertical component is contained in accordance with (Klyatchko 2004).

5. The calculation of the complex individual risk on the territorial level is realized by the maximum value, i.e. an envelope of risks, the values of which with a high probability (90%, 95% and/or 98%) will not be exceed. The risks of losses & damages caused under secondary disasters are summed up.

Estimation of Consequences and Risks of the Secondary Industrial Dangers

The procedure of estimation of additional risk introduced by secondary disasters and, in particular, by industrial striking factors (fire, explosion, chemical impact of PORTOs) is to be made in several stages. At the first stage the list of PORTOs with regard of the accepted scale of risk analysis is made:

- on the territorial level – PORTOs of the 1st, 2nd and third class the destruction of which may result in national, regional or territorial emergencies;
- on the city (municipal) level of the risk analysis the PORTOs of the 4th and 5th class the damages of which may result in local emergencies, are to be taken into account.

At the next stages of risk analysis for the earthquakes of different intensity the probability of the fact that the dangerous objects can receive the level of damage that can exceed threshold value (serviceability limit state) is estimated. Then the fields of striking factors (excessive pressure in the case of explosion, temperature of fire, concentration of chemically hazardous matters) with regard of wind rose, temperature and pressure of air, landscape, etc. are constructed; the social losses and the individual risk are calculated. The criteria and probabilities of emergency situation on the PORTOs are assessed for each selected PORTOs on the base of BANCNOTE, which was created using the processing the data on consequences of well-known earthquakes of the last and current century (UNDP, RMS, WSSI, Munich Re, etc). Structure of GIS and methodology of assessment of secondary industrial risk are worked out in the Extreme Situation Research Centre, Russia (Larionov 2001).

Criteria of Risk and Indicators of Stable Safety

For estimation of the safety of population and territory and for monitoring and control of safe development it is necessary to have the criteria of safety and indicators of safe development. The criteria of safety can be assigned within an expedient range. In this case both PERIL and the permissible parameters of the probable disaster are recommended to be broadly applied and implemented into practice.

The main control indicators of safe development are listed below:
1 Individual aggregate (complex = natural and man-made) risk;
2 Magnitude of probable design disaster – Md;
3 Relative social vulnerability of population (p) under probable working disaster taken into consideration;
4 Relative index which depends on economic stability of the territory – dm.

Parameters # 2, # 3, # 4 are calculated accordance with scale of disaster magnitude “DIMAK” (Klyatchko 1994, 1995, 1996a, 2000).

As the unconditional priority when developing the policy and realizing the strategy of safe development of disaster is the improvement of life quality through the increase of safety of population, the main criteria of risk and the main component of PERIL are criteria # 1 and # 3. Permissible (limit) parameters are assigning for each socio-economic community by means of Acts of safety and building codes, dependently of economic capacity, democracy etc. Table 1 shows the criteria and parameters, which are suggested both for actual estimations and for monitoring and control of safety on the urbanized and economic areas.

Table 1. Parameters for estimation and control of the territorial safety.

№	Criterion		Acceptability	Permissibility
1	2		3	4
1.	Obl.	Individual risk	10^{-7} (10^{-6})	10^{-6} (10^{-5})
2.		Magnitude of disaster – Md	≤ 3.0 – 3.5	≤ 3.5 - 4.5
3.		Relative social vulnerability – p	≤ 0.25	≤ 0.25 - 0.5; (0.5 – 0.75)
4.	Add.	Index of economic stability of the territory to the disaster – dm	Territorial dm ≤ 5	Territorial dm ≤ 5 – 10
5.	Des.	Insurance of dwelling	Total (health, dwelling, property, entrepreneurship, business)	Partial compensation

Limit parameters indicated in Table 1 in brackets are recommended for developing countries.

In the process of social and economic development the monitoring and control of safety is realized in accordance with Figure1. Doing so we use special kind of disaster scenario – control DISC "DISCONT" (Klyatchko 2004).

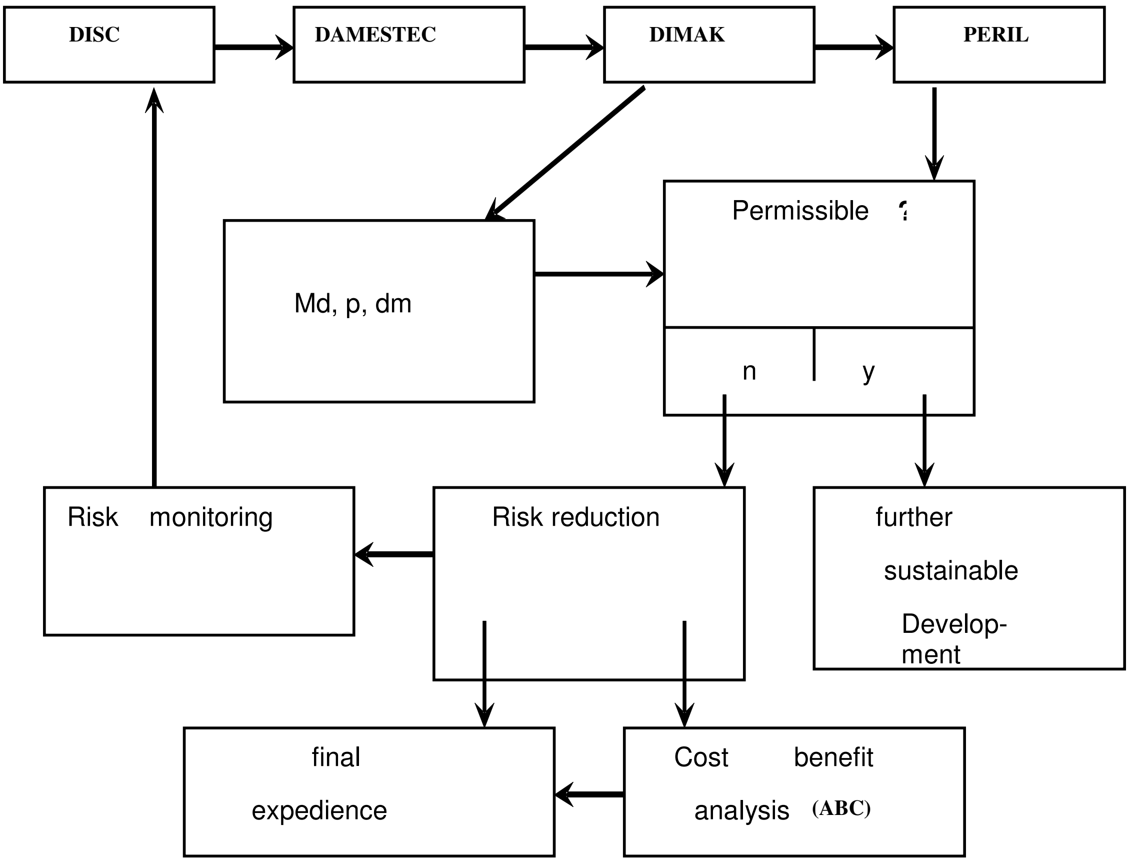

Figure 2. Scheme of risk monitoring and control.

Note: in the Figure 2 "DAMESTEC" means Damage Estimation Technique.

Examples of Seismic Risk Control in Safe Development

Example 1

The complex of measures on decreasing the seismic risk and mitigation of the disaster being expected has been developed and realized on the urbanized territory around the Avacha Bay on the south-east of Kamchatka Peninsular since 1987 because of the forecast of destructive earthquake which may happen in near future.

The effect of decrease of probable seismic disaster by preventive strengthening of buildings with insufficient seismic stability in Petropavlovsk-Kamchatski is shown in Table 2 where the consequences of the earthquake being expected are estimated by one working DISC (chosen from 6 scenarios of the seismic event). To estimate required disaster parameters the DIMAC scale was used. Target (desirable) indicators are: # 2 – Md < 4; # 3 – p< 0.5.

Table 2. Managing the seismic risk when strengthening the buildings on Kamchatka.

Stage of managing risk		Consequences of the earthquake				Estimation of disasters by the DIMAK scale		
		Killed K	Injured I	Homeless H	Econom. losses ($, mln)	Md	Term of disaster	Score of disaster permissib-lity
Before strenthening, 1990		3 000	14 000	100 000	8 000	5.63	Major disaster of national scale	Unaccep-table
By 2000		2 000	6 000	65 000	4 200	5.29	Major disaster of national scale	Unaccep-table
Target results	by 2010	200	1 500	9 000	1 200	4.29	Disaster of territorial scale	Semi acceptable
	by 2020	50	200	5 00	1 000	3.95	Disaster of local scale	Permissible

Eearthquake prognosis is forecasting the destructive seismic event near Petropavlovsk-Kamchatski during nearest years. Seismologists appealed that earthquake may happen tomorrow, and main objective of authority became human protection realized very quick. This prognosis was repeated again and again during last 20 years. That is why in this example the management of risk was realized only for increasing the seismic safety of the territory and population but the policy and strategy of mitigation of the probable disaster was not connected with the prospective social and economic development of the city and region.

Here indicator # 1 – individual shaking risk is extremely high because the destructive event probability determines probable tragic consequences on this unprepared urban area. In this example not only indicator # 2 remains behind the values required, but indicator # 3 is hardly managing. Indicator # 4 shows, how difficult for this region being granted to cope with the disaster by own forces and means.

Example 2

On the territory of intensively developing Krasnodar region, in 2004-2005 CENDR together with Extreme Situation Research Centre for the first time carried out the mapping of complex seismic risk on the territorial level (M 1:200 000) with the purpose of social and economic development and territorial planning (Klyachko, Larionov 2005, Klyachko 2006).

Table 3 shows the estimations of individual seismic risk for the largest urbanized territories of the Russia Black Sea region.Target (desirable) PERIL was assigned equal to 10^{-5} per year (as a first stage). Risk analysis showed that the risk of damage on PORTOs (highly fire and explosive and chemically hazardous objects) results in increase of indicator # 1 for some cities by 10-40%.

Beside the calculations of the risk there were elaborated 5 disaster scenarios on the basis of working (virtual) scenarios of seismic events and 17 scenarios of disasters on the basis of historical (analog) seismic events were studied. According to the worst DISC, deaths are estimated as K = 4700 and the injured as I = 13500. But the probability of such seismic event is very low and, hence, indicator # 3 is beyond any significance when monitoring and control the safe development for a period of 50 years. Especial attention should be given to indicator # 1 that can be explained by creation of a new map of general seismic zonation of Russia. Estimations of seismic hazard for the settlements under consideration increased greatly and the built environment in existence was planned without required earthquake resistance.

Table 3. Estimations of the individual seismic risk without and with regard of secondary industrial dangers.

Name of settlement	Population, thousands	Seismic risk x 10^{-5} / year	
		With regard of direct losses	With regard of damages on PORTOs
Anapa District	136.35	26.39	28.04
Armavir	181.89	1.27	2.43
Gelendgyk	85.01	24.89	26.08
Krasnodar	879.43	5.30	7.60
Novorossiisk	251.64	23.28	31.25
Sochi	596.1	27.08	29.75

Example 3

To support a new urban planning documentation for the town of Anapa the initial stage of the complex risk analysis on the municipal level was carried out. The analysis showed that the estimation of individual complex risk for Anapa exceeds 28 x 10^{-5}/year and in some settlements even 37 x 10^{-5}/year that is absolutely inadmissible and requires an obligatory regulation (decrease by 50-100) in case of territorial development. The following target values of indicator # 1 are recommended:

- 10^{-5}/year for all settlements till 2015 year;
- 10^{-6}/year for all settlements till 2030 year.

It is necessary to note that if the seismic hazard has been taken into consideration since 2001 in construction designing on the Black Sea coast near Anapa, there are no estimations and any tsunami-risk map until now. This secondary disastrous factor can significantly worsen the economic losses in case of the seismic disaster and, thus, worsen the values of indicator # 2 but in this work tsunami is not under consideration.

Conclusions

1. The developed and approved 1995 complex apparatus for seismic risk-analysis on the urbanized and industrial territories is a necessary and sufficient tool-box for understanding the aggregate risk and its further systematic decrease within the frames of the sustainable development.

2. The proposed indicators of safe development describe the state of safety on one or another urbanized or industrial territory full enough and allow to plan and manage the risk in short- and long-term aspects with the use of special procedure of controlling the risk in a virtual form and in real time.

3. The practical works being carried out on Kamchatka and in Krasnodar region is a very important strategic stage for further understanding, perception and obligatory regard of the risk under the space-time planning of the territories being considered and for the current policy of rational land use and investment into construction on the one hand and for decrease of the complex seismic risk up to PERIL on the other.

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