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Guidelines on Urban Disaster Scenarios Development and their Application for Risk Control

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SUMMARY

Basing on the 15 year experience in urban seismic analysis the Guidelines on developing the Urba Disaster Scenarios was elaborated. This Guidelines is supposed to become a unified methodical document fc developing the probable disaster scenarios of different levels and aims on urban areas. Preparing th Guidelines, author used the tool-box developed previously for seismic risk analysis, such as: Method c Logistic Estimations and System Analysis (MELESA), Vulnerable City Analysis (VULCAN), Damag Estimation Technique (DAMESTEC), Disaster Magnitude Scale “DIMAK”, Aggregate Risk Analysi (AGRA), Acceptable Risk Criteria (ARC) and Permissible Risk Level (PERIL).

These implemented and tested methods and tools have become a basis for the Guidelines, which contains goal and objectives; terms and definitions; DISC’s classification and composition; obligatoriness, necessity desirability of DISC development; requirements and rules for database collection; requirements for seismi hazard identification and defining EQ event scenarios; requirements for secondary hazards identificatior requirements and rules for Disasters Scenarios (DISC) development; requirements and rules for vulnerabilit assessment; loss estimation technique and risk assessment; rules for probable disaster measuring and analysis rules and recommendations for DISC application.

Guidelines are supported by appendix, which includes a practical supplementary and examples c DISC application for urban risk analysis and management.

INTRODUCTION, PREHISTORY AND BACKGROUND

Understanding the problem what happens if the EQ occurs is the initial and the key question in th disaster mitigation policy. The Disaster Scenario (DISC) approach to and methodology for urban seismic ris understanding and reduction have been developed and used by the author since 1987.

The Decree of the Soviet Union Government of November 1986 on quick preparation for destructiv earthquake (EQ), which had been forecasted for near-Pacific coast of Kamchatka provided an opportunity t implement a comprehensive, systematic and logical approach to the issue.

First scenarios of probable consequences of the EQs (DISC) was created under author's leadership in 1989 - 90 for Petropavlovsk (Kamchatka, Russia) as a computer info-search system.

Second one was DISC on the basis of GEOPROC – 3.0 (together with G.Koff).

Third DISC was developed on the basis of GIS "ONEGA" (together with Yu. Shevchenko) in 1991 fc Viluchinsk (Avacha bay area).

A new high-quality development of DISC was received due to GIS technologies which was realized in th Emergency Situation Research Center (Russia) and applied for the multifunctional DISC "EXTREMUM" i 1998-99 (Shakramanjyan et al, 1999).

No wonder that in the frames of the DNDR a place of especial importance at the end of 90s was taken b the UN project "Risk Assessment Tools for Diagnosis of Urban Areas against Seismic Disasters (RADIUS)' which involved almost 60 cities located in the seismic prone urban areas (SPUR) worldwide. However thi project which was basically targeted to the developing countries provided the creation of the DISC basicall for risk awareness and necessity of developing the Action Plan. At the same time the DISCs can provide deep and multisided analysis of the risk and can be widely used.

That's why the necessity in developing the unified Guidelines, which would contain the generalize approach and procedure appeared. These Guidelines should be suitable for developing the disaster scenario c any level and application. It is important to note that by the end of the last century the apparatus for th structural vulnerability assessment, loss estimation and risk analysis has been completed. In developing th Guidelines the result of the previous works of the author (Klyachko, 1993-2003) and the base created by suc pioneers as B. Bolt, J. Blume, L. Finn, I. Idriss, H. Sead, H. Shah, were used.

Accumulated knowledge and experience found a reflection in the Guidelines which was elaborated i 2001.

DISCS' CONTENT AND STRUCTURE

The Methodology for developing DISC consist of necessary and sufficient set of special methods and tool for the structural vulnerability diagnostics and for risk analysis.

The essence and contents of this Guidelines are briefly described below.

DISC development is based on the following accepted principles, statements and assumptions. DISCs ar subdivided in accordance with aims, levels and volume of risk analysis. Since 1990 we can distinguish:

DISC-1 for estimation of direct seismic risk (shaking only);

DISC-2 for estimation of complex risk taking into account secondary disasters;

DISC-3 for aggregate (full, total) risk analysis taking into account indirect risk, Civil Defense readiness, long term consequences, etc.

Each DISC has a special name which reflect its essence.

Scheme of interrelation and improvement of DISC is shown in Fig. 1.

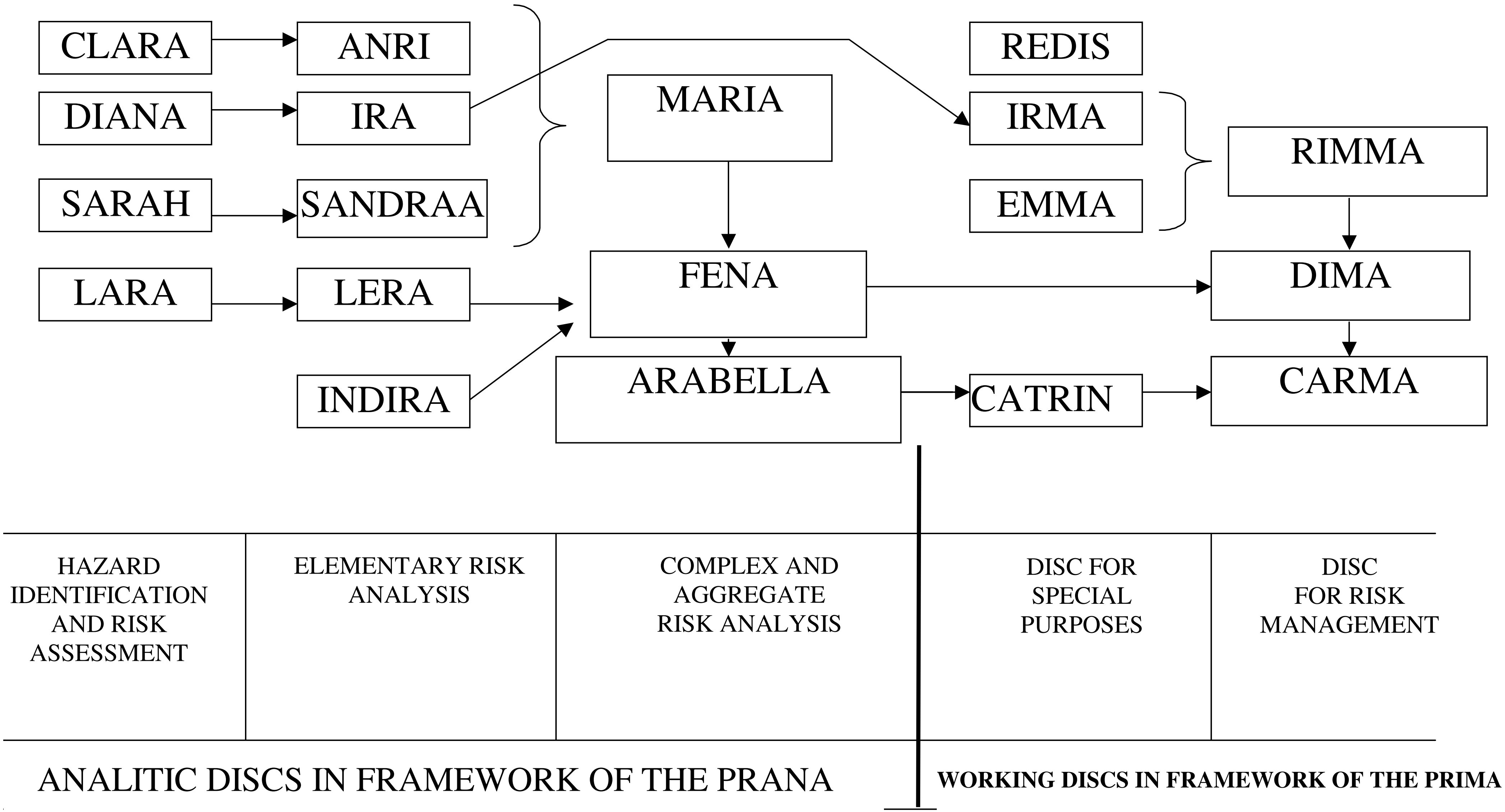


Fig. 1

Scheme of interrelation and improvement of DISC

Depending on the tasks of the DISC the estimation of the probable disaster magnitude and risk analysis are carried out on the basis of

DISC ANRI – I,II (ANRI-1+LARA), III (ANRI-1+LERA) and ANRI IV (direct risk)

DISC of the SANDRA and IRA type (secondary risk)

DISC MARIA (complex risk)

DISC INDIRA (indirect risk)

DISC ARABELLA (aggregate risk analysis)

Abbreviations accepted are given in the end of the article.

GENERAL APPROACH AND REQUIREMENTS FOR DEVELOPING THE DISCs.

Obligatoriness, necessity, desirability of the DISC development for each concrete city or other Seismically-Prone URbanization (SPUR) depend on seismic zone where it is located, its number of population and strategic importance. For example, DISC is mandatory, if the city with population of 1,0; 0,5; 0,25 is located in the seismically prone zone with intencity of 7,8,and 9 MSK/EMS correspondingly.

Any DISC's developing procedure consists of following stages:

a) database collection and creation AMFORA – (Applied Materials For Risk Analysis), which is filled from two sources:

- local database DIABASE (Info-Analytic Database);
- BANKER (Bank of Knowledge & Experience on the Risk).

a) defining damage-forming factors (DFF), analysis of damage accumulation in the object at the risk under the impact of DFF and vulnerability assessment of this object;
b) modeling a process of disaster developing; estimation of elementary, direct, complex, secondary, aggregate, indirect and total losses and damages;
c) final risk analysis of the level given;
d) risk monitoring and control for the PERIL not to be exceeded.

The special analytic tool as Method of Logic Estimations and System Analysis MELESA is used on each above mentioned stage.

The DISC can be developed both for SPURs which have passed through damaging EQs and for SPURs without such experience. For each and concrete case the volume and interrelation of DIABASE and BANKER in the AMFORA will be different.

Any SPURs are represented by a complex Socio-Economic System of Urbanization (SESURB) which consists of the built environment as a part of SESURB.

Correspondingly, we are taking into consideration both social and economic risk (losses and damages). Also the structural vulnerability and human vulnerability are distinguished.

Risk analysis is made after the built environment inventory and certification during which the Basic Objects for Analysis of Buildings (BAOBABs) are also assigned. The main core of BAOBABs are the Objects of Impact and Respond (OBIR) suitable for the EQ-intensity assigning according to the EMS-98. The most reliable part of the OBIR is represented by buildings on which strong-motion observation stations, involved in the Observation Network for Engineering Seismic Control (OBNENSC), are installed.

Besides, the life facilities and other key objects (KEYs), which are to operate reliably during the emergency management are included into the DIABASE and BAOBAB for risk analysis beginning from the extended DISK-1.

When the DISC-2 and/or DISC-3 are under development, a database on the Potentially Risk-prone Technological Object (PORTOs) must be also included into the DIABASE and BAOBAB for secondary man-made risk analysis.

When any DISC type is under development the complex damage D of multielement object W_k at the risk R under multicomponent impact A_j is described by the following matrix formularies for the Risk Analysis (FORA).

$$\mathbf{R} = \mathbf{A} \times \mathbf{V} \qquad (1)$$

The multiparametral impact on the object at risk.

$$\mathbf{D} = \mathbf{A_j} \times \mathbf{W_k} \times \mathbf{V_{jk}} \times T_{st} \qquad (2)$$

$$\mathbf{A_j} = \mathbf{H_i} \times \mathbf{U_j} \times \mathbf{I_{ik}} \qquad (3)$$

Where:

D – matrix of complex damage of object at the risk;

$\mathbf{A_j}$ – matrix of complex impact (j=1, 2, 3…) on the object at the risk;

$\mathbf{H_i}$ – matrix of hazards, i=1, 2,3…;

$\mathbf{U_j}$ – block- matrix of damage forming factors (DFF);

$\mathbf{I_{ik}}$ – matrix of influence (weight) of each DFF on the damage;

$\mathbf{W_k}$ – block - matrix of values (k=1, 2, 3…) under impact $\mathbf{A_j}$;

$\mathbf{V_{jk}}$ – block - matrix of vulnerability of values (k=1, 2…) to impacts (j=1, 2, 3…);

T_{st} – time-operator (s-season 1, 2, 3, 4; t-day time 1, 2 …24);

i – index of hazards or danger;

j – index of damage forming impact (j = i);

k – index of valuable element of object at the risk;

Consequences of various DFF can be summarized in the real time for emergency preparedness and management provision.

To avoid the underestimation of the probable consequences and to ensure the most effective preparation for the disaster it is considered expedient to summarize all the damages which occur simultaneously within the frames of the scenario period given. If the coefficients of interaction of these DFF are not available from DIABASE, we have to find them in the database BANKER. Losses and damages during emergency management (rescue works, etc.) are not taken in consideration when DISC is developing. It's a special additional question.

The results of any DISC must be a clear picture of probable damage forming process in the object at risk and contain quantitative estimates of social-economic damage, expressed by number of fatalities (K), injured (I) and homeless (HL) people, economic losses ($mlnUSD).

DISC's approach is developed and realized from simple DISC CLARA to more complicated ones. (see Fig. 1).

REQUREMENTS FOR THE EQ SCENARIO AND SEISMIC LOADING

The topic related to choosing EQ-scenario is excellently described in (B. Bolt, 1993) where he suggested to do it by means of set of the basic EQ types and paid attention to the strong motion specifications and seismological analysis, geotechnical analysis and quantitative response analysis. In practice the uncertainties involved are allowed for the application of safety factors. Consequently, large-than-necessary ground motion, given realistic lifetime of structure, may be the result.

Thus, the seismic hazard for the DISC can be assigned in the DIABASE by the set of possible EQ scenarios. It is desirable to know the seismic reoccurrence, probability, magnitude and durability of the forshocks, main shock and aftershocks. It is allowed to assign the seismic hazard by:

- the set of probable epicenters of the EQ with their coordinates and the expected EQ magnitude. In practice, when using the formulae of N. Shebalin's type of M-I correlation, we get down to the assignment of intensity;
- the seismicity maps, seismomicrozonation maps, etc., which are also advised to be used. These maps provide usually the estimates of the EQ intensity that allows to apply the intensity scales (MSK, EMS, MM, etc.). Such approach is justified for the OBIR.
- the design set of local and synthetic accelerograms for the forming of the seismic impact and assigning the seismic loads on the structure. In doing so, we choose the seismic loads which are of the most danger for the structure under consideration. That's why the spectral characteristics of

impact and its effective durability are very important. Such approach is usually used for PORTOS and desirable for the KEYs.

If possible, the short term (3-5 years) seismic prognosis should be taken into account. The requirement is for the set of scenarios for large cities, SPURs and megacities to be considered and approved by the national seismological Commissions. It is need to underline a very high importance of the "COSMOS" activity and International Project "Safer Cities" for objectives described above.

RULES FOR VULNERABILITY ASSESSMENT, LOSS ESTIMATION AND RISK ANALYSIS

Being under development since 1987 an integrated apparatus for aggregate risk analysis (AGRA) had been practically formed by 1996 (Klyachko, 1996a).

It is no doubt today, and it has become an axiom now, that vulnerability is an only component of the natural risk by means of which we can and must reduce this risk. That's why, before all, we have to understand all kinds of vulnerability in each SPUR.

Step-by-step procedure of structural vulnerability assessment and the risk analysis is developed in (Klyachko, 1993-2003) and represented below.

1. Screening and certification of the certain construction type of the housing. (Methodical Manual:, 1987)
2. Assignment of vulnerability levels or/and classes, (VULK) applying the MELESA and using BANKER.
3. Vulnerability (d) assessment, using VULCAN.

In doing so, five main and five intermediate vulnerability levels are in use:

Main: negligible (n), light (l), moderate (m), high (h), full (f);

Intermediate: zero(0), slight (sl), lm, mh, very high (vh).

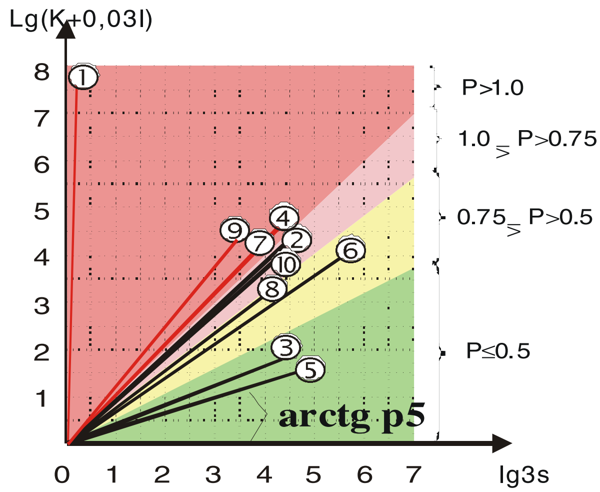
Also, an extended EMS-98 involving 8 classes of vulnerability (VULK) - G, F, E, D, C, B, A, O (Out Of Order) - can be applied.

The Guidelines involves the rules for the city planning vulnerability assessment that is a new direction in the urban risk analysis. The exceptional importance of such direction in the risk analysis of the urban areas has been well-known before, but it became an axiom after the tragedy in Neftegorsk (1995) where the collapse of 17 5-storeyed residential closely located buildings resulted in continuous debris which buried almost three thousand people. In spite of the sufficient availability of the rescue facilities, about 400 people were found dead only on the tenth day after the disaster because of difficult access to the central part of the ruined area.

4. Property damage and human losses estimation for the SPUR using DAMESTECH.

5. Direct seismic risk assessment using the DIMAK; estimation of risk permissibility using PERIL.

The magnitude of the probable disaster (Md), the coefficient of the relative social vulnerability (p), the relative national (territorial) economic stability against disaster and others are determined under the DIMAC scale (Klyachko, 1994, 1996b). The size of the disaster expressed by Md and p is recommended to be fixed on the disaster plane. Examples of real disasters are shown in Fig.2.



1 - Murrain, Europe, 1337-1352; Md=7.8; p=0;
2 - Spitak, USSR, 07.12.88; Md=6.45; p=0.94;
3 - Loma Prieta, USA, 17.01.89, Md=4.80; p=0.42;
4 - Manjil , Iran, 21.06.90, Md=6.3; p=1.06
or Bam, Iran 26.12.03, Md=6.4; p=1.05;
5 - Northridge, USA, 17.01.94; Md=4.93; p=0.38;
6 - Kobe, Japan, 17.01.95; MD=6.67; p=0.68;
7 - Turkey , 17.08.99; Md=5.75; p=1.06;
8 - Taiwan, 21.10.99, 04.10.94; Md=5.15; p=0.83;
9 - Bhuj, India, 27.01.01, Md=5,64; p=1,17;
10 - Terror attack, USA, 11.09.01; MD=5.52; p=0,9.

Fig.2 Disaster Plane (K –S plots).

Such disaster representation allows to compare it with other real or predicted hazardous events that is necessary on all levels of DISC, i.e. the awareness, understanding, analysis of disaster, from DISC CLARA up to DISC CARMA.

Before the assessment of disaster's acceptability (permissability) by the results of DISC MARIA, POLINA or ARABELLA, it is necessary to find the disaster magnitude (Md), the index of relative social vulnerability (p), the economic index of disaster stability (Sd), the degree of the disaster's economic impact on the SPUR or the SPUR's economic capacity against disaster (Dm). These parameters are defined in accordance with (Klyachko, 2002b).

Acceptability and permissibility of the probable disaster is determined by Table 1.

Table 1. Conditions for acceptable and permissible risk

NN п/п	Criteria		Acceptability (not exceed ARC)	Admissibility (not exceed PERIL)
1.	M a n	Disaster magnitude – Md	= 3	= 4.5

	datory			
2.		Index of Relative social vulnerability – p For developed countries For developing countries	 < 0.25 < 0.5	 < 0.5 < 0.75
3.		Individual risk For developed countries For developing countries	 $= 5x10^{-7}$ $= 10^{-6}$	 $= 10^{-6}$ $= 10^{-5}$
3.	Additional	Economic capacity against disaster – dm (economic resource is sufficient for disaster limitation and sustainable safety provision by own means).	Disaster must not exceed the territorial level dm = 5	 dm = 10
4.	Special	Life and health insurance Property Insurance House Insurance Business Safety	Full coverage by insurance	Housing provision, rehabilitation life supporting, particular compensation of property damage and health insurance

The determination of disaster acceptability and permissibility is very fine and comprehensive issue conditions above are basic only , and final conditions are assigning taking into consideration national, cultural, religion and other local features.

APPLICATION OF DISK AND RISK CONTROL

Directions for application:

- land-use and urban planning;
- built environment diagnostics and protection against EQ;
- Civil Defense readiness to respond;
- housing policy strategy;
- city planning and development;
- public risk awareness and permissible risk control;
- insurance policy;
- operative measures and long-term program for disaster mitigation, manual for decision makers;
- ensuring sustainable safety.

Risk monitoring and control are provided with the scenario on duty DISCONT which is developed on the basis of such advanced types of DISCs as EMMA, RIMMA or CARMA. DISCONT is to be renovated each five years and in the following cases:

a) any changing in AMFORA including renovation in DIABASE due to each EQ of intensity higher than 5, worsening the geological conditions, deterioration of buildings, changes in BANKER after receiving knowledge and experience learned from new EQ-disaster;
b) realization of measures for disaster mitigation;
c) changing in seismological prognosis, seismicity maps, etc.
d) improving the seismic codes, intensity scale, other norms and regulation

Monitoring and control of seismic risk in the SPUR are provided by means of scheme shown in Fig.3

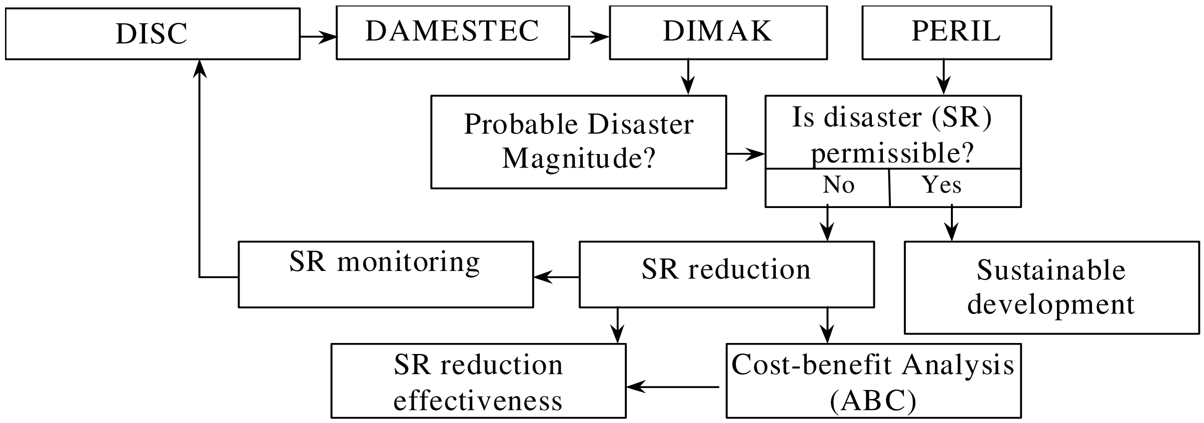


Fig. 3. Scheme of SR reduction and control for sustainable development.

Rules for estimation of prevented damage and effectiveness of expenses on corresponding measures are given in the Guidelines.

For example since 1990 the current target parameters of seismic risk on the SPUR of Petropavlosk (Kamchatka, Russia) are under control procedure which is realised by DISCONT in framework of Federal Program "Seismoprotection". Initial intermediate and target disaster estimates changed due to the prevented seismic strengthening (PRESS) building are shown below.

Table 2. Probable EQ – Consequences in the SPUR of Petropavlovsk (Kamchatka, Russia)

Period	EQ-consequences						
	Killed	Injured	Homeless	Total losses ($,mln)	DIMAK scale scores		
					Md	Terms for disaster description	Score of disaster permissibility
Initial, before PRESS (1990)	3 000	14 000	100 000	8 000	5.63	Major disaster of national scale	Unacceptable
Current, during PRESS (2000).	2 000	6 000	65 000	4 200	5.29	Major disaster of national scale	Unacceptable

Target results 1	200	1 500	9 000	1 200	4.29	Disaster of territorial scale	semiacceptable
Target results 2	50	200	5 000	1 000	3.95	Disaster of local scale	permissible

EXAMPLE OF URBAN RISK ANALYSIS WITH ANALYTIC DISC.

One of examples given in the supplement to the Guidelines demonstrates the extended DISC-1 which consists of DISC ANRI + DISC LARA. The impact of the EQ with intensity 9 (MSK/EMS) results in the following average direct consequences for SPUR of 950 000 residents: killed (K) = 8.500, injured (I) = 33.000, property damage (S) = $5bln. According to the disaster magnitude scale DIMAC, this disaster is valued by the magnitude Md = 5.7 and p = 0.93, that is the relative social vulnerability of this SPUR under consideration is extremely high. The disaster is of the third degree and can be defined as a "very significant". The economic stability index of this area (Sd) is 1,5 that is not too high. The degree of disaster's economic impact on the SPUR (Dm) is 5.5 that is higher than 5 i.e. this area cannot withstand such disaster with its own capacity. Hence, the disaster is beyond the SPUR capacity and has the national (Russia) scale. The disaster of such a size is not permissible and the urgent measures for the disaster mitigation are necessary to be undertaken.

ABBREVEATIONS APPLIED TO FIG.1

ANRI – ANalysis of Risk

ARABELLA – Aggregative Risk Analysis of Built Environment, Lifelines & Economics

CARMA – Catastrophic Aggregate Risk Management

CATRIN/CATRIN(E) – Catastrophic Insurance Risk

CLARA – Clarified Risk Assessment for Awareness

DIANA – Disaster Assessment for Awareness

DIMA – DIsaster MAnagement

EMMA – EMergency Management

FENA – Full Engineering Analysis

INDIRA – INDIrect Risk-Analysis

IRA – Industrial Risk Analysis

IRMA – Industrial Risk Management

LARA – Lifelines Risk Assessment for Awareness

LERA – Life Engineering Risk-Analysis

MARIA – Multi Aggregative Risk Analysis

PRANA – Program (Plan) For Risk Analysis

PRIMA - Program (Plan) For Risk Management

REDIS – READIness to disaster

RIMMA – Risk Mitigation & Management

SANDRA – Secondary Appeared Natural Disaster Risk Analysis

SARAH – Simple Risk Analysis and Secondary Hazards Assessment

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