Motto:

At their birth, risks have been cursed to be underestimated.
And so they are.
And it is therefore that we so often complained to have been struck by unexpectable events and disasters.

A MANDATORY COMPONENT OF DEVELOPMENT STRATEGIES: DISASTER PREVENTION / MITIGATION

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Rezumat. Lucrarea este dedicată unui domeniu care, conform convingerii autorului, este încă subdezvoltat în țara noastră. O privire asupra aspectelor de considerat în legătură cu protecția împotriva dezastrelor evidențiază necesitatea alocării unor resurse suuplimen tare importante de diferite naturi. O serie de considerații introductive sunt urmate de o discuție asupra unor aspecte metodologice privind analizele de risc. Sunt făcute referiri la diferite scări alternative ale analizelor de risc, pe lângă mențiuni privind unele activități deschizătoare de drumuri în acest domeniu. Sunt evidențiate câteva componente principale ale activităților de protecție împotriva dezastrelor. Sunt discutate succint câteva obstacole în calea reducerii riscurilor. Sunt discutate necesități de dezvoltare a activităților specifice. Sunt prezentate două anexe de natură analitică.

Cuvinte cheie: prevenția dezastrelor, analiză de risc, reducerea riscurilor la cutremure.

Abstract. The paper is devoted to a field which, according to the author's belief, is yet underdeveloped in our country. In case one looks at the aspects to be considered in connection with the prevention / mitigation of disasters, it turns out that huge additional resources of several kinds should be provided in this field. Some introductory considerations are followed by a discussion on some methodological aspects concerning risk analyses. Alternative scales of risk analysis are referred to, besides some mentions on activities representing a forefront in this field. Some main components of disaster prevention / mitigation activities are emphasized. Some obstacles to risk reduction are briefly discussed. Some needs of development of specific activities are discussed. Two appendices of analytical nature are presented.

Keywords: disaster prevention, risk analysis, earthquake risks reduction.

1. INTRODUCTION

Development strategies represent a main topic dealt with in the frame of this meeting. They are, of course, a basic component of social, technological, economic etc. development. Unfortunately, the history of human development witnessed countless cases where various development strategies and activities were brutally hurt by events that could be qualified as disasters. We live now in a period in which more advanced/developed communities (or countries) are proportionally more cautious to prevent, or at least to mitigate, the occurrence of disasters. The outcome of consistently adopting this philosophy is obvious: the proneness of more advanced communities to undergo paralizing disasters is considerably lower than that of less developed communities. There are numerous cases (or points of view) where advanced communities conduct a continuous activity of investigating sources of potential disasters and of taking strong measures for their prevention / mitigation. And, in spite of this, disaasters occur, as a sad proof that even more is to be done in this sense.

The activities devoted to disaster prevention / mitigation encompass complex aspects. They raise some common problems, irrespective of the nature of potential disasters, as well as specific problems, when concrete strategies are to be developed. Above all, a social task of highest importance must be emphasized: the development of disaster prevention culture, by means of appropriate education. The IDNDR Project (International Decade of Natural Disaster Reduction), enforced by the UN General Assembly on 25 December 1989, in operation from 1990 to 2000, put strong emphasis on the development and dissemination of the disaster prevention culture, and this sustained effort [9] had considerable positive consequences.

The author was involved in several activities and projects devoted to disaster prevention / mitigation, especially as a researcher on risk and safety of civil engineering structures and as an author of codes and standards on structural design. He encountered quite often, especially before 1990, a repulsive attitude, against in depth risk control, of persons in charge of supervising the regulatory basis of structural design, or of supervising some concrete projects. This was a sad proof of the precarity of their professional education, if not even worse.

2. SOME REFERENCES TO THE FRAMEWORK OF RISK ANALYSIS

Risk analysis represents a basic ngredent of disaster prevention. Like in many other cases of development of science and know how, risk analysis developed gradually, starting from some quite modest beginnings. The importance of using probabilistic approaches was increasingly recognized, due to the experience of randomness of occurrence of critical events and due to the increasing ability of specialists to understand and use probability based tools of analysis. An important step ahead was represented by the interdisciplinary meeting hosted in 1979 by UNDRO (United Nations Disaster Relief Office) – Geneva [8]. The document referred to presented a kind of first list of entities to be considered in risk analysis: *natural hazard*, *vulnerability*, *element at risk*, *specific risk*, *risk*. Even if the attempts of definitions of these entities, presented at that time, were quite vague and questionable, this first step played an uncontestably positive role in further activities of this field. As a notable example, the activities developed in the frame of the UNDP/UNESCO Balkan Project RER/79014, "Earthquake Risk Reduction in the Balkan Region" (1981 – 1983), [6], relied on this philosophy. An attempt of settting up of more precise definitions, to be usable for engineeering analyses (adapted to the case of seismic risk), was subsequently presented in the frame of activities of an EAEE (European Asssociation of Earthquake Engineering) Working Group [1].

Starting from these latter developments, with some updating, the system of entities presented in Table 1 is used subsequently as a reference. Further developments are presented in two appendices.

Table 1

Basic entities used in risk analyses

Entities considered	Definitions
Elements at risk	Any social value (people, property, function of social importance etc.) that can be adversely affected by the occurrence of a critical action specific to the framework adopted for risk analysis.
Critical action	An action that can, in case of occurrence, generate adverse effects upon the elements at risk .
Hazard	The expectancy of occurrence of a critical action (the use of probability based tools, if feasible, is desirable in order to conduct risk analyses; the use of the concept of stochastic process in order to quantify the expected recurrence characteristics is recommendable in this sense).

Table 1 (continued)

Entities considered	**Definitions**
Adverse effects	Any effects affecting elements at risk, like casualties to people, damage to buildings and property, losses to functional capacities etc.
Vulnerability	The proneness of elements at risk to undergo adverse effects in case of occurrence of citical actions. In case of appropriate quantifications of actions and of adverse effects, the use of conditional probabilities (or distributions) in order to characterize vulnerability is recommendable.
Exposure	The likelyhood of elements at risk to be exposed in case of occurrence of a critical action. The exposure may be full and permanent (as in case of a building located in a seismic area) or it can be variable (as in case of the audience in an auditory).
Risk	The expectancy of occurrence of adverse effects upon some elements at risk dealt with (the use of probability based tools, if feasible, is desirable in order to conduct risk analyses; the use of the concept of stochastic process in order to quantify the expected recurrence features is recommendable in this sense).
Scenario	A substitute to proper risk analysis, relying on conducting estimates of effects due to a conventional kind of action ("scenario action"), agreed upon.

3. REFERENCES TO SOME SPECIFIC ACTIVITIES

A look at literature or at specific practical activities dealing with risk analyses reveals the fact that there exists a wide variety of possible specific objects of such projects or activities. Taking into account at the beginning, as a reference, the activity of structural engineers, one can conduct such analyses at the scale of verification of a critical section of a structural member, as routinely done in current engineering practice, but one can shift gradually the scale of concern up to more complex objects, like the bearing structure as a whole for a building, for a bridge, for a tower etc. etc. Note here that, in case of estimating the probability of survival or, conversely, of failure of a critical section, the use of analytical approaches, as dealt with in Appendix I, may be feasible per se. On the other hand, passing, as a kind of next step, from the analysis of safety of a simple entity, like a critical section, to the analysis of a more complex entity, like a bearing structure as a whole, raises methodological difficulties hard to be overcome, as well as the need to develop / adopt techniques of a rather holistic nature. In case of dealing with bearing structures as a whole, a practically unlimited variety of concrete problems may be raised, due to differences in structural topology, in features of detailing, in features of critical actions etc. etc. Several further steps involving corresponding complications of the tasks of analysts can be easily emphasized, in case one thinks of even more complex entities like lifelines as a whole, like urban systems etc. In spite of this tremendous variety, the various activities of this field may and should rely on a common philosophy and, according to the author's belief, in order to develop reasonable approaches, this should be related at its turn to the concepts and bases of probability theory.

The fact that we do live in the era of computers may provide a hope to overcome the tremendous complications raised by the attempts to perform proper calculations: one can adapt the philosophy of Monte Carlo analyses as far as one is ready to pay for that in terms of corrresponding amounts of computing. The power of Monte Carlo procedures led FEMA (US Federal Emergency Management Agency [7]) to pay special attention to this way of doing and to edit corresponding manuals for practice. Of course, the adoption of the Monte Carlo approaches will require generation of huge samples of artificial input data corresponding to stochastic models of the various input entities (e.g. in case of analyses concerning loadbearing structures: actions, material characteristics, alternative assumptions on presence / incidence of various other factors etc.).

The disaster prevention/mitigation activities play an important role in advanced countries, where significant resources are allocated for them. A short look at the activities of just a few other organizations of USA, complementary to FEMA, acting in this field, like the Earthquake Engineering Research Institute [6], the World Institute for Disaster Risk Management of Virginia Tech. [11], or the Risk Management and Decision Processes Center at the Wharton School of the University of Pennsylvania [12], reveals promptly the proportions of the overall social efforts devoted to disaster prevention / mitigation. The manifold of activities under way in the USA, as well as the fact that, from several points of view, those activities are at the forefront of initiatives aimed at implementing more advanced procedures to engineering practice, resulted in the fact that, in several specific activities, the procedures developed there are adopted in other regions too. Perhaps one of the best known examples is represented by the calibration of the return period for which conventional seismic action is specified: 475 years (which is equivalent to 10% probability of exceedance for an exposure duration of 50 years). This calibration was adopted e.g. in the Eurocode EC8 [5]. Not to neglect here the fact that there exists a sustained trend to increase the return period referred to, in order to reduce the exceedance probability mentioned previously.

As mentioned before, the problematique of engineering structures is by far not the single one to be considered in this frame. We can think of various vital networks / lifelines, like water, gas, oil pipelines, of transport networks like roads, freeways or railroads, of urban systems as a whole, for which the protection / preservation of functionality is required etc. etc.

Of course, this is not a pledge in favour of eliminating the contribution of expert judgement, whose capital importance is to be recognized and which may often come up with contributions of paramount importance to the activities of disaster prevention / mitigation.

4. SOME MAIN COMPONENTS OF DISASTER PREVENTION / MITIGATION ACTIVITIES

Disaster prevention / mitigation activities involve, as main components:

- protection measures aimed at limitation of effects of eventual occurrence of critical actions / events, which should rely at their turn on appropriate hazard, vulnerability and risk analyses;
- preparedness measures aimed at providing the capacity of post-occurrence mitigation and relief reaction, which should rely at their turn on a development of disaster scenarios;
- preparedness measures aimed at providing the capacity of developing recovery programs and of achieving their goals, which should rely at their turn on appropriate strategies of general development.

5. AN ILLUSTRATIVE CASE: OBSTACLES TO EARTHQUAKE RISK REDUCTION ENCOUNTERED IN ROMANIA

Seismic risk is widely recognized to be the most important natural risk affecting Romania. Besides specific evaluations, the experience of the destructive earthquake of 1977.03.04 [1] dramatically confirms the proportions and social importance of this factor.

It is appropriate, for illustration, to mention some problems encountered by the author in connection with the need to control and reduce the seismic risk that is specific to Romania [4]. The experience at hand and the examination of the causes of non-satisfactory results to date in relation to seismic risk reduction makes it possible, and also necessary, to emphasize some main causes and obstacles having led to this non-satisfactory situation.

There are definitely important obstacles of financial nature to earthquake risk reduction. While the total resources required in order to bring the existing elements at risk (first of all those for which the primary vulnerability, i.e. the vulnerability against ground motion, counts) to a state of risk as accepted by the regulatory basis currently in force, would reach the range of thousands of millions of US$, the resources made available yearly for risk reduction activities were during the post-1977 decades in the range of millions or of tens of millions of US$. Yet the lack of appropriate financial resources cannot be by far blamed as a unique obstacle hindering these activities. It is a main point of this paper to emphasize some other critical factors in this connection.

A crucial category of obstacles, routinely not referred to, is represented by the limits to various kinds to knowledge and by the reluctance to spend more resources in order to improve knowledge. First of all, there do not exist satisfactory databases listing the elements at risk to be tackled, in all fields where such elements at risk exist. Then, there do not exist satisfactory databases on the outcome of evaluation of the relevant elements at risk. Moreover, there are often quite severe methodological limits concerning the ability of experts to evaluate existing works in a way to lead to results compatible with the outcome of observation of actual performance during strong earthquakes, as well as the ability to derive efficient and economical solutions of reducing vulnerability. In some way, on a complementary side, there are limits to the know-how on hazard evaluation, especially for sites of facilities raising special problems (facilities including high-risk sources, strategic facilities etc. [3]), as illustrated in previous subsection.

Another category of obstacles is represented by the shortcomings of the current legislation and regulatory basis. There is e.g. no regulation for creating buffer room (which was so important in 1977 and thereafter) as required for people having become homeless during earthquakes or for occupants of buildings requiring temporary evacuation in order to make possible radical strengthening. There is no efficient regulation to compel to evacuation by occupants in cases when radical strengthening solutions impose this. There is no regulation to provide efficient leverage created by insurance activities in order to push owners/occupants to become active partners in risk reduction activities. In a different connection, the author encountered often severe secret mania in connection with the actual level of protection of works including high risk sources.

Finally, one should not neglect some categories of obstacles of less tangible nature, yet of undeniable importance. They refer essentially to the lack of appropriate willingness of various socio-economic groups involved, to surpass the difficulties and, ultimately, get risk reduced. One may state in this connection that the disaster prevention culture is not sufficiently developed. One may state this often in relation to the attitude of the population as a whole, but also at the level of specialists or of persons or groups having special responsibilities. One could state, from a somewhat different viewpoint, that there is a lack of appropriate political will, at the level of various agencies or persons playing a formal role in the frame of various agencies, institutional structures etc., as well as at the level of what should be a vigorous civil society (even honesty questions may be raised in this latter connection too). The allocation of appropriate resources for risk reduction depends heavily, of course, on this political will.

The picture of obstacles presented may be not sufficiently comprehensive or detailed, but the obstacles referred to and their critical character can be hardly denied. It provides a view on the actual size of the task of reducing seismic risk to a level not too far from the philosophy and requirements of regulations in force for new developments.

6. SOME MEASURES PROPOSED IN THE SHORT TERM

1. It is necessary to promptly initiate the development of a general national strategy for disaster prevention / mitigation.

2. As one of the essential components of this strategy a comprehensive plan of education of various socio-economic categories is to be developed. This should be addressed in specific terms to

the specialists of various categories, to the politicians and decision makers, to the mass media of various categories, as well as to the population as a whole. This should efficiently contribute to the improvement of the disaster prevention culture.

3. In order to enforce the development of activities required in this field, a trans-party binding political agreement is to be conceived and solemnly adopted.

4. A comprehensive inventory of risks and of factors related to them, as specific to our country, is to be developed. This should function as a guideline aiming at avoiding to neglect some relevant contributors to the system of risks affecting our country.

5. The transparency of information on the features of various risks and factors related to them should be provided. The various socio-economic categories should be enrightened by law to be informed and to be able to participate in the adoption of specific strategies and measures.

6. The mass media should prepared to play a systematic and positive role in the control and mitigation of risks, avoiding tabloid type activities.

7. The NGO’s should be informed and educated in order to be active and useful prtners in this field.

8. Information of strategies and activities under way in advanced country should be made available.

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Appendix I

AN IDEALIZED ILLUSTRATIVE CASE: SOME REFERENCES TO STRUCTURAL RISK ANALYSIS

A formal, schematic, framework of analysis of seismic risk affecting structures, is used at this point as a reference for more specific developments, as referred to in subsequent sections. A probabilistic approach is used. The approach presented corresponds to the so-called 3-rd level approach, to distinguish it from the 1-st level approach on which current codes for practice (e.g. the Eurocode *EC8* [I, 1]) rely, or from the 2-nd level approach (e.g. FOSM), based on the use of lower order moments of random variables involved. It may be worth mentioning in this respect that only the 3-rd level approach, which is currently not yet a tool for practice, allows for consistent, in depth, safety / risk analyses with a suitable flexibility of objectives.

The basic model, obviously strongly idealized (1D approach, discrete modelling etc.) is as follows:

a) *with respect to seismic action and hazard*:

- it is assumed that seismic action may occur, as a sequence of events of negligible individual duration, at various possible time moments t_i, during a certain reference (long) time interval of duration T;
- it is assumed that seismic action (at the level of a definite site) may occur with various severity characteristics, which may be globally quantified by means of a scalar parameter q, which is quantified subsequently at its turn by means of discrete values q_j, (where the indices j = 1... J are positive, integer values); moreover, it is assumed that the sequence of values q_j represents levels of severity increasing with increasing j;
- the likelihood of occurrence of seismic action (at a sequence of randomly occurring levels of severity that may endanger various exposed elements), is referred to as *seismic hazard* (at a site of interest dealt with) and is quantified according to subsequent developments;
- the seismicity at site level, or more precisely local seismic hazard, referred to at a level that is relevant for a site of interest, is assumed to be stationary and to correspond to a Poissonian model, which is basically characterized by the sequence of values $n^{(h)-}{}_j$ (where the superscript $^{(h)}$ stands for *hazard*), representing (in probabilistic terms) the *expected frequencies of occurrence* of events of severity levels q_j; besides this, one may consider the *expected cumulated frequencies* of reaching or exceeding the values q_j, $N^{(h)-}{}_j$,

$$N^{(h)-}{}_j = \Sigma_{j'}{}^{j,J}\, n^{(h)-}{}_{j'}, \tag{I.1}$$

the *expected return periods* $T^{(h)-}{}_j$ of events having levels of severity at least q_j, i.e. $q_{j'} \in (q_j, q_J)$,

$$T^{(h)-}{}_j = (N^{(h)-}{}_j)^{-1}, \tag{I.2}$$

the *probabilities of non – occurrence and non – exceedance*, *during an observation time interval T*, of a level of severity q_j, $\boldsymbol{P}^{(h)}{}_{j0}\,(T)$ (where bold characters stand in this section for probabilities), which according to the Poissonian model are

$$\boldsymbol{P}^{(h)}{}_{j0}\,(T) = \exp\,(-\,T\,/\,T^{(h)-}{}_j\,), \tag{I.3}$$

more generally, the *probabilities of m times occurremce or exceedance* (m = 0, 1, 2, ...), *during an observation time interval T*, of a level of severity q_j, $\boldsymbol{P}^{(h)}{}_{jm}\,(T)$, which according to the Poissonian model are

$$\boldsymbol{P}^{(h)}{}_{jm}\,(T) = \exp\,(-\,T\,/\,T^{(h)-}{}_j\,) \times (\,T\,/\,T^{(h)-}{}_j\,)^m\,/\,m! \tag{I.3'}$$

$$\text{(of course, } \Sigma_m{}^{0,\infty}\ \boldsymbol{P}^{(h)}{}_{jm}\,(T) \equiv 1\text{);}$$

b) *with respect to a structure dealt with*:

- it is assumed that the structure may be affected, due to earthquake occurrence, at various levels of damage, which may be globally quantified by means of a scalar parameter d, which may take discrete values d_k, (where the indices k = 0... K are non-negative, integer values); moreover, it is assumed that the sequence of values d_k represents levels of damage severity increasing with increasing k, where k = 0 means intact structure, while k = K means maximum possible damage, or destruction;
- it is assumed that, after every seismic event, the structure is promptly and perfectly rehabilitated, such that successive seismic events encounter, in each case of occurence, the same structure;

- the possible effect of occurrence of seismic action at a level of severity q_j will be that, that damage of a level of severity d_k may affect the structure, i.e. that the structure is vulnerable; the damage severity level d_k is random; the *vulnerability of a structure dealt with* will be characterized by the system of conditional probabilities $\boldsymbol{p}^{(v)}{}_{k/j}$ (where the superscript $^{(v)}$ stands for vulnerability); (of course, $\Sigma_k^{0,K}\, \boldsymbol{p}^{(v)}{}_{k/j} \equiv 1$, for any index j);

c) *with respect to the risk of structures to be affected*:

- it is assumed that earthquake induced damage may occur, as a sequence of events at various possible time moments t_i, during a certain reference time interval T, due to the occurrence of earthquakes and to the existence of seismic vulnerabililty of structures; the sequence of these (adverse) effects is characterized and quantified according to the features of hazard and vulnerability, referred to previously;
- the likelihood of occurrence of earthquake induced damage (at randomly occurring levels of severity), is referred to as *seismic risk* (for a structure dealt with) and is dealt with according to subsequent developments;
- the seismic risk is assumed to be stationary and to correspond to a Poissonian model, which is basically characterized by the sequence of values $n^{(r)-}{}_k$ (where the superscript $^{(r)}$ stands for *risk*), representing (in probabilistic terms) the *expected frequencies of occurrence* of damage of severities d_k; the values $n^{(r)-}{}_k$ are determined on the basis of the convolution expression

$$n^{(r)-}{}_k = \Sigma_j^{0,J}\, \boldsymbol{p}^{(v)}{}_{k/j} \times n^{(h)-}{}_j. \qquad \text{(I.4)}$$

- besides this, one may consider the *expected cumulated frequencies* $N^{(r)-}{}_k$, the *expected return periods* $T^{(r)-}{}_k$ of events having levels of severity not less than d_k, the *probabilities of non – occurrence and non – exceedance*, *during an observation time interval* T, of a level of severity d_k, $\boldsymbol{P}^{(r)}{}_{k0}$ (T), or more generally, the *probabilities of m times occurrence or exceedance* (m = 0, 1, 2, ...), *during an observation time interval* T, of a level of severity d_k, $\boldsymbol{P}^{(r)}{}_{km}$ (T), on the basis of expressions that are homologous to the expressions (I.1)...(I.3').

It must be mentioned that previous developments are rather illustrative and correspond to the simplest possible situation, or models. The various assumptions accepted may be questioned and may be generalized, which would lead, of course, to more complex ways of quantification and relations.

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Appendix II
DERIVING LOCAL SEISMIC HAZARD CHARACTERISTICS

It is assumed, in this appendix, that the overall size of an earthquake is quantified in scalar terms, by means of a certain type of *magnitude*, denoted M. It is also assumed that the severity of ground motion at a certain site is quantified in scalar terms too, by means of an *intensity*, denoted I. In case one looks at the features of earthquakes, one remarks a statistical tendency of decrease of intensities at various sites, with increasing distance from source to site, called *attenuation*. Experience shows that the attenuation phenomenon is characterized by considerable randomness. According to data obtained during recent strong earthqaukes of Romania, the r.m.s. of the random intensity, σ_I, is not less than one intensity unit [II.5], [II.6].

A first notable attempt to derive local hazard characteristics using probability based tools is due to Cornell [II.1]. The attenuation randomness was unfortunately neglected in that paper. A more recent attempt, which takes consistently into account the attenuation randomness (keeping nevertheless the assumptions on the scalar nature of M and I), is due to Mc Guire [II.2]. The author presented in [II.3] a more general attempt, in abstract, discrete terms, allowing for a multi-parameter characterization of earthquake as a whole and of ground motion severity at a site. He derived, already earlier than Mc Guire, equivalent relations, in [II.4]. This latter approach is as briefly presented subsequently, using notations that are congruent with those of Appendix I.

Assuming that an earthquake source is located at a point of coordinates (x, y, z), the frequency density of events of magnitude $M = m$ at that point is denoted $n^{(M3)}$ (m, x, y, z). The frequency density of events of magnitude $M = m$ in a definite source domain, $n^{(M)}$ (m), may be determined by means of the relation

$$n^{(M)}(m) = \int_x \int_y \int_z n^{(M3)}(m, x, y, z)\, \mathrm{d}x\, \mathrm{d}y\, \mathrm{d}z \qquad \text{(II.1)}$$

The attenuation phenomenon is characterized by the conditional probability density of intensity $I = i$ at a surface point (x_0, y_0), in case an event of magnitude $M = m$ occurs at a point (x, y, z), expressed as $f^{(I,\, M)}(i, x_0, y_0 | m, x, y, z)$. Adapting the formula of total probabilities to the problem, it turns out that the frequency density of intensity $I = i$ at the point (x_0, y_0), $n^{(I)}$ (i, x_0, y_0), is given by the expression

$$n^{(I)}(i, x_0, y_0) = \int_m \int_x \int_y \int_z f^{(I,\, M)}(i, x_0, y_0 | m, x, y, z)\, n^{(M3)}(m, x, y, z)\, \mathrm{d}m\, \mathrm{d}x\, \mathrm{d}y\, \mathrm{d}z \qquad \text{(II.2)}$$

In case one wants to determine other characteristics of local hazard, homologous expressions to those of Appendix I are to be used.

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