A practical Strategy to Reduce Earthquake Risk for Critical Infrastructure Systems

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Extended abstract

Unlike other natural hazards like slope instabilities, avalanches, floods etc., earthquakes affect large areas. Earthquakes happen unexpectedly, and all persons and structures in a whole region are affected at the same time. This leads to a widespread damage to the building stock, equipment and to human beings, and also to significant psychological stress even to those not physically harmed, resulting in a lack of overview and confusion in the first hours to few days after an event.

Modern earthquake resistant design codes for structures only exist since the 70's and 80's of the last century, whereas similar codes for equipment and installations mostly do still not exist. Therefore it is estimated that over 80% of the building stock and equipments in industrial and developing countries are not designed against earthquake effects. The corresponding earthquake resistance is unknown, in general not sufficient. Due to economic reasons, an earthquake resistant building stock can be achieved in a long term perspective only. Taking this into account, disaster response and reconstruction will still have a high priority also in the near future.

For an efficient disaster response, the emergency assistance and the following reconstruction efforts (and therefore for the economic recovery), a - at least partially - **functioning** infrastructure is mandatory. The priority in the prevention activities should therefore be given to endeavours which protect the infrastructure system. As experience show, authorities are aware of this fact, but do not know how to handle this task efficiently. That is why prevention projects are started which often do not lead from the beginning to a fast and efficient improvement.

Infrastructure systems like water supply and waste disposal, power supply, health systems and transport systems are wide and complex systems consisting of linear elements (e.g. main and distribution lines) and local elements (e.g. command/control centres, hospitals, computer centres, etc.) which are interconnected and with each element interacting with the others. The function of the whole system is affected by all elements and depends not only on the structural behaviour of the elements, but also on power supply, communication, control systems, redundancies and the possibility of human intervention.

Infrastructures are large, very complex systems, ranging from main distribution systems to simple feeder systems for individual consumers. The elements of such a system are daily exposed to several, often not known effects in respect to size and number. Therefore limited damage has to be expected also in ordinary times, even for well-maintained systems. This is acceptable as long as the damage can easily be repaired and does not affect the functionality of the entire system. An example would be a pipe break in a water distribution system.

The so-called **"critical infrastructure"** is a part of an infrastructure system. It consists of the main feeder lines and the main command/control centres. It is a backbone for the services of a

nation, a region or a large metropolitan area. It is essential for the operation of industrial services and for the living condition of the population.

The individual infrastructure systems have different legal status. Some are directly government-owned (e.g. road systems), other are owned by utilities (which in turn are owned by individual or several Municipalities or private companies), other are directly controlled by local Governments, and still other are private or belong to private/public partnerships. Often the result of this different legal status leads to unclear responsibilities and guidelines in respect of emergency requirements and of interfaces between the different infrastructure systems.

In case of an emergency, the public cannot expect the infrastructure systems to behave like in normal times. Depending on the size of the emergency event, a so-called "reduced mode" of operation has to be accepted due to economic reasons. E.g., in case of a large event, it may be acceptable that the water supply will break down in low density residential areas, but it should still function in areas with high population density (fire fighting) or in industrial zones.

Generally, the utility personnel has a very good knowledge and understanding of the characteristics of their systems with their weak and strong points, but are lacking the knowledge of the earthquake effects. At least in industrial nations, utilities can usually rely on computer programs and other planning instruments to study the flow pattern in their systems and can therefore simulate the effects of a damaged and only partly functioning system in advance.

The following strategy has been successfully fully or partly implemented in several cases in practice. **It aims to enable a predefined functionality of the entire system in a predefined scenario event.** An example of a reduced operational mode for a water supply system could be:

- In an event with a return period of 475 years (equivalent to the building code earthquake return period) the main distribution system (including main reservoirs) as well as the command/control centres remain fully operational. Widespread damage to the distribution system of the individual households is allowed, whereas the feeder system to large industrial complexes has to remain functional.
- In case of the largest credible event in this area, also limited damage to the main system is acceptable, but the repair of the system should be possible within one to four weeks.

Based on a threefold triage, the elements of the system which need an improvement of their functional capacity are identified. Thus a substantial enhancement of the functionality in case of an earthquake event can be efficiently achieved from the beginning. With this concept the responsible authorities are able to prepare a long-term investment planning, taking into account their financial capabilities.

The paper / presentation describes the following procedure and the criteria for individual decisions in more detail:

1. The owner of the utility has to define an acceptable "reduced mode of operation" of its system for individual earthquake scenarios (e.g. for an event with return period of 500 years and for a very seldom event). This is a socio-political decision.
2. Segmenting the system in individual elements (linear and local elements) and defining their importance in respect to the functioning of the whole system (Triage 1). This will lead to few elements whose functionality is crucial for achieving the defined reduced mode, and a larger number of elements of lower importance. See also Figure 1 (importance classes). The segmentation and the allocation of elements to different importance classes can be performed by the utility itself, with the help of their experience and their planning software. The earthquake engineer will be the counterpart to discuss individual points.
3. Triage procedure 2 for the essential elements: Individual estimate of the local earthquake hazard (taking into account local geotechnical conditions and topography) and vulnerability of each element based on different indicators (geotechnical, structural, power communication related, etc.). Grouping in three classes "ok" (no further action needed", "not o.k." and "uncertain". See also Figure 2. The criteria in this triage are very crude (structure: e.g. age of structure, structure type, building material; earthquake hazard: e.g. earthquake zone and soil types of building code, power redundancies, etc.)
4. Triage procedure 3 for elements in the group "uncertain" and "not ok": Individual assessment of the local earthquake hazard (taking into account local geotechnical conditions and topography) and vulnerability of each element based on different checklists and simple calculations. Grouping in two classes "ok" (no further action needed" and "upgrade needed". See also Figure 2. The level of this triage is such that a clear distinction between "o.k." and "upgrade needed" is achieved. Upgrade concepts for individual elements will be performed in a later planning stage of an individual element.
5. Upgrade concept for class “upgrade needed” and program for realisation.
6. Iterating the points 3 to 5 for the “important elements”.
7. If needed, also some investigations for selected “less important elements” are performed.

This concept can also be used to evaluate the risk in other natural hazards.

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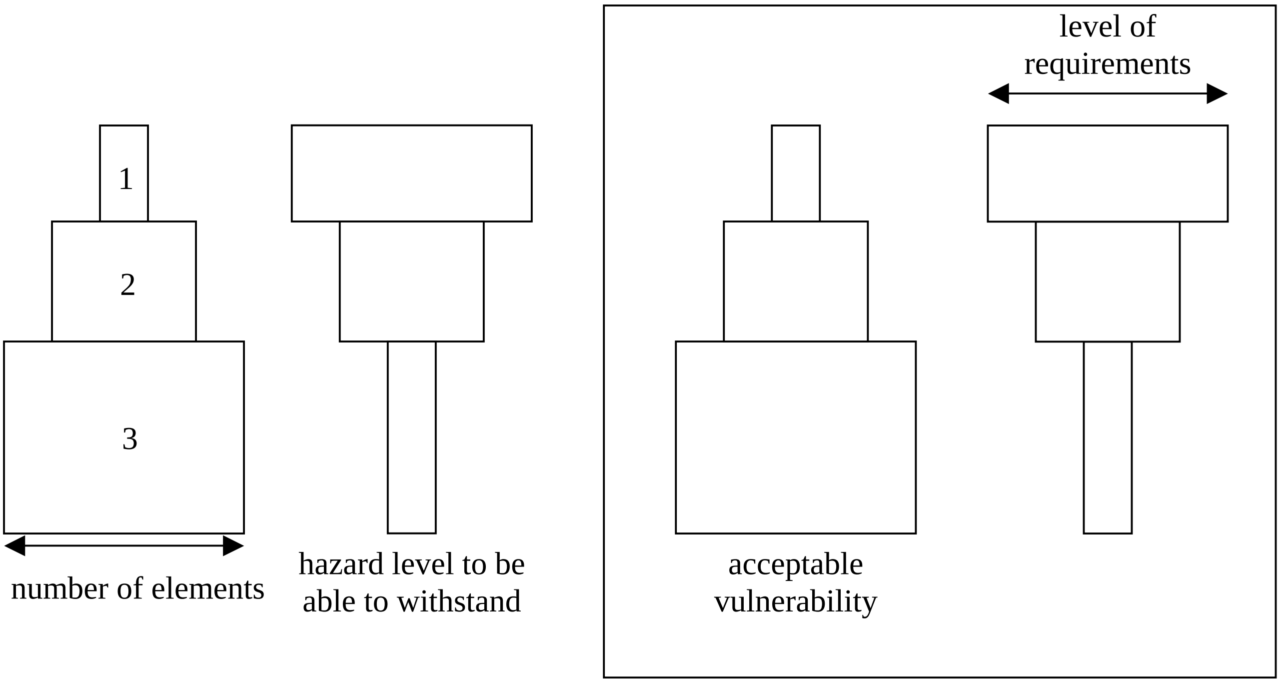

Legend:
1 “essential elements”: e.g. command/control centres, reservoirs, backbone distribution lines, etc.
2 “important elements”
3 “less important elements”: e.g. distribution systems to households, etc.

Figure 1: Importance classes and their acceptable vulnerabilities for a selected hazard level

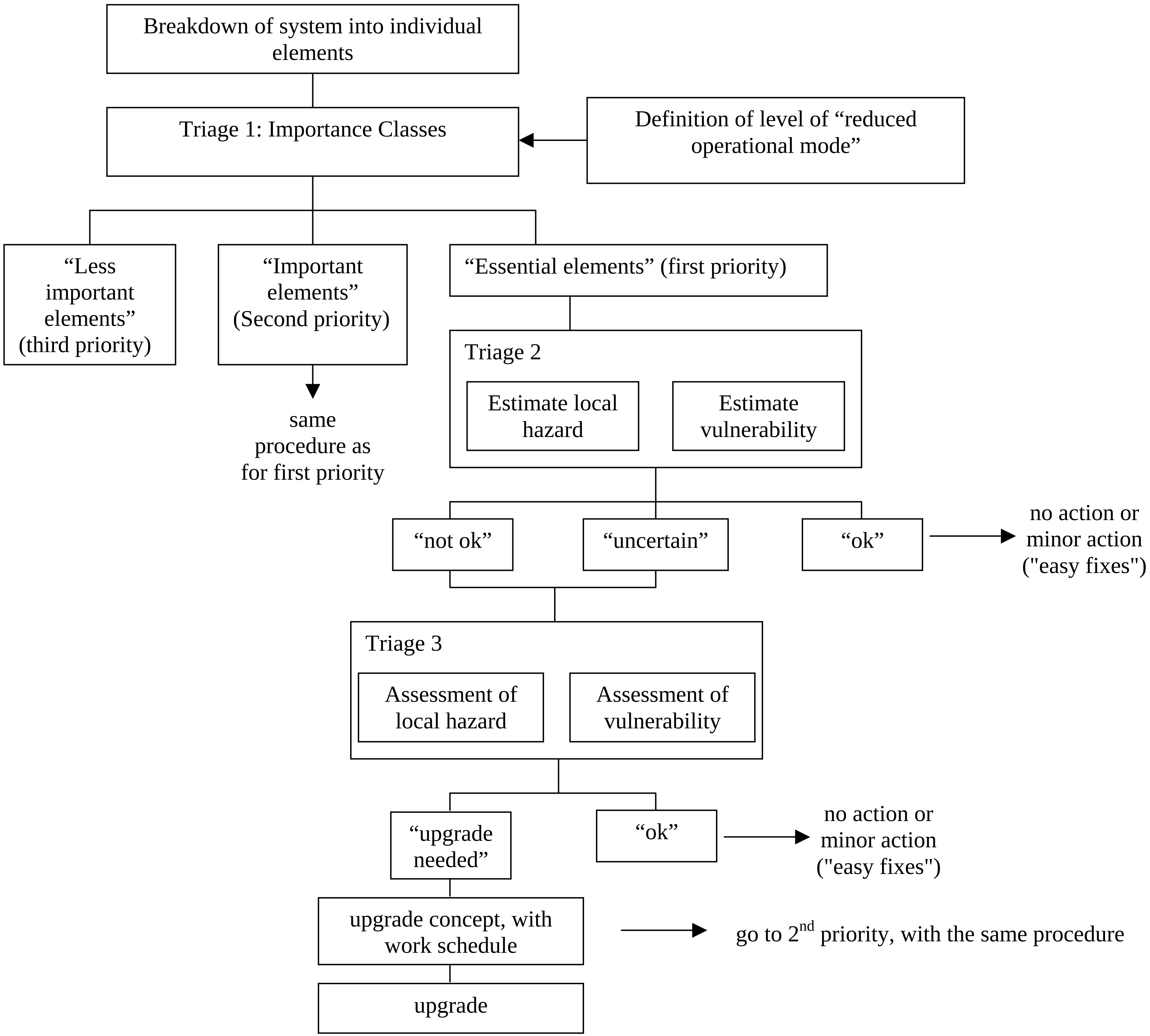

Figure 2: Triage procedure