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RESILIENZA DELLE CITTÀ D'ARTE AI TERREMOTI

ENHANCING RESILIENCE OF HISTORIC CITIES TO EARTHQUAKES

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Il Convegno è stato organizzato con il contributo della
Compagnia di San Paolo di Torino

INTRODUZIONE

L'Accademia Nazionale dei Lincei, anche a seguito di un invito pervenuto dall'IAP (già InterAcademy Panel, oggi Global Network of Science Academies) ad avviare iniziative scientifiche in materia di "Disaster risk reduction", ha deciso di organizzare tre incontri scientifici.

Il primo convegno *Resilienza delle città d'arte alle catastrofi idrogeologiche: successi e insuccessi dell'esperienza italiana* si è svolto a Roma nei giorni 4 e 5 novembre 2014 (i cui contributi sono editi nel volume Atti dei Convegni Lincei 293, Roma 2016).

Il presente volume raccoglie tutti i contributi ricevuti dall'Accademia a conclusione del convegno *Resilienza delle città d'arte ai terremoti - Enhancing resilience of historic cities to earthquakes*, organizzato dall'Accademia dei Lincei – Comitato ordinatore: M. Caputo, R. Codello, G. De Felice, C. Doglioni, M. Livi Bacci (Coordinatore), G. Panza (Coordinatore), A. Quadrio Curzio, G. Seminara, A. Sgamellotti, L. Ubertini – come contributo alla XXXIII giornata mondiale dell'Ambiente e svoltosi a Roma nei giorni 3 e 4 novembre 2015.

Molti i temi che sono stati trattati, con particolare attenzione ai successi ed alle migliorie possibili, non solo nella definizione realistica e responsabile della pericolosità sismica ma anche nella scelta consapevole delle misure ottimali che devono essere adottate per prevenire i disastri, nell'ottica di una effettiva costruzione di una società resiliente alle catastrofi. I tragici eventi legati al sisma di Amatrice, avvenuto mentre questi Atti erano in stampa, confermano l'urgente attualità della questione.

Nella home page dell'Accademia (http://www.lincei.it/), alla voce "Foto e Video", è presente un canale YouTube all'interno del quale, alla sezione "Conferenze e Convegni" è visibile la registrazione delle presentazioni orali, suddivisa in cinque parti.

Roma, Settembre 2016

MASSIMO LIVI BACCI
GIULIANO FRANCESCO PANZA

Paolo Rugarli[(a)]

THE ROLE OF THE STANDARDS IN *THE INVENTION OF THE TRUTH*

Introduction

The invention of the Truth is an essay written in 1934 by Bruno de Finetti (de Finetti 1934), one of the leading Italian mathematicians and thinker of the XX[th] century, famous for his proposal of the subjective interpretation of probability.

According to this view, which got increasing importance in the last decades, no objective probability can be estimated: each probability estimate is fully subjective and can be considered as the "degree of belief" that someone has toward a fact or an experimental evidence, a "degree of belief" that is in a continuous evolution as a function of new evidence (so called Bayesian approach).

The essay is important because de Finetti explains how human beings build a possible representation of the outer world, based on inductions and definitions. One of the side effects of the essay is that "objective" probability definition is clearly explained as impossible and baseless. Consequently, founding a Law on probability estimates is meaningless, or dictatorial.

In current engineering practice, many *inventions of the truths* are needed in order to assure a common practice and a common language, when dealing with engineering issues. Albeit some of them have kept their place during the centuries and are considered universal achievements, or Nature Laws, like energy conservation principle, or classical mechanics laws, some agreed concepts in physics, or practice in engineering, turned out to be false, or dangerous, and had been gradually dismissed. This was true not only for general concepts (like space and time independence, or absolute time, a buttress of classical physics) but even more for specific techniques and or engineering "practices" and "theoretical" models.

For instance, the practice of reinforced concrete buildings has been deeply modified in the last decades, when earthquakes have shown some of

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the weaknesses of the rules previously considered safe because evaluated in light of too partial, and sometimes blind, *invention of the truths*. Some examples:

- the role of the distance of the stirrups, and their proper closing, in restraining the outward buckling of longitudinal reinforcing bars of columns, has been fully understood only when the external buckling of these bars under strong percussive loads had been observed (for decades and decades Italian laws did not ask for 135° bending of stirrups, preventing their out-of-core opening).
- The danger related to irregularity in elevation and in plan has for long time been unknown, because the *invented truth* was that reinforced concrete structure were *safe, and that's it*. Many multistorey reinforced concrete buildings, presently inhabited, were computed assuming columns loaded only by perfectly aligned vertical *axial forces*, with no lateral loads at all.
- Assuming that many Italian municipalities (almost all) were "not seismic", and building according to this *truth*, led to hundreds thousands unsafe structures, currently up and full of people, whose life is at stake. Thousands trilithic industrial buildings have been built, in Italy, with no connections of the transverse over the columns: "friction will be enough", following the same invented *truth*.
- The addition of stiff massive slabs to masonry structures roofs has often been observed as potentially triggering disasters, during earthquakes, but it was considered a good step toward a "box behavior".
- ...

Today, many forced-by-law *inventions of the truth* are put at stake by new evidence, with deep consequences when dealing with historical, not repeatable structure and heritage. One of the common concepts emerging in the literature criticizing these *inventions of the truth*, is the danger of forcing reality to fit the model, and not the opposite. This can have the unwanted effect of wasting enormous amounts of time and money, or the effect of underestimating the risk, as using probabilistic seismic hazard assessment (PSHA). It can also have the risk of raping the historical heritage with reinforced concrete elements, ugly, out of context, false, and potentially dangerous.

The need of Laws enforcing the *inventions of the truth,* has been progressively considered necessary in structural engineering, especially in Europe where Laws are particularly complex (it is not true in medical care or other critical professions). This was due to the spreading of the constructions, their increased complexity, and to the need of quick and safely built structures. But this is also due to the loss of the typical skill of old building masters and workers, often replaced by people lacking any skill in the building yards (at least in Italy), and also, unfortunately, in the technical offices. The Law should then teach. Or oblige. The side effect of this degeneration is that one of the current *truths*, completely false, is on one hand that all is written in the Law must be strictly applied even if it's not applicable, and on the other hand that if something is not required by the Law, or not explicitly listed, it is not necessary. "The Law was not upgraded", is then the excuse.

Technical Laws, including Italian Technical Laws (NTC 2008) and Eurocodes, are written in a too specific and too prescriptive fashion (albeit paradoxically declared "performance based"), and consider models too simple, some would say too rough, and too generic, to be applied to the existing historical buildings. The Italian specific heritage hardly fits into the models provided by NTC or Eurocodes, and this has posed and is continuously posing tough problems to engineers, architects and heritage caretakers. In the author's opinion, a specific new branch of structural engineering is needed to take care of our historical heritage. It is questionable to apply methods conceived for Los Angeles high rise (for us), highly regular steel buildings, to two floors, highly irregular masonry skin walls medieval buildings, or churches (read: pushover).

The effect of models unfit for their target, but forced by Law, is sometimes disastrous. As it is the Law to require their use, engineers are forced to apply them and consider a potential danger for their career and honors to openly refuse to apply these rules even when they are not applicable or baseless. Besides, confusion between ignorance and criticism has been triggered by too simplistic comments coming from the academic world.

It's time to turn the page.

Mass fallacies

A considerable set of studies of cognitive sciences shows that human behavior is not always rational (for a review and an excellent well known introduction Kahneman 2011). Several effects might operate in order to reduce the rational behavior of human beings, when considered in light of the axioms of rational choice, sometimes leading to "less than optimal" decisions (e.g. Stanovich 2013, where it is also claimed that humans are sometimes less *rational* than other animals).

Starting from the 50s, the influential work by Kahneman and Tversky and other scientists, has shown that human beings use heuristics and are affected by bias issuing judgments and taking decision. A number of cognitive fallacies have been enumerated, in order to help distinguish and remove them. Some of these fallacies are directly related to the tendency of human beings to believe or accept theories or assumptions, which are not rational, but that trigger simple heuristics (so called *Type One Processes*, Kahneman 2011). Moreover, social errors like the *halo effect* (the erroneous assumption that if a source is valid in doing something, or attractive, or powerful, will do well everything) or the *genetic fallacy* (the tendency to accept as not questionable what is issued by experts or authorities), tend to drive masses, and not only single human beings, to a bad and badly aligned cognitive performance. The result is puzzling: collective meaningless and senseless behaviors.

History, news and literature are full of examples of these general failures to recognize evidences.

As to history, one can think at the difficulties faced by Galileo Galilei, so well known that is useless to remember; or faced by Ignàc Semmelweiss, who proposed to wash hands before touching pregnant woman after having touched corpses, reducing dramatically the puerperal fever incidence, and was fired; or the difficulties faced by Alfred Wegener himself, who proposed the Continental Drift theory and was bitterly criticized.

As to news, my preferred example is the case of The Fake Modigliani's Heads, 1984, when a whole Nation turned into art experts, claiming the authenticity of stones actually sculpted by some boys using a Black and Decker device (Mangiapane). Academics were in the first row. Only when the boys who made the fakes where shown on TV replicating the trick, people (but not some experts!) ended believing they were Modigliani's.

As to literature, *magistra vitae* not less than history, the clear example is Andersen's tale *The Emperor's New Clothes*, derived from an ancient Hispanic tale, *El Conde Lucanor* by Don Juan Mauel, even more convincing, or *The Pied Piper of Hamelin*, by Brothers Grimm also taken from older traditions.

So we can assume that mass fallacies are there, ready to fool us. It has already happened, and will again.

In generating mass fallacies, a special part is played by the Law, or the Standard, or by the behavior of majority. In order to avoid socially shameful choices, like explicitly criticizing Law, or suggesting to refuse its application, the majority obeys. Many experiments have been carried out referring to the issue, "irrational adhesion to majority" (e.g. see Sherif 1935).

An irrational mass behavior has been observed with particular strength and evidence in history. For instance, one example is the criminal behavior of soldiers during WW II infamous mass killings. Goldhagen (Goldhagen 1996) writes about the mass-murdering perpetrated by Battalion 101: very few soldiers refused to kill no matter the freedom to refuse. Why? Another example is the surprising acceptance of shameful laws like those issued in the 30s in Italy and Germany. Some were shameful, but some other silly:

During the 30s, new laws were issued asking to change the salutation formula: “Heil Hitler!”, was then required also when meeting a doctor informing of the death of your mother. Basically stupid, but followed in due respect, and not only for fear, by millions of people.

So it’s clear that the mass behavior is often irrational, and this happens also in subsets of the population that indeed should use rationality as a working tool, like engineers and scientists (e.g. Kahneman 2011, Gigerenzer 2002).

> “Finally, the illusions of validity and skill are supported by a powerful professional culture. We know that people can maintain an unshakable faith in any proposition, however absurd, when they are sustained by a community of like-minded believers.”
>
> (*Thinking Fast and Slow*, Kahneman, 2011)

However, there are problems when issues where *normative reasoning* should prevail, are instead managed by social heuristics and biases. The danger is the waste of money and the public threat.

In the next two sections, two *truths* currently enforced by the Italian Law, and “sustained by a community of like-minded believers” will be examined. As their inability to properly tackle the problems for which they were proposed is evident, the only possible explanation for their use is the mass fallacies that have been briefly remembered, or the legitimate interest of a subset of players, related to them.

Probabilistic Seismic Hazard Assessment (PSHA)

Probabilistic seismic hazard assessment (PSHA) is a method proposed by engineers, in the late 60s, in order to assess the seismic hazard in a probabilistic fashion (Cornell 1968).

Fixed a site and a *probability of exceedance*[1] **P** in a *reference period* V_R, a *return period* T_r of earthquake is found, which is then used to assess the severity of the shaking at a site, using historical catalogues, Gutenberg Richter relation (GR) and more.

GR is valid only at a global, or very large scale level (very large areas, large enough so that any earthquake, regardless his spatial extension, can be considered a point), and states that, in the point-source approximation, the number of earthquakes and their magnitude are related by a linear law in a logarithmic plane: decreasing earthquake magnitude M of one unit, the number of events N is multiplied more or less by ten.

(1) I will use italics to emphasize these are fakes.

$$\text{Log } N = a - bM.$$

where b is around 1, and a is a constant.

For normal buildings, the Italian Law requires **P**=10%, V_R=50 years which leads (see below) to T_r=475 years. If the *probability* **P** is changed, e.g. from 10% to 5%, or if the *reference period* V_R is changed, e.g. from 50 years to 30 or 100 years, it changes the *return period,* and thus the severity of the earthquake used to evaluate structural behavior. Ideally, if a continuous set of values is used, **P**=0.01-0.02-0.03…, V_R=35-36…101-102…, a continuous set of *return periods* and of severities of ground shaking can be found. However, no such continuity has been observed, in a specific site, nor it can be proved theoretically. So, its existence is an uncheckable postulate.

As the choice of *probability* and *reference period* is arbitrary, one can choose the severity fit for his/her need. This is what I call the "earthquake supermarket", but surprisingly is considered strength of the method due to "performance design" needs (see below).

Albeit clever, the method has no ground. An impressive number of works, not issued in the last months, but in the last decades, have shown that it is baseless and that moreover unsafe. It is just not possible to list all these works here, a tentative of summary can be found in Italian in (Rugarli 2014), but other sources also exist. PSHA has been demolished from a geophysical point of view (Molchan *et al.* 1997; Castanos, Lomnitz 2002, Peresan *et al*. 2005, Bizzarri 2012…); from a statistical point of view (Freedman, Stark 2002; Klügel 2007, …); from a mathematical point of view (Wang *et al.* 2013, …); from an engineering point of view (e.g. Rugarli 2008, 2014) and from an experimental point of view (e.g. Wyss *et al.* 2012, Stein *et al.* 2012, …).

It's almost embarrassing talking about PSHA as it is now evident that it is a completely baseless method as recognized by experts of several different disciplines (e.g. Wyss and Rosset 2012).

However, following the rules of mass fallacies, and with no mention of the criticism already appeared in the literature, the Italian Laws in 2008 (NTC 2008) enforced it as the unique tool to evaluate seismic hazard. Successive official documents (CNR 2013, MIBACT 2011), recommended or enforced PSHA approach for existing buildings and for historical heritage protection. This is a true problem.

In the remaining part of the section some of the reasons by which it is baseless are briefly listed.

Basic hypotheses of PSHA:

1. Annual *probability* of an earthquake $M > M_0$, in a site, does not change from year to year. **FALSE**.

2. The seismic source is a point. **FALSE**.
3. GR is valid at local scale, and can be extrapolated to very severe earthquakes. **FALSE.**
4. Annual probability is independent on the ones of previous years. **UNCHECKABLE**.
5. Earthquakes "return" with perfect regularity or the historical "average return period" is useful. **FALSE**.
6. The average of the estimates of experts (logic tree) is preferable to each single data. **UNCHECKABLE.**
7. ….

The *return period* concept is one of the pillars of PSHA and deserves a special mention in the pantheon of seismic fallacies.

Assume that in a specific site the annual *probability* of an earthquake $M>M_0$, i.e. the *probability of exceedance*, is Q: the annual *probability* of no-earthquake $M>M_0$ is then necessarily (1-Q). In 2 years the no-earthquake $M>M_0$ *probability* is (1-Q)x(1-Q) as events are independent. In 50 years it is $(1-Q)^{50}$. This stems from the PSHA hypotheses.

Now if we wish this no-earthquake $M>M_0$ *probability* in 50 years is 90% (and so probability of exceedance **P**=0.1, 10%). we must equate

$$(1-0.1)= 0.9 = (1-Q)^{50}$$

which leads to $Q\approx$ 1/475. Q is a pure number, it's *annual probability of exceedance*.

Now, the next PSHA step is astonishing: according to PSHA believers, this means that "the average *return period* T_r of the earthquake $M>M_0$ is 475 years". These words and values are in the current Italian Technical laws, and so they are sacred by Law.

But they have no real meaning: albeit an average of *return periods* can be defined (the numbers are very different), this is not useful to assess the occurence of next strong earthquakes. Moreover, if M is high, the "average" is done using very few data. The *invention of the truth*, here, is that the future will be like the models would like, and that Earth behaves like dice. Reality is fit to match the model.

Now, the earthquakes to be determined, coherently with the *exceedance probability* 0.1 in 50 years, are those whose observed or estimated *return period* is 475 years. Historical catalogues of earthquakes, and "local" GRs will now help, zone by zone, to assess the severity bound, M_0 related to T_r. From this magnitude level, by attenuation relations, point source hypothesis and with severe errors, ground shaking can be estimated.

According to this view, if tossing a die the probability of 3 is (1/6), the *return period* of 3 is 6 throws. However, 3 comes out when it wants, for sure not keeping into account its *return period* of 6 throws. It is not true that after 4 throws, 3 will come out in next 2 throws.

Clearly, the words are misleading, especially for populations. "475" is just the inverse of a *probability*. But transforming it into a time span, several dangerous concepts are subliminally delivered.

a. That after a historical earthquake $M>M_0$ next event will occur after T_r years, "more or less".
b. That if *return period* is long enough, we can be confident that a severe earthquake won't occur tomorrow.
c. That if the severity estimated in this way does not lead to problems to the structures, they can be safe.

Now, *a* and *b* are clearly baseless. But also *c* is baseless, as the severity of the earthquake that might hit can be $M=M_1>>M_0$, with no relation with the probability and reference period, fixed at the beginning of the procedure. In fact, this has been observed many times (e.g. Wyss *et al.* 2012), making PSHA maps useless.

Transforming a *probability* in a *return period* is pretty much like waiting for "delaying numbers" at the lottery. Probability has no memory, and especially the probability of PSHA, which is memoryless by definition. Plate tectonic has indeed memory, but memory cannot be reinserted in a procedure that is based on memoryless models, otherwise an unbearable mixture of ad hoc tricks is generated. As de Finetti put it:

> "In a more general meaning, it seems that many of the current conceptions consider as a success the introduction of mathematical methods so powerful, or the introduction of settings tricks so smart, to allow a univocal answer to a problem even when, due to data insufficiency, this is undetermined".
>
> (*Teoria delle Probabilità*, de Finetti, translation of the author)

The use of the word "return" is dangerous. The experts themselves are fooled by the biased concept, as has been seen at L'Aquila in 2009, when an Official Commission held to assess the risk related to the continuous shaking (that was indeed a precursor) affirmed, six days before the M6.3 earthquake which destroyed part of the ancient city: "strong earthquakes in Abruzzo have very long return periods. It is improbable that in a short while a new shake like that of 1703 would happen, albeit it cannot be absolutely excluded". The emphasis applied underlines the words directly related to what should be called the *return period fallacy*.

A second important knot in the PSHA procedure, is the use of "expert elicitation" in order to evaluate by weights, different mutually exclusive choices.

Expert elicitation has been used with some success in medicine, for instance, in order to tune the performance of Bayesian nets used by software to deliver a diagnosis to patients having liver diseases (Aspinall, Cooke 2013). However there is a clear difference with seismology: physicians have tested their diagnosis against experimental data (i.e. patients) for decades, and so their expert opinion has some root and can be tested against data. Seismologists and engineers, did not and cannot do that with the severe earthquakes at a given site (there are thousands grid points). because it would take tens thousands years.

Due to high uncertainties, two 2-answers choices and one 4-answers choice are related to current Italian seismic map, each choice being weighted. So the number of maps are 2^2x4=16. The actual design map in NTC 2008 is the median of all 16, i.e. a simple average is taken.

Weights like 40/60, or 33/33/17/17, multiplied by themselves several times, lead to inexistent precisions, e.g. (0.6x0.6x0.33=0.1188). Italian Law lists the PGAs (peak ground acceleration at bedrock) with 3 to 4 significant figures, in more than 10,000 points of a 5.5 Km grid. No clean up has been applied to results. However, weighting maps with weights like 60/40, almost means tossing a coin: how could results have 4 digits precision?

When considered from the fallacy generation viewpoint, all these figures are well able to *invent a truth*: the truth of precision, and subliminally, the truth of reliability. In fact, a simple heuristic says that if the numbers are printed they must mean something *underlying*. Here the *underlying* inconvenient truth, however, is that someone forgot to clean the results, but the *apparent* truth is that PGA estimates are precise and reliable. Who would compute useless numbers? Believers in a faith, or forgetful scientists.

The last feature of PSHA I will discuss is its ability to correctly (?) tune the performance of buildings against the different frequencies of earthquakes. Unfortunately as probabilities are fakes, this is as well false. Moreover, as explained, there is no prove that a continuous set of earthquakes with M belonging to a given interval will really ever happen.

Tuning the probabilities **P** and the reference periods V_r, in a unique site a high number of different earthquakes, having different probabilities, can be got by PSHA (in “theory”, infinite). Different kind of buildings designers, or different owners, may decide to design their buildings against different level of earthquake severity (and probability of occurrence). I call this the *earthquake supermarket*. This is analogue to deciding the *performance* of a floor specifying the loads that can be applied. The *performance* of the floor will be the ability to carry safely an X, or Y load. The users of the floor will be able to avoid loading too much the floor, as its *performance* have been set by design, and as the floor users might drive the load applied. Elevators work in a similar manner, max weight is clearly visible in specific warnings.

However, with earthquakes, it is much different. We cannot know which will be the magnitude of the earthquake that a structure will face, during its real life (I don't want to use tricky concepts like *nominal life*, or *reference period*). And in a given site, all the buildings will face the same earthquake (not considering soil effects). So, if the level of severity assessed by PSHA is too low, all the buildings will face a destructive earthquake, no matter the probabilities they have been designed with. And this underestimate has already happened.

As setting properly *probability, reference period* and *confidence level*, one can set the earthquake he/she wants, this is used by the Law (NTC 2008 and MIBACT 2011) to assign daredevil "safe" labels thanks to the *remaining nominal life* concept. This is a dangerous fallacy. Reducing *return period* to values lower than those usually required by law, a ground shaking compatible with the existing structure can almost always be found. In turn, a reduced *reference period* will be set, assuring the same probability level (e.g. 10%). For instance, instead of using an *exceedance probability* equal to 10% and a *return period* of 475 years, leading to 50 years *reference period*, and a given severity of ground shaking, 10% can be used with 100 years *return period*. So, *reference period* will be much lower, 10 years, and not 50 years, and also the ground shaking to be checked will be much lower (you can always find one at the *earthquake supermarket*). According to Italian Law, that means that the structure can be declared "safe" for ten years. At the end of ten years, reintroducing memory in a memoryless model, and so violating the axioms of rational choice, a new check will be performed, but keeping into account the years passed (MIBACT 2011, §2.4). However, it is not clear why in the future we will have to keep into account the time span since today, but today we do not keep into account the time span since the structure was built. It is not clear because the whole process is self contradictory, baseless, and assigns irresponsible "safe" labels to structures at stake. So, the whole process is a dangerous fallacy enforced by Law (MIBACT 2011, §2.1, §2.2, §2.4).

One of the side effects of the enforced-by-Law mantra is that another method, NDSHA Neo Deterministic Seismic Hazard Assessment (Panza *et al.* 2001, 2012, 2013), much sounder and with no 4 digits estimates, is somehow blocked and at first sight cannot formally be used under the Law. However, it has been used recently by Provincia di Trieste for its buildings (Stolfo 2015), and a method to implement it within the frame of current Laws has been proposed (Panza *et al.* 2015). NDSHA uses earthquake scenarios and the concept of MCE, maximum credible earthquake, that, due to the lack of data, is the only correct engineering choice. As it is clear by Table 1, this method, which uses envelopes, and does not print un-significant digits, warns us that ground acceleration values much higher than those requested by PSHA should be the right design values for very important Italian cities, full of people and of historical unique heritage, e.g. Naples, Venice, Verona and many more listed by UNESCO.

TABLE 1 – Design ground acceleration at the bedrock, in g units (Romanelli, Panza 2015). UNESCO sites.

DGA: as evaluated by NDSHA using MCE concept.

PSHA values are listed for 475 and 2475 years return period, and for 50 and 84 percentile (considering a log normal distribution over the 16 seismic maps elicited by experts by weights). No interpolation: it has been considered the worst point of the 4 points of the pertinent quad of the grid (if interpolation is applied, as requested by NTC 2008, PSHA PGA values would be lower). Last column is the percent variation taking maxima. Highlighted column is PGAs according to PSHA-NTC 2008 for normal buildings**.**

Site (Lat, Long)	**NDSHA DGA (g)**	**PSHA DGA (g) T_r=475 50%**	**PSHA DGA (g) T_r=2475 50%**	**PSHA DGA (g) T_r=475 84%**	**PSHA DGA (g) T_r=2475 84%**	**Δ% Max Column 2 Minus Column 6**
Rome (41,9°-12,4°)	0.15-0.30	0.1583	0.2671	0.1917	0.3199	-6.2%
Florence (43,8°-11,3°)	0.15-0.30	0.1338	0.2285	0.1475	0.2489	+20.5%
Venice (45,4°-12,3°)	0.15-0.30	0.0775	0.1385	0.0866	0.1526	+96.6%
Pisa (43,7°-10,4°)	0.15-0.30	0.1177	0.2043	0.1244	0.2255	+33.0%
Matera (40.7°-16.6°)	0.15-0.30	0.1512	0.2619	0.1662	0.2974	+0.87%
Vicenza (45,5°-11,5°)	0.30-0.60	0.1562	0.2810	0.1697	0.3419	+75.5%
Siena (43,3°-11,3°)	0.15-0.30	0.1390	0.2246	0.1554	0.2695	+11.3%
Naples (40,9°-14,2°)	0.60-1.20	0.1679	0.2798	0.1857	0.3148	+281%
Ferrara (44,8°-11,6°)	0.30-0.60	0.1424	0.2771	0.1653	0.3263	+83.9%
Ravenna (44,4°-12,2°)	0.15-0.30	0.1642	0.3049	0.1891	0.3566	-15.9%
Caserta (41,1°-14,3°)	0.60-1.20	0.1398	0.2330	0.1457	0.2445	+391%
Padova (45,4°-11,9°)	0.30-0.60	0.0887	0.1535	0.1003	0.1776	+238%

Site (Lat, Long)	**NDSHA DGA (g)**	**PSHA DGA (g) T_r=475 50%**	**PSHA DGA (g) T_r=2475 50%**	**PSHA DGA (g) T_r=475 84%**	**PSHA DGA (g) T_r=2475 84%**	**Δ% Max Column 2 Minus Column 6**
Modena (44.6°-10.9°)	0.15-0.30	0.1635	0.2989	0.1683	0.3083	-2.7%
Agrigento (37,3°-13,6°)	0.15-0.30	0.0572	0.0891	0.0644	0.1027	+192%
Verona (45,4°-11,0°)	0.30-0.60	0.1525	0.2793	0.1679	0.3410	+75.9%
Siracusa (37,1°-15,3°)	0.60-1.20	0.2283	0.5166	0.2692	0.6156	+94.9%
Genova (44,4°-8,9°)	0.30-0.60	0.0740	0.1346	0.0808	0.1498	+300%
Mantova (45,1°-10,8°)	0.30-0.60	0.0905	0.1561	0.1010	0.1824	+229%
Palermo (38,1°-13,4°)	0.15-0.30	0.1810	0.3155	0.1955	0.3672	-18.3%

Some quick notes about these quite important results:

1. PSHA has not one value but at least four for each site. Truly, changing *return period* and *percentile* other values can be got (as many as one wishes). However there is no real rule to decide which is the correct couple *percentiles / return period*, as it is largely left to subjective decision. One must be warned that the *probabilities* related to *return periods*, in the *reference periods*, are not the familiar probabilities we use in everyday life, but fakes.
2. PSHA uses 3 to 4 digits which is clearly misleading. The 3rd column lists PGAs according to PSHA-NTC 2008 for normal buildings.
3. The difference between 50 and 84 percentile is due to the scatter between the 16 different maps used by PSHA. According to PSHA believers, taking the average of the logarithms of 16 PGA values, and the standard deviation of the 16 data for each site, a normal distribution can be used to assess the "confidence levels" or the "probabilities" related to the use of 16 different maps. The values in NTC 2008 and proposed for normal buildings are related to 50 percentile (columns 3 and 4). So there is another degree of freedom besides *probability of exceedance* and *reference period*: the expert elicitation scatter and the related *probabilities*…
4. As one can use each set of data she/he prefers, it is also clear that an experimentally measured PGA value not compliant with the map, can be considered out of interval only because higher return period, or con-

fidence levels, would have to be used. A not checkable tricky nightmare that has nothing to do with the safety of people and of art heritage.

5. The differences between the two methods are huge. This is coherent with what experimentally tested (e.g. Wyss 2012). These data pose a serious problem to politicians, administrators, caretakers, engineers, and to the population.

The aim of this work is not assessing if PSHA is baseless or not, because it has been proved with no doubt by decades of research that it is unreliable, but to discuss why we still have to talk about this. The answer clearly is related to the logical and social fallacies already listed, and to the strength of Law. Here, the Law invents an unbelievable *truth*. As the wrong method is enforced by Law, tremendous waste of private and public money has been spent and is currently spent.

The quantification dogma

For a long time, constructions were built with no calculation at all. As explained by Jacques Hayman in his masterpiece work (Heyman 1995), *The Stone Skeleton*, old masonry buildings where built using geometrical proportion, starting from a variable "great measure".

When dealing with the problem of retrofitting the Dome of S. Peter's, Rome, Poleni, in 1748, used simple wire and weigths, and graphics, to assess that the Dome was not at immediate stake (see Heyman 1995 for a summary).

The static of masonry is quite different from that of reinforced concrete or steel, because masonry cannot be considered a continuum. Due to lateral loads, masonry cracks open, and the structure adapts to external loads changing the configuration of these cracks. Different lines of thrust are found, depending on the history of loads.

The availability of the general theory of elasticity, and later of the theory of plasticity, mixed with the personal computer era, led to the wide spread use of computer software in the design offices. In turn this led to severe problems which can be thus summarized (Rugarli 2003, 2005, 2014):

- Lacking the knowledge and preparation to use pertinently this software, many designers use it as a black box or *oracle*.
- The availability of trains of figures, colored maps, and sexy graphical display, helped to completely forget the limits of applicability of the mathematical methods implemented in computer software.
- People are pushed to do this by the market and by the Law, which explicitly asks for the "computation" of virtually anything.

In this section I wish to briefly discuss if the quantification dogma has ground or not: recently similar questions have also resounded (Borri 2015), meaning that the problem is also perceived by other scholars, which is good.

When dealing with materials having clear and stable constitutive laws, like steel, and with structural elements clearly and safely defined within the geometrical limit of classic theories, when connections are clear, and when the actions are defined properly or properly enveloped, the theoretical methods have ground and can be used safely.

But when the material is heterogeneous, chaotically laid, and the structural elements are not within the geometrical limit of applicability of the simplified theories (beam, plate, membrane), their connection uncertain and unclear, when the loads are not known or properly enveloped, the use of computer or complex quantitative models gets from questionable to completely baseless, depending on the situations and the methods.

In the last decades, since the mid 80s, i.e. since Microsoft booming sales, the Law has been progressively made more complex and requiring more complex computations. The need of complex computations triggered the offer of complex software which is used as a tool to fill the knowledge gap. The secondary effect is that a high number of incompetent use software, printing baseless numbers (Rugarli 2014).

Is this need of computation based?

When dealing with ancient structures, a computer model can be nice to see, but how much is it pertinent?

One way to solve the issue is to hardly modify the existing structure to fit the model. It is well known that a box behavior for masonry building is good for seismic resistance. However if I say

A box behavior is good for seismic resistance. All well done boxes are seismic resistant (and computable).

That does not mean

In order to be seismic resistant a structure must be a computable box.

There may be different kind of structures that behave in a different manner, and there may be construction techniques which, out of the box model, do however grant a good seismic protection. As Italy has buildings so precious and spanning from several centuries b.c. to present days, built with stone, masonry, rubble, wood, clay, mortar, and using techniques which are not always fit to the box model, we have three choices: 1) leave all as it is, may be with the help of invented numbers like the "nominal remaining life", based on "probabilistic" methods (MIBACT 2011); 2) convert into boxes these structures, or 3) study why they are still there no matter they are not box and no matter the severe actions they sometimes faced, and understand which retrofitting actions not necessarily computable, but surely useful, we can set to help protect these structures, not raping them.

Affirming that each retrofitting action must be computable requires computations which are often baseless. In turn, this is on one hand a limitation to the widespread use of good non computable techniques, and on the other hand an implicit request of software acting as *oracle*.

As Italy is the house of Beauty, it deserves a better treatment.

Conclusions

Science and Engineering are not error free, and are not a place where the mass fallacies that have been observed in other branches of human behavior are excluded. On the contrary, Science and Engineering are subjected to irrational beliefs, which the use of the Law as enforcing tool makes very difficult to remove.

The costs of such distortion of the main goal of Science and Engineering can be very huge. This is particularly frightening when applied to the unique historical heritage that features Italy.

Caretakers and politicians should be aware that new strong earthquakes are possible every single day of next weeks, months and years. From an engineering viewpoint, it is useful to estimate an upper bound of ground shaking, and to design against it, while the determination of probabilities is baseless. When dealing with ancient structures, there is a whole set of possible actions which have been proved useful, albeit it is just not possible the quantification of their effects. Traditionally, no computation was done, but this did not avoid the construction and repair of complex historical structures. Caretakers and politicians must not be fooled by methods which are simply not able to predict anything, or that are just unfit for many ancient buildings.

It is duty of the scientists and of the engineers who have rightly understood the high risk that the Country is currently facing, to act boldly in order to reduce it, informing the citizens and the politicians, that irreplaceable Cities, Monuments, Art Works and Masterpieces, may be hit every single day in such a way to make it hard to regain them.

A loss of that kind would simply delete a part of national identity, making us truly the Country

D'un volgo disperso che nome non ha[2].

(*Adelchi*, Alessandro Manzoni)

(2) *Of a disperse rabble that name has not.*

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