The value of visual inspections for emergency management of bridges under seismic hazard

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ABSTRACT: One of the major problems in the aftermath of an earthquake is the management of the emergency inspection operations. Traffic restriction, including limited emergency operations or bridge closure due to safety concerns, may be issued to keep an appropriate level of safety. Visual inspections may be conducted to provide useful information on the damage state of the bridge and support the decision of imposing traffic restriction up to the complete closure of the bridge, or for allowing the immediate use of safe bridges after the event. The cost related to the inspection shall be at least balanced by the uncertainty reduction provided by the inspection data and the benefit is higher when the costs associated with taking a wrong management decision are high, but may be negligible if this is not the case. Practical tools and methods to forecast this benefit before collecting the information exist in classical decision theory, but are seldom applied by engineers. In this paper a framework based on the concept of Value of Information (VoI) from the pre-posterior Bayesian decision analysis is adopted and applied to the case study of a two span reinforced concrete bridge.

1 INTRODUCTION

In this paper, the value of information from visual inspections for the seismic emergency management of bridges is investigated. One of the major problems in the aftermath of an earthquake concerns the decision about possible traffic restrictions to issue for infrastructures like bridges. The bridge can be closed to traffic, it can be kept open, or traffic can be restricted in volume or velocity or limited to emergency vehicles. Each of these choices implies different consequences and corresponding risks.

The decision regarding traffic restrictions can be made based on the so-called prior knowledge, i.e. without any information collected on the state of the bridge after the seismic event or exploiting information from a visual inspection performed after the earthquake. Collecting information has a cost, therefore it would be important to know, before the inspection is performed, if its cost is balanced by the benefit it brings in terms of risk reduction. In this paper, a procedure based on pre-posterior Bayesian analysis (Schaifer&Raiffa, 1961, Faber &Thöns, 2013) is proposed to quantify the value of information from a visual inspection before it is performed in a phase of post-earthquake emergency management. The procedure has been applied to the case study of a two span reinforced concrete bridge located in a region at high seismic hazard.

2 VISUAL INSPECTION SUPPORTED TRAFFIC RESTRICTIONS

The general framework of the Value of Information analyses applied to management of traffic restrictions after a seismic event has been already presented in Limongelli et al. (2017). Herein, this approach will be briefly recalled in order to make the paper self-contained and adapted to the case of visual inspections. Figure 1 illustrates the decision tree describing this problem. In the decision tree, squares denote decision nodes and circles represent random outcome nodes (e.g. states of nature or outcomes of the visual inspection).

After the earthquake, the bridge can be in a damaged state DS_l ranging from no/negligible damage DS_1, to total collapse DS_L with intermediate levels corresponding to e.g. light, moderate and severe damage. Herein, L=5 damage states are considered (see Table 2 in section 3.3) as in Mander (1999).

The inspection, if performed, could result in different outcomes, each corresponding to a branch of the DS node in the decision tree. Note that these outcomes represent a discretization of the probability distribution of the damage state.

The risk connected to the decision on traffic restriction TR_k (bridge closed TR_N, bridge open TR_0), is proportional to both direct consequences $C_d(TR_k)$, due to the failure of the bridge (cost of the bridge, loss of lives) and indirect consequences $C_{id}(TR_k)$, due to the loss of functionality of the bridge and related diversion of traffic (user costs, pollution, fatalities related to the unavailability of the bridge for emergency vehicles).

The direct component of the risk upon a certain traffic restriction (TR_k) is then represented by the expected value of consequences to the failure event as in Eq.(1).

$$E[C_d(TR_k)] = c_d(F|TR_k)\sum_{l=1}^{L} P(F|DS_l)\cdot P(DS_l) \tag{1}$$

where $c_d(F|TR_k)$ is the direct cost of failure upon the introduction of the traffic restriction TR_k, $P(F|DS_l)$ is the probability of failure upon the occurrence of the damage state DS_l. and $P(DS_l)$ is the probability of occurrence of the damage state DS_l.

The direct costs will be zero if the bridge does not fail.

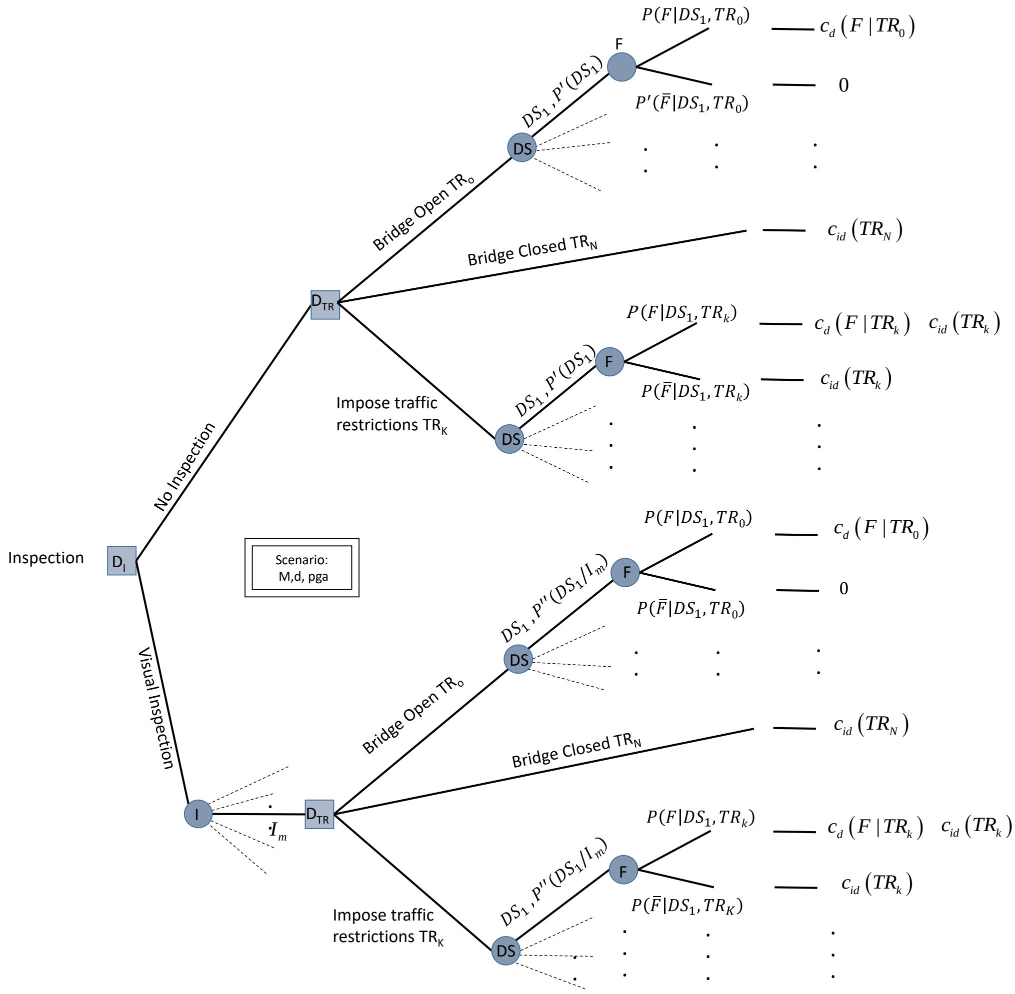

Figure 1. Decision tree for the bridge upon knowing the earthquake scenario

If the bridge collapses, the corresponding cost is given by the cost of the bridge and the cost related to fatalities. The latter depends on the probability that a given number of persons pass the bridge when it collapses. This probability depends on the traffic restriction: if the traffic is restricted, a lower number of persons is expected to be on the bridge with respect to the situation of open bridge. The indirect consequences include economic losses due to delays and loss of service (e.g. increased travel time, fuel consumption), but also fatalities related to delays in getting the injured to a hospital, and losses related to environment, i.e. to the increased pollution induced by the diversion (Imam & Chryssanthopoulos, 2012).

In analogy with the expression in Eq. (1), the indirect component of the consequences is given as:

$$E[C_{id}(TR_k)] = c_{id}(F|TR_k)\sum_{l=1}^{L} P(F|DS_i)\cdot P(DS_i) \tag{2}$$

Indirect consequences depend as well on the traffic restriction and increase with the amount of traffic that is diverted. Therefore, indirect consequences reach the maximum value when the bridge is closed and are zero when the bridge is open.
The total risk related to a given traffic restriction is thus:

$$E[C(TR_k)] = E[C_d(TR_k)] + E[\mathrm{C}_{id}(TR_k))\ ] \quad (3)$$

The optimal decision is the one that minimizes the risk:

$$TR^* = \min_k\{E[C(TR_k)]\} \quad (4)$$

According to the VoI framework (Schaifer & Raiffa, 1961, Faber &Thöns, 2013), a decision regarding performing a visual inspection to support the decision related to traffic restrictions can be made. Herein, we consider the simple case where only two choices regarding the inspection are possible, i.e. performing it or not. These two options correspond to the two initial branches of the decision tree in Figure 1 and are described in the following sections.

2.1 *Upper branch of the tree: decision made without performing the inspection*

If an inspection is not carried out (branch '*No inspection*'), the decision about possible traffic restrictions has to be made based only on the probability of the different damage states DS_l available from *prior* knowledge (i.e. prior analysis).

The probability of bridge collapse under traffic load upon the damage state DS_l caused by the earthquake will differ according to the chosen traffic restriction. The total expected risk connected to one action (*k*-th traffic restriction) is given by Eq. (5), where the probabilities of the damage states are computed without information from an inspection thus are the *prior* probabilities $P'(DS_i)$.

$$E'[\ C(TR_k)] = \sum_{l=1}^{L} c(\ F|TR_k) \cdot P'(F|DS_l, TR_k) \cdot P'(DS_i) \quad (5)$$

The optimal decision is made by choosing the action that corresponds to the lowest expected risk:

$$TR^* = \min_k\{E'[C(TR_k)]\} \quad (6)$$

2.2 *Lower branch of the: decision made with the inspection*

If a visual inspection is carried out (branch '*Visual Inspection*') the decision about the traffic restriction can be made accounting for the information available from the inspection (posterior analysis). Given the outcome I_m, the probabilities of the damage states $P(DS_l)$ can be computed updating the prior probabilities using the Bayes theorem, thus they are '*posterior probabilities*':

$$P''(DS_l|I_m) = \frac{P(I_m|DS_l)\cdot P'(DS_l)}{\sum_{l=1}^{L} P(I_m|DS_l)\cdot P'(DS_l)} \quad (7)$$

The likelihoods $P(I_m|DS_l)$ are calculated on the basis of the information collected during the inspection. Therefore, with respect to the previous case where the inspection was not performed, the difference is the knowledge provided by the inspection that enters the process of risk estimation through the likelihood functions. The posterior value of the expected risk associated to the action TR_k, given the information I_m from the inspection, is given by:

$$E''[C(TR_k|I_m)] = \sum_{l=1}^{L} c(\ F|TR_k) \cdot P(F|DS_l, TR_k) \cdot P''(DS_l|I_m) \quad (8)$$

The optimal action is the one that minimizes the expected cost:

$$TR^* = \min_k\{E''[C(TR_k|I_m)]\} \quad (9)$$

Before performing the inspection, its outcome is not known with certainty. Therefore, to evaluate the total expected risk corresponding to the decision TR_k, we have to consider all the possible inspection outcomes I_m , with m=1,…*M.*

The expected cost over all the possible outcomes of the inspections for the decision TR_k is:

$$E[C(TR_k)] = c(\ F|TR_k)(\sum_{m=1}^{M}[P(I_m) \cdot \sum_{l=1}^{L} P(F|DS_l, TR_k) \cdot P''(DS_l|I_m)]) \quad (10)$$

With $P(I_m) = \sum_{l=1}^{L} P(I_m|DS_l) \cdot P'(DS_l)$ probability of the inspection outcome I_m. The conditional probabilities $P(I_m|DS_l)$ are probabilities of the outcome I_m when damage state l has been sustained.
The optimal action is the one that minimizes the overall risk of failure of the bridge under traffic load after being damaged by the earthquake:

$$TR^* = \min_l \min_k\{E[C(TR_k)]\} \quad (11)$$

2.3 *Value of information from visual inspection*

In order to quantify the value added by the information from the visual inspection, before actually performing it, we have to compare the expected costs for the two cases reported in section 2.1 (risk of a decision without inspection, Eq.(5)) and 2.2 (risk of a decision for all possible inspection outcomes, Eq. (8)):

$$VoI = E'[C(TR^*)] - E[C(TR^*)] \quad (12)$$

3 THE CASE STUDY

3.1 *The context*

In the following, the best decision over the use of a bridge has to be made when an earthquake has just occurred. Main assumption is that the bridge is not collapsed, but there is substantial uncertainty on its capacity, therefore rising the risk for its users. However, there is a certain probability that the bridge has still enough capacity to withstand traffic without jeopardizing human lives. At the same time, the bridge can be located in a strategic network for the emergency and its closure may involve an even higher risk, with respect to its continued use, due to delayed emergency operations.

The context in which the decision shall be made is during the emergency phase, therefore it is assumed that the intensity of the earthquake (e.g. peak ground acceleration, PGA) is known. For the specific example a spectral acceleration Sa= 0.5g for a period T=1s is considered.

The decision can be made on the basis of prior knowledge about the bridge damage state, or on the basis of new information through a visual inspection. The last option has a cost that must be considered when the decision about the need to perform an inspection is made.

This case study aims at using VoI to quantify the value of the information provided by a visual inspection prior to its occurrence in the context of emergency management.

3.2 *The bridge*

The bridge considered in this example is a two span reinforced concrete bridge with the deck skewed 45° and not designed according to seismic standards (Mander, 1999). The bridge is located on the road that connects a village to a hospital (see figure Figure 2).

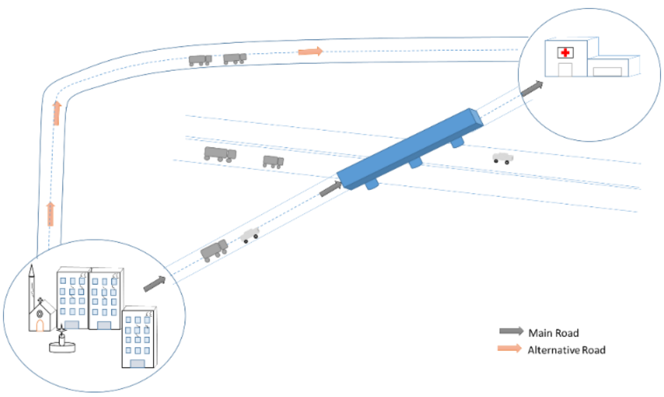

Figure 2. The hypothetical configuration for the case study

It is assumed that before the earthquake, the bridge is in its original (intact) configuration. The fragility curves have been computed according to this assumption using the parameter in Mander (1999).

Other data about the case study are reported in Table 1. It is underlined that the number reported in Table 1 are meant to give a reasonable order of magnitude of the costs involved. A sensitivity analyses with respect to the parameters involved will be needed in order to drawn more conclusive results.

Table 1. Data of the problem

length of the bridge	30m
soil type	soft rock
daily number of vehicles	18000
mean number of persons per vehicle	2
mean velocity of vehicles	60km/h
length of diversion due to traffic limitations	30km
cost of fuel	1.5€/l
value of time per person [Dept Transp. UK]	30€/h
average value of life [Daniell et al]	3m€/person
cost of injuries with long term assistance	3m€/person
total number of fatalities	100
% fatalities for delayed emergency [Ukai]	5%
Value of the bridge	$30 \cdot 10^6$ €

3.3 *Definition of the damage states (DS).*

Herein the 5 damage states defined in Table 2 (Mander, 1999) will be considered

The parameters μ_c and σ_c are respectively mean of the residual capacity expressed as a percentage of the original value, and increment of standard deviation over the original value.

The values of the median spectral acceleration (for a reference period *T*=1s) in [*g*] corresponding to the 5 damage states for a standard bridge are reported in the 5th column of Table 2 (Mander, 1999).

Depending on the characteristics of the bridge and of the soil, these values are modified to account for the specific characteristics of the considered bridge (deck skew, number of spans, soil type). The value of the modified spectral accelerations reported in the last column of Table 2 have been computed as functions of the relevant values in column 5, assuming a soil type 'soft rock' and the characteristics of the bridge (deck skew, number of span) reported in Table 1. With reference to (Mander 1999) and to the values reported in Table 1, the modification factors are: k_{skew}=0.84, k_{3D}=1.16, S=1.52.

Table 2. Definition of the damage states DS

Damage State	d_i	μ_{c_i} [%]	σ_{c_i} [%]	a_i [g]	A_i [g]
DS_1	no damage	100	0	0	0
DS_2	slight	98	0.05	0.26	0.17
DS_3	moderate	92	0.3	0.35	0.22
DS_4	extensive	75	7.5	0.44	0.28
DS_5	complete	30	15	0.65	0.42

3.4 *Fragility curves and prior probabilities*

A fragility curve represents the conditional probabilities that the damage state (DS) exceeds a certain level (corresponding to a limit damage state d_i), given the value of the intensity measure (e.g. Spectral Acceleration S_a at a reference period here assumed to be T=1s):

$$F_{d_i}\left(S_a\right) = P\left[DS \geq d_i \middle| S_a\right] \qquad (13)$$

The most common form of a seismic fragility function is the standard lognormal cumulative distribution (Mander, 1999):

$$F\left(S_a\right) = \Phi\left[\frac{1}{\beta_{d_i}} \ln\left(\frac{S_a}{A_i}\right)\right] \qquad (14)$$

where the spectral acceleration amplitude A_i (for a period T=1s) is the parameter describing the intensity of the ground motion. The parameter β_{di} is the normalized composite log-normal standard deviation in the i-th damage state DS_l. In Mander (1999) a constant value equal to 0.6 is suggested for β_{di} for all d_i. The fragility curves for the considered bridge are reported in Figure 3.

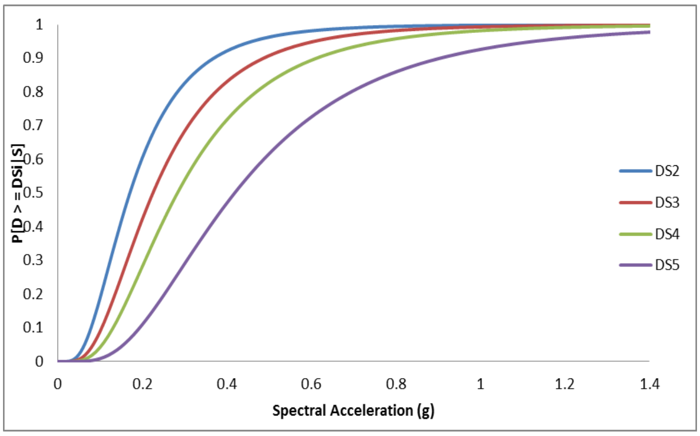

Figure 3. Fragility curves calculated according to Mander (1999).

Herein the fragility curves are used to calculate the prior probabilities of exceedance associated to the damage states DS1 to DS5 as listed in the 3rd column of Table 2. They are obtained as differences between the probabilities of exceedance of two consecutive damage states reported in the 2nd column of the table.

Table 3. Probabilities of the damage states DS

Damage State	Probability of exceedance of *DS*	*P'*(*DS*)
DS_1	1.00	0.17
DS_2	0.83	0.15
DS_3	0.68	0.14
DS_4	0.54	0.25
DS_5	0.29	0.29

3.5 *Definition of the capacity in the different damage states*

Some simplifying hypothesis are introduced to avoid making the example too complex and distract the reader from its main meaning. Both traffic load and capacity are considered Log-normal distributed with distribution parameters calibrated with respect to a target safety level. They are not representative of a real bridge. The traffic load is represented by the total vehicle weight of a truck, since for a bridge with 30m span the load is mainly represented by the distribution of maxima of single truck weights (Steenbergen, 2010). For the considered two span bridge, we assume a traffic load q with Log-normal distribution with mean value of 25t (249kN) and coefficient of variation of 20%. The distribution of the capacity is then calibrated according to CEN (1990) and Holický et al (1990) for reliability class 3 (high consequences, bridges and public buildings) as Log-normal distributed with mean value equal to 51t (507.96kN) and c.o.v. of 8%. This is done assuming a linear limit state function $g = C - Q$ and a minimum reliability index in 50yr equal to 4.3, which is equivalent to a minimum reliability index of 5.2 in 1 year - i.e. failure probability of 10^{-7}- (equivalence on safety level).

Due to the damage caused by the earthquake, a reduction of capacity to withstand traffic load is foreseen according to the values in Table 2. Considering the new limit state function $g_i = C_i - Q$ where c_i is the new capacity at damage state DS_i, the new probability of failure under the damage state can be calculated using the FORM method. The new failure probabilities under the damage states DS_i are listed in Table 4.

Table 4. Probability of failure for damage states DS

Damage State	β in 50yrs	P(F|DS) in 50 yrs	β in 1yr	P(F|DS) in 1 yr
DS_1	4.3	$8.5\cdot10^{-6}$	5.2	$9.96\cdot10^{-8}$
DS_2	4.17	$1.46\cdot10^{-5}$	4.99	$2.93\cdot10^{-7}$
DS_3	3.43	$2.91\cdot10^{-3}$	4.38	$5.83\cdot10^{-6}$
DS_4	0.90	0.182	2.65	$4.05\cdot10^{-3}$
DS_5	-4.24	0.999	0.82	0.204

3.6 *Definition of the traffic restrictions*

The traffic restrictions are herein computed fixing the minimum value of reliability index (β) that we are willing to accept. Following ISO2394 (1998), we consider the value of β=3.1 corresponding to high relative costs of safety measures (traffic restrictions) and great consequence in case of failure, in cases where no specific design life time is given. Herein we consider the value of the probability of failure corresponding to one year traffic load, despite the temporal window in which the decision shall be made active is of two weeks after the earthquake. Despite the choice of this beta value in the context of emergency management may seem arbitrary, this assumption is both a simplification, but mostly it is necessary since no specific recommendations are available for temporary and emergency situations.

The value of β is used to compute the traffic restriction relevant to DS_5 which is the state with the highest damage, being thus the one that rules the traffic restriction aimed to keep the minimum accepted reliability. For the target value of β=3.1, the new parameters of the distributions of the traffic load are listed in Table 5 where the values are calculated maintaining the initial coefficient of variation of 20% for the traffic load. The maximum allowable weight on the bridge corresponding to each traffic restriction, has been computed considering the characteristic value of the traffic load (5% percentile) scaled for the partial safety factor γ_C (see equation 15) corresponding to lognormal distribution of the capacity with V_C=0.72, $\alpha_C = 0.98$ at DS_5 (Holický et al., 1990).

$$\gamma_C = R_k/R_d = \exp[-1.645V_C]/\exp[-\alpha_C \beta V_C] \tag{15}$$

Table 5. Distribution parameters for traffic load at DS5 for the chosen reliability targets

TR	β	μ_q	σ_q	% residual traffic on mean value	max load [t]
TR1	3.1	10.4	1.86	41.6	4.8

The values of the probability of failure for the damage states 1 to 5 when the traffic restrictions corresponding to β=3.1 are applied are listed inTable 6. Due to the imposed traffic restriction to vehicles, part of the traffic flow will be redirected to an alternative road. Considering a traffic composition of 70% of 'light' vehicles (length<5m), and a total average number of 18000 vehicles per day per traffic lane, we can calculate the total number of vehicles that is redirected by scaling the initial distribution of traffic load (LN(25, 5)). The number of heavy trucks redirected for traffic restriction at 4.8t per day per lane is 157 (total of 314 on both directions).

Table 6. Probability of failure in 1yr for damage states DS with traffic restriction at 4.8t

Damage State	β in 1yr	P(F|DS) in 1 yr
DS_1	21.7	~ 0
DS_2	21.2	~ 0
DS_3	19.5	~ 0
DS_4	14.9	$1.07 \cdot 10^{-50}$
DS_5	3.1	$9.68 \cdot 10^{-4}$

4 CONSEQUENCES

As remarked Limongelli et al. (2017), earthquakes affect larger areas simultaneously. Therefore, consequences, e.g. casualties and injuries, are not only those directly induced by the failure of the bridge, but also those due to the loss of road network functionality (e.g. bridge located on a critical route to a hospital). To quantify the expected number of people in need of hospitalisation in the aftermath of an earthquake, a full seismic risk study would be needed regarding the entire area the bridge is located in and is expected to serve during emergency (e.g. to estimate the number of collapsing buildings and consequently the number of casualties).Furthermore, the economic losses due to traffic delays, detours and loss of business can be significant. Rigorous analysis of the direct and indirect consequences would require the knowledge of the complete scenario, including information about the infrastructural network the bridge belongs to and the vulnerability of the built environment in the region served by the bridge. Herein, several simplifying assumptions will be done since the aim of this application is not obtain a solution for a specific problem, but rather to illustrate a possible use of Value of Information analysis in the context of emergency management. A broad overview of the consequences of bridge failure is presented in Imam & Chryssanthopoulos (2012).

Table 7 Consequences of bridge failure considered (adapted from Imam&Chryssanthopoulos, 2012)

Category	
Human	Deaths Injuries
Economic	Replacement costs Loss of functionality Traffic delay/re-routing
Environmental	CO_2 emissions NOx emissions

The authors consider the categorization into four main groups: human, economic, environmental and social. Herein, only the subcategories in Table 7 are considered. Social costs have been neglected (e.g. reputational damage, diminished public confidence in infrastructure, undue changes in professional practice).

4.1 *Direct consequences*

Direct consequences of failure consist in bridge replacement costs (30m€ according to the data in Table 1) and the cost of fatalities depending on the adopted traffic restriction. The number of fatalities (Daniell et al., 2015) has been computed based on the assumption of constant traffic flow during the day, corresponding to 0.83 persons passing the bridge every second (there is a very small difference between TR_0 and TR_1) according to the assumptions in Table 1 over vehicles speed and bridge length. Therefore, 1.5persons (rounded to 2) are considered on the bridge at the same time (the time interval of 1.8s needed to pass the bridge).

Table 8. Fatalities due to the collapse of the bridge

Restriction	Cost of fatalities
TR_0	6m€
TR_1	6m€
TR_N	0

4.2 *Indirect consequences*

4.2.1 *Human*

If the bridge is closed, there could be an increased number of fatalities due to delayed emergency vehicles. Based on information reported in Ukai (1996), a percentage of about 5% of the total fatalities is due to crush syndrome (delay in emergency treatment. Assuming a total number of 100 casualties in the village to the earthquake, the indirect cost of fatalities due to delayed emergency is therefore 15m€.

4.2.2 *Environmental*

Due to the traffic restriction applied to heavy trucks, which have to travel longer distance when bypassing the bridge, additional environmental pollution is foreseen.

Table 9. Average environmental emissions and costs for EU trucks

vehicle	Average emission NOx	Unit environmental price NOx in €/kg	Average emission CO_2	Unit environmental price CO_2 in €/kg	Fuel consumption l/km
cars	0.8	34.7	120	0.057	0.048
truck	0.2	34.7	1070	0.057	0.35

Herein, only the pollution from CO_2 and NOx emission are considered as they are the most harmful to human health. The environmental cost can be calculated using the average values of unit emissions and unit costs for European countries (see Muncrief, 2016, de Bruin, 2017, Mock, 2017) listed in Table 9. The corresponding daily costs due to increased pollution for the three considered traffic restrictions are listed in Table 10.

Table 10. Daily costs due to increased pollution

Restriction	Cost of pollution
TR_0	0
TR_1	640
TR_N	48167

4.2.3 *Economic*

The economic costs are related to increased fuel consumption and to the additional travel time for the diversion of 30km. For the three considered traffic restrictions and for each day of bridge closure these costs are listed in Table 11.

Table 11. Daily economic costs related to fuel consumption and user time delay

Restriction	Cost of fuel	Cost of users time delay	Total economic cost
TR_0	0	0	0
TR_1	148365	9420	157785
TR_N	6735960	1080000	7815960

5 VOI ANALYSIS

Referring to the decision tree in Figure 1, the prior/posterior/pre-posterior analysis results are described in the following. The expected risk for each considered decision alternative (bridge open TR_0, traffic restricted TR_1, bridge closed TR_N) over traffic restriction in prior analysis (branch 'no inspection' in Figure 1) are reported in Table 12. Results in Table 12 show that the traffic restriction decision to 4.8t is the best decision because it corresponds to the minimum expected consequences of 0. 3155 m.€.

Table 12. Expected risk in Prior analysis

restriction	$E'[C(TR_k)]$ [m€]
TR_0	2.1579
TR_1	0. 3155
TR_N	22.8641

In order to compute the pre-posterior values of the risk connected to the different traffic restriction likelihood values $P(I_m|DS)$ are needed in order to compute posterior probabilities $P''(DS_l)$ according to Eq. (7). The likelihoods for each damage state have been assumed normal distributed (Estes et al., 2003) with mean equal to the inspection score in the damage state (1,2,…5) and standard deviation equal to 1. The last values correspond to the assumption that the inspector has enough expertize to be erroneously allocating the bridge damage state by shifting into maximum one class of inspection score. We can now evaluate the expected costs for the three decision alternatives before the inspection is performed, by considering all possible outcome of the inspection (see Eq. (10) & (11)). Results in

Table 13 show that, also in this case, the traffic restriction decision to 4.8t is the best decision because it corresponds to the minimum expected consequences of 0. 3154 m€.

Table 13. Expected risks in Pre-Posterior analysis

restriction	$E[C(TR_k)]$ m€
TR_0	2.0153
TR_1	0. 3154
TR_N	22.8641

The Value of Information (VoI) (see Schaifer&Raiffa, 1961) can now be computed using Eq. (12):

$$VoI = E'[C(TR^*)] - E[C(TR^*)] = 0.3155m€ - 0.3154€ = 0.001m€ \quad (16)$$

The expected value of information is 1000€. Therefore, in the specific scenario considered, there is a benefit in making the inspection only if the inspection costs (including the costs of personnel safety) is lower than this value.

5.1 *Conclusions*

In this paper the framework for quantifying the value of information proposed in COST Action TU1402 has been applied to the case of the post-earthquake emergency management of a bridge. Given a specific earthquake scenario, the value of information from visual inspections in the phase of the emergency is computed using the Bayesian pre-posterior approach to decision making. Optimal decisions whether to perform an inspection before imposing traffic restrictions on a potentially damaged structure or take the decision based on the prior knowledge on the bridge, provided by the fragility curves, is identified by minimizing the expected total consequences. For the specific scenario considered herein, traffic restriction that excludes heavy trucks, but allows emergency vehicles is the best solution. The results are of course valid in the limited context of the hypothetical case study with the declared hypothesis. A sensitivity analyses with respect to the considered cost related to direct and direct consequences will be the object of future research efforts.

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