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COMMUNITY RESILIENCE ASSESSMENT TOOLS BASED ON THE PEOPLES FRAMEWORK: WEB APP AND DESKTOP SOFTWARE

Ali ZAMANI NOORI[1], Omar KAMMOUH[2], Sebastiano MARASCO[3], Gian Paolo CIMELLARO[4]

ABSTRACT

Measuring community resilience has been an exploding field of inquiry in the last decade. Many options for measuring resilience ranging from specific measurements to frameworks can be found in literature. Among the different options available, indicators are perceived as an important instrument to assess the resilience of communities due to the simplicity involved in the process. This paper introduces indicator-based software tools to compute the resilience of communities against earthquakes. The tools are implemented in the form of web and desktop software that is accessible from any platform. The algorithm adopted in these tools is based on the PEOPLES framework. PEOPLES is a framework for defining and measuring the resilience of communities at various scales. The presented tools allow the user to choose the type community (rural, urban, industry) for which the resilience is measured. These inputs identify what indicators should be considered and suggest what weighting factor each indicator should take. The software tools take as inputs the performance of the indicators before and after a disaster event as well as the restoration time. The output is presented in the form of a resilience curve of the whole community. The developed tools have been tested to assess the level of resilience of San Francisco given an earthquake. Results of the case study show that the developed tools allow decision makers to derive key aspects on which most effort should be placed to improve their community resilience.

Keywords: PEOPLES framework; Community resilience; Software tools; hazards; resilience indicators

1. INTRODUCTION

Over the years, community resilience has attracted remarkable attention due to the increasing number of natural and man-made disasters. The concept of resilience is multi-dimensional, and therefore involves various subjects of different disciplines (Cimellaro 2016b; Chang et al., 2014, Bonstrom and Corotis, 2016). In communities, resilience is defined as "the ability of social units (e.g. organizations, communities) to mitigate hazards, contain the effects of disasters when they occur, and carry out recovery activities in ways to minimize social disruption and mitigate the effects of further earthquakes" (Bruneau et al. 2003; Cimellaro et al., 2010). Allenby & Fink defined resilience as "the capability of a system to stay in a functional state and to degrade gracefully in the face of internal and external changes" (Allenby and Fink 2005). An engineering system can be defined as any entity that provides service for the population (e.g. community, infrastructure, building, etc.).

In engineering, resilience is the ability to "withstand stress, survive, adapt, and bounce back from a crisis or disaster and rapidly move on" (Wagner and Breil 2013). From the several definitions provided above, it is clear that it is still difficult to find a generally accepted definition for engineering resilience (Hosseini et al. 2016), mainly because this concept has only recently been applied in the

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[1] PhD Student, Dept. of Civil Structural & Geotechnical Engineering, Politecnico di Torino, Torino, Italy, 10129 (email: ali.zamani@polito.it)

[2] PhD Student, Dept. of Civil Structural & Geotechnical Engineering, Politecnico di Torino, Torino, Italy, 10129 (email: omar.kammouh@polito.it)

[3] PhD Student, Dept. of Civil Structural & Geotechnical Engineering, Politecnico di Torino, Torino, Italy, 10129 (email: sebastiano.marasco@polito.it)

[4] Visiting Professor, Dept. of Civil and Environmental Engineering, University of California, Berkeley, CA, US, 94720

engineering field.

Resilience assessment provides a measure of a system's ability to cope with external factors. According to Bruneau et al. (2003), the resilience of a system depends on its serviceability performance. The serviceability performance (Q) ranges from 0 % to 100 %, where 100% and 0% imply full availability and non-availability of services, respectively. The occurrence of a disaster at time t_0 causes damage to the system and this produces an instant drop in the system's serviceability (ΔQ). Afterward, the system is restored to its initial state over the recovery period (t_0-t_1). The loss in resilience is considered equivalent to the service degradation of the system over the recovery period. This concept is mathematically defined as:

$$LOR = \int_{t0}^{t1} \left[100 - Q(t)\right] dt \qquad (1)$$

where LOR is the loss-of-resilience measure, t_0 is the time at which a disastrous event occurs, t_1 is the time at which the system recovers to 100% of its initial serviceability, $Q(t)$ is the serviceability of the system at a given time t.

Several solutions for measuring resilience are available in the literature (Cimellaro 2016; Cimellaro et al. 2014; Cimellaro et al. 2016a). Liuet al. (2017) introduced a method that combines dynamic modelling with resilience analysis. Interdependent critical infrastructures have been analyzed in terms of design, operation, and control using this method by performing a numerical analysis. Kammouh et al. (2017a) have introduced a quantitative method to assess the resilience at the state level based on the Hyogo Framework for Action (Kammouh et al. 2017a; UNISDR 2011). The approach introduced was an evolution of the risk assessment concept. The resilience of 37 countries has been evaluated and a resilience score between 0 and 100 has been assigned to each of them (Kammouh et al. 2017a; Kammouh et al. 2018). Cutter et al. (2014) reported that research on measuring community resilience is still in the early stages of development. Although many attempts have been made to consolidate research on community resilience (e.g. Twigg 2009; Norris et al. 2008; Cutter et al. 2010), no accepted method exists so far and there are still difficulties in developing concrete assessment approaches and reliable indicators (Abeling et al. 2014).

While simulation-based approaches are considered non-affordable to measure the resilience of a system because of the modelling complexity, the use of indicators is usually preferred, and therefore it is herein adopted. This paper introduces two software tools to measure the resilience of communities against earthquakes. The first is implemented in the form of web application that is accessible from all platforms while the second is presented in the form of a desktop software. An indicator-based approach based on the PEOPLES framework introduced in (Cimellaro et al. 2016a) is adopted as an engine for the tools. The methodology allows decision makers to take proper actions under emergencies because it provides a visual interpretation of the community performance. As a case study, the methodology has been applied to the city of San Francisco city given the 1989 Loma Prieta earthquake.

2. INDICATOR-BASED APPROACH FOR COMMUNITY RESILIENCE

PEOPLES is a framework for defining and measuring disaster resilience of a community at various scales. It is divided into seven *components* and each of them is divided into several *sub-components*. The goal is to convert PEOPLES from a qualitative to a quantitative framework. To do so, a large number of *indicators* available in literature have been collected and then allocated to PEOPLES' sub-components, creating a condensed list of 115 indicators.

A single *measure* is assigned to each indicator to make it quantifiable. The measures are then normalized to be ranged between 0 and 1. This is done by introducing a new parameter, the *target value* (TV). TV is a quantity that represents the reference point of the corresponding measure, defined by the competent authority. For example, if we consider the measure "*Red cross volunteers per 10,000* *people*”, the measure would give us an absolute number of volunteers as an output. This quantity cannot be integrated with other measures unless it is normalized; therefore, the result is divided over TV, which in this case represents the “BEST” number of volunteers per 10,000 people (e.g. SN=100 volunteers /10,000 people). If the ratio between the value of the measure and SN is less than one, it means that the indicator can still be improved, whereas if it is larger than one, the measure is considered “resilient”, and a value of 1 is assigned to that measure. Having all measures normalized enables the comparison among systems of similar or different types (e.g. hospitals and water networks).

Each indicator contributes with a certain degree towards the goal of achieving resilience; therefore, the measures are also classified according to their importance. An importance factor “*I*” has been assigned to each measure. This factor ranges from 1 to 3; where 1 means low importance and 3 means high importance. What’s more, two types of measures are identified: “static measures (*S*)”, assigned to the measures that are not affected by the disastrous event, and “dynamic measure (*D*)” or event-sensitive measures, assigned to the measures whose values change after a hazard takes place.

Table 1 shows a list of PEOPLES’ dimensions, sub-components, indicators, and measures, with their corresponding importance factors (I = 1, 2, or 3) and indicators’ nature (Nat. = S (static) or D (dynamic)). For the sake of clearness, only one component of the PEOPLES’ seven components have been included and expanded in the table. The hierarchal logic of the methodology is shown in Figure 1. More details about the methodology can be found in (Kammouh et al. 2017b).

Table 1. PEOPLES’ components, sub-components, indicators, and measures with corresponding importance factors (I) and indicators’ nature (Nat.)

Component/ sub-component/indicator	**Measure (0 ≤value ≤1)**	**Rel.**	**I**	**Nat.**
1- Population and demographics			**2**	
1-1- Distribution\ Density			3	
-Population density	Average number of people per area ÷ SN	N	3	D
-Population distribution	% population living in urban area	P	2	D
1-2- Composition			2	
-Age	% population whose age is between 18 and 65	P	3	S
-Place attachment-not recent immigrants	% population not foreign-born persons who came within previous five years	N	1	S
-Population stability	% population change over previous five year period	N	2	S
-Equity	% nonminority population – % minority population	P	3	S
-Race/Ethnicity	Absolute value of (% white – % nonwhite)	N	1	S
-Family stability	% two parent families	P	2	S
-Gender	Absolute value of (%female–%male)	N	1	S
1-3- Socio- Economic Status			2	
-Educational attainment equality	% population with college education – % population with less than high school education	P	3	S
-Homeownership	% owned-occupied housing units	P	2	S
-Race/ethnicity income equality	Gini coefficient	N	3	S
-Gender income equality	Absolute value of (% male median income – % female median income)	N	2	S
-Income	Capita household income ÷ SN	P	3	S
-Poverty	% population whose income is below minimum wage	N	3	S
-Occupation	Employment rate %	P	3	S

3. SOFTWARE TOOLS BASED ON PEOPLES FRAMEWORK

This section introduces two software tools in which the community resilience approach described above is implemented. The first tool is an online software that is accessible at: http://www.resiltronics.org/PEOPLES/login.php or http://borispio.ddns.net/PEOPLES/login.php, while the other is a portable desktop software (*Note: contact the author if the webpages are unreachable or to request the desktop software)*. Both tools require the same input and return the same output. As an input, the user is asked to insert information about specific community resilience indicators before and after a disaster event. The output is presented in the form of a resilience curve for the whole community. In the following, the use of each tool is described in details.

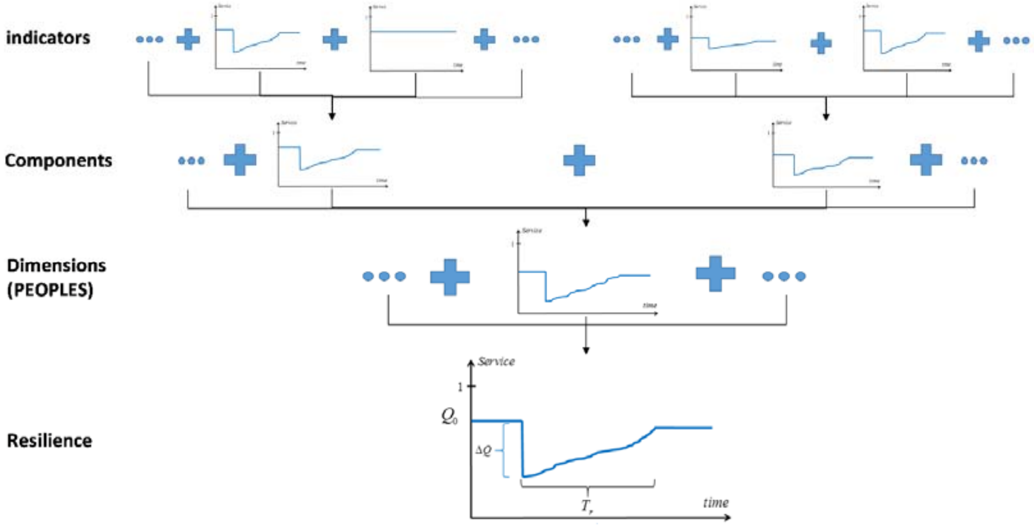
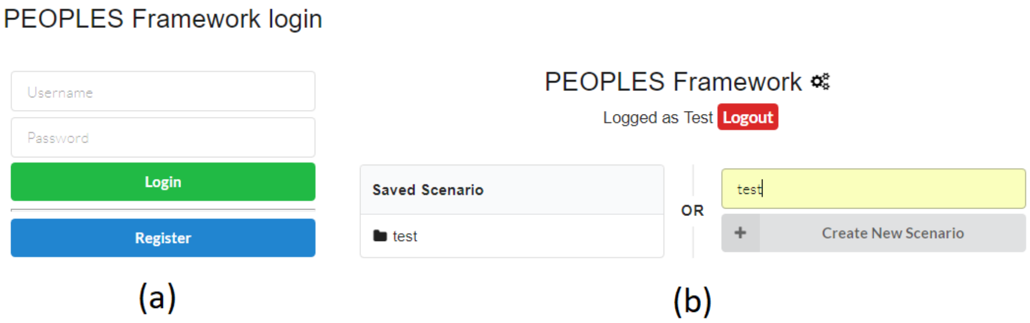


Figure 1. Hierarchical scheme of the adopted indicator-based resilience methodology

3.1. Web Application tool

The use of the online software is illustrated here. A Login/Register window appears when accessing the website (Figure 2a). The user must register prior to using the tool. Once registered, the user can start a new scenario for which the resilience is to be evaluated (Figure 2b). The scenario is composed of two main ingredients: (1) the analyzed community (i.e. city, country, etc.), and (2) the hazard considered (e.g. earthquake, tsunami, fire, etc.).



(a) (b)

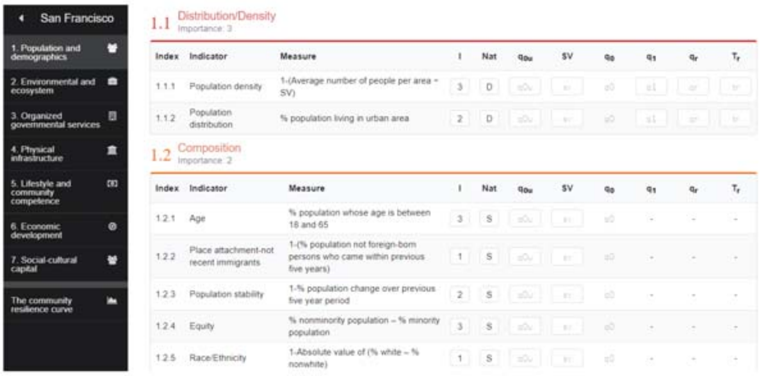
Figure 2. (a) Registration/login page, (b) new scenario definition/load scenario

After defining the scenario, a data-entry page that displays the various variables of the PEOPLES framework appears (Figure 3). On the left side of the webpage, the seven dimensions of PEOPLES are listed. A separate page for each dimension can be accessed by clicking on the dimension. For each dimension, a list of components and indicators is shown with blank spaces to insert the data of the parameters required for the resilience evaluation. A pop-up description is triggered when hoovering the mouse over a parameter in the window. This is to get extra information that helps the user identify what kind of information they should insert. The parameters involved in the resilience evaluation are:

- Importance factor (*I*): each indicator is associated with an importance factor between 1 and 3 representing the weight of the indicator towards the resilience output.
- Indicator nature (*Nat*): the indicators are classified according to their nature: "Static (*S*)", assigned to the measures that are not affected by the disastrous event, and "Dynamic (*D*)" or event-sensitive measures, assigned to the measures whose values change after a hazard takes place;
- Un-normalized serviceability before the event (q_{0u}): is the unnormalized initial serviceability of the measure;
- Standard value (*SV*): represents the optimal quantity for the indicator in order to be considered as fully resilient;
- Normalized serviceability before the event (q_0): is the normalized initial serviceability of the measure. It is obtained automatically by the software by dividing the unnormalized serviceability q_{0u} over the standard value *SV*;
- Serviceability after the event (q_1): The residual serviceability after the disaster. This quantity should be normalized by the user with respect to *SV*;
- Serviceability after recovery (q_r): it is the recovered serviceability, which can be equal, higher, or lower than the initial serviceability (q_0). In this paper. The recovered serviceability q_r is assumed equal to the initial serviceability q_0;
- Restoration time (T_r): it is the time needed to finish the recovery process. This value is usually determined using probabilistic or statistical approaches.

A list of importance factors (*I*) has been set as default in the software; however, the user can change the numerical values in the list according to their preference. The importance factors can be set all to "1" in case the user finds no justification to assign weights to the indicators; in this case, the indicators will be equally weighted. The nature of the indicator "*Nat*" can also be changed by the user because this parameter depends on the type of hazard and type of community considered in the analysis. If the indicator is *Static 'S'*, it is enough for the user to insert data about the initial serviceability of the system q_{0u}, and the standard value *SV*. If otherwise the indicator is *Dynamic 'D'*, the user should proceed and insert data about the post-event damage q_1, serviceability level after restoration q_r, and restoration time T_r. The parameter $q_{0u}$is inserted as unnormalized value while the other serviceability parameters q_1 and q_r have to be normalized by the user with respect to *SV* (divide over *SV*). A serviceability curve for each component is shown at the bottom of the page after inserting the indicators' data. The serviceability curve of the analyzed dimension, which is the weighted average of all serviceability functions of the components, is also shown on the same graph.

After inserting the required data for all PEOPLES seven dimensions, the user will be able to see the serviceability curve of the community by clicking on the 'The community resilience curve' on the left side of the screen. For each of the serviceability curves, the software automatically evaluates the *LOR*, which is an indicator for the serviceability loss incurred during the event.



1.1 Distribution/Density
Importance: 3

Index	Indicator	Measure	I	Nat	q_{0u}	SV	q_0	q_1	q_r	T_r
1.1.1	Population density	1-(Average number of people per area ÷ SV)	3	D	q0u	sv	q0	q1	qr	tr
1.1.2	Population distribution	% population living in urban area	2	D	q0u	sv	q0	q1	qr	tr

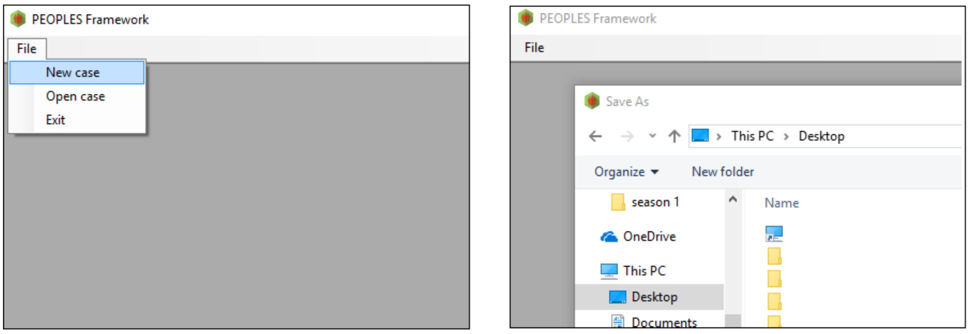
1.2 Composition
Importance: 2

Index	Indicator	Measure	I	Nat	q_{0u}	SV	q_0	q_1	q_r	T_r
1.2.1	Age	% population whose age is between 18 and 65	3	S	q0u	sv	q0	-	-	-
1.2.2	Place attachment-not recent immigrants	1-(% population not foreign-born persons who came within previous five years)	1	S	q0u	sv	q0	-	-	-
1.2.3	Population stability	1-% population change over previous five year period	2	S	q0u	sv	q0	-	-	-
1.2.4	Equity	% nonminority population – % minority population	3	S	q0u	sv	q0	-	-	-
1.2.5	Race/Ethnicity	1-Absolute value of (% white – % nonwhite)	1	S	q0u	sv	q0	-	-	-

Figure 3. User interface and data entry environment

3.2. Desktop Software

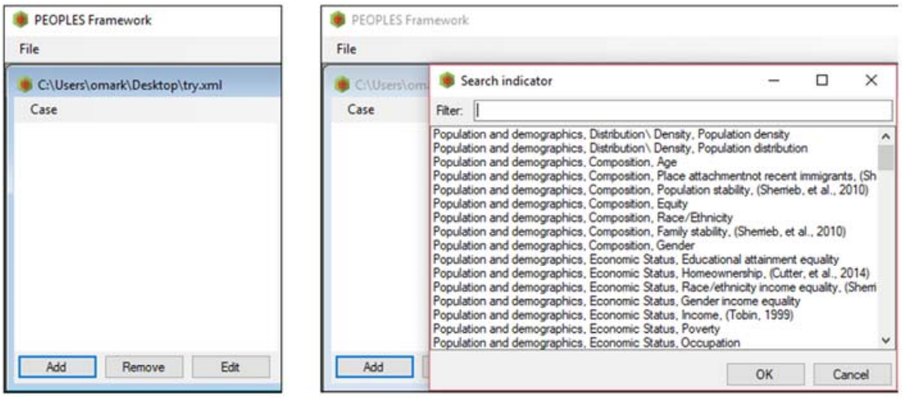
The software introduced in this section is a portable version that does not require installation. To run the software, only one file containing the indicators database is required. This file comes preloaded in the software package. The user cannot modify the indicators and the results accumulation hierarchy of the methodology as these are fixed according to the PEOPLES framework. When the software is run, the user will be required to choose whether they want to start a new scenario “New case” or to load a saved one “Open case” (Figure 4a). If the user chooses to start a new scenario, a new window, shown in Figure 4(b), asking the user to define the directory to which the scenario is saved will pop up.



(a) (b)

Figure 4. (a) Starting a new scenario “New case” or loading a saved scenario “Open case”, (b) saving the scenario if the option “New case” is chosen

After saving the new scenario, a new blank page with only three functions “Add”, “Remove”, and “Edit” will display (Figure 5a). At this stage, the user needs to insert the database specific to the analyzed case study. To do that, the user should click on the “Add” function, which triggers a window containing all the indicators of the PEOPLES framework (Figure 5b). The user can delete and modify the indicators using the functions “Remove” and “Edit”. Each of the indicators is accessed independently to insert the data required for its evaluation.

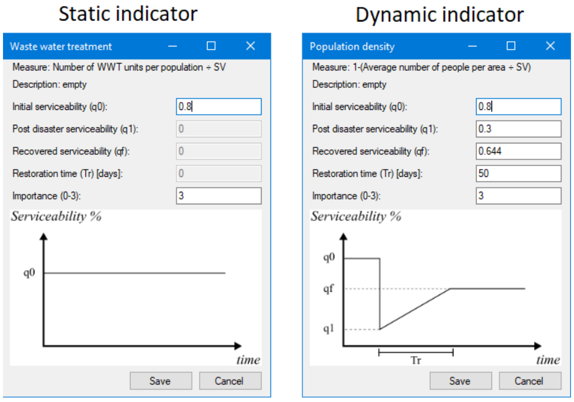


Population and demographics, Distribution\ Density, Population density
Population and demographics, Distribution\ Density, Population distribution
Population and demographics, Composition, Age
Population and demographics, Composition, Place attachmentnot recent immigrants, (Sh
Population and demographics, Composition, Population stability, (Sherrieb, et al., 2010)
Population and demographics, Composition, Equity
Population and demographics, Composition, Race/Ethnicity
Population and demographics, Composition, Family stability, (Sherrieb, et al., 2010)
Population and demographics, Composition, Gender
Population and demographics, Economic Status, Educational attainment equality
Population and demographics, Economic Status, Homeownership, (Cutter, et al., 2014)
Population and demographics, Economic Status, Race/ethnicity income equality, (Sherri
Population and demographics, Economic Status, Gender income equality
Population and demographics, Economic Status, Income, (Tobin, 1999)
Population and demographics, Economic Status, Poverty
Population and demographics, Economic Status, Occupation

(a) (b)

Figure 5. Indicators database

The number of inputs required depends on the nature of the indicator. Static indicators require only two parameters for their evaluation (q_0 and I) (Figure 6a) whereas dynamic indicators need five inputs (q_0, q_1, q_f, T_r, and I) (Figure 6(b)). It is very important to note that unlike the web app software introduced in the previous section, all the serviceability parameters q_0, q_1 and q_r MUST be normalized by the user (i.e., the user has to divide these quantities over SV).



Static indicator

Waste water treatment

Measure: Number of WWT units per population ÷ SV

Description: empty

Initial serviceability (q0): 0.8

Post disaster serviceability (q1): 0

Recovered serviceability (qf): 0

Restoration time (Tr) [days]: 0

Importance (0-3): 3

Dynamic indicator

Population density

Measure: 1-(Average number of people per area ÷ SV)

Description: empty

Initial serviceability (q0): 0.8

Post disaster serviceability (q1): 0.3

Recovered serviceability (qf): 0.644

Restoration time (Tr) [days]: 50

Importance (0-3): 3

(a) (b)

Figure 6. Use interface and data entry sheet for the indicators

4. CASE STUDY

The resilience of the city of San Francisco is evaluated using the introduced resilience assessment tools. The case study intends to show the applicability of the proposed methodology and not the actual evaluation of the resilience of San Francisco. The 1989 Loma Prieta earthquake, with a moment magnitude of 6.9, has been considered as the disaster event. Only one of the PEOPLES' dimension 'Physical Infrastructure' has been considered for the sake of simplification. Table 2 shows the extended list of the components and indicators within the dimension 'Physical Infrastructure' along with the data associated with each indicator. In this study, damage data was determined using open database sources (see notes under Table 2), which offer data for all cities across the US. Restoration fragility curves recently developed in (Kammouh and Cimellaro 2017) have been used to determine the restoration time for the different indicators.The case study can be replicated in the software tools by inserting the data of Table 2 in their corresponding fields in the web app and desktop software as explained earlier in the paper.

Data collection was the most difficult part of the analysis since data about the serviceability of community systems is scares and not shareable with the public. However, this does not imply that data is not available but rather is not accessible. Interested parties, such as decision makers and authorities, can use the framework with its full potential since data is usually available to them.

The software combines the serviceability functions of the group of indicators under a component point by point into a single serviceability function, taking into account their weighting factors. This curve represents the serviceability function of the underlying component. Similarly, the serviceability function of the dimension (i.e. Physical Infrastructure) is derived by computing the weighted average of serviceability functions of the corresponding components (i.e. facilities and lifelines).The tool evaluates the loss of resilience of the physical infrastructure using Equation 1. The time interval for calculation of resilience is considered from the time that the event occurs (t_0=0) until the end of full recovery (i.e. the time corresponding to the instance where the curve reaches its pre-disaster level, which coincides with the maximum restoration time among all indicators; t_r=700 days). The control time T_c is determined based on the user's period of interest so it can take any value. In this example, T_c is set equal to t_r automatically by the software. Figure 7 and 8 show the resilience curve of the case study obtained using the online and the desktop software tools, respectively. The obtained *LOR* value (25.6%) corresponds only to the physical infrastructure dimension of the community.

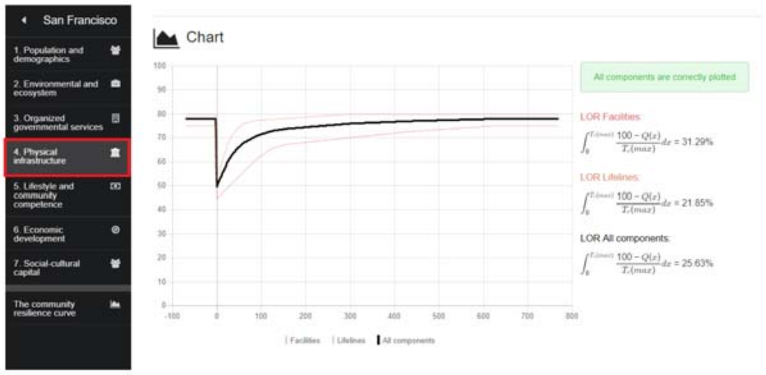
In order to have a resilience index for the whole community, the serviceability functions of other dimensions have to be similarly evaluated and combined in the same way. It is also interesting to compare the resilience of the two components *facilities* and *lifelines* shown in Fig. 7. It is clear that the city of San Francisco has more problems in facilities (*LOR*=31.29%) than lifelines (*LOR*=21.85%); therefore, it is suggested that the authority focuses more on enhancing their facilities.

Table 2. Serviceability parameters of the indicators within the Physical Infrastructure dimension for the city of San Francisco after the Loma Prieta earthquake.

Physical infrastructure									
Component /indicator	**Measure**	**w**	**Nat**	q_{0u}	***TV***	q_0	q_1	q_r	T_r (days)
4.1 Facilities	-		-						
4.1.1 Sturdy (robust) housing types	% housing units that are not manufactured homes	3	D	1	1	1	0.599	0.998	120
4.1.2 Temporary housing availability	% vacant units that are for rent	3	D	2.68	5	0.536	0.050	0.536	620
4.1.3 Housing stock construction quality	100-% housing units built prior to 1970	3	D	0.241	1	0.241	0.145	0.241	700
4.1.4 Community services	%Area of community services (recreational facilities, parks, historic sites, libraries, museums) total area ÷ TV	2	D	0.16	0.2	0.800	0.480	0.800	430
4.1.5 Economic infrastructure exposure	% commercial establishments outside of high hazard zones ÷ total commercial establishment	2	S	0.85	1	0.850	-	-	-
4.1.6 Distribution commercial facilities	%Commercial infrastructure area per area ÷ TV	3	D	0.13	0.15	0.867	0.520	0.867	160
4.1.7 Hotels and accommodations	Number of hotels per total area ÷ TV	3	D	102	128	0.797	0.478	0.797	130
4.1.8 Schools	Schools area (primary and secondary education) per population ÷ TV	3	D	134	140	0.957	0.574	0.957	90
4.2 Lifelines									
4.2.1 Telecommunication	Average number of Internet, television, radio, telephone, and telecommunications broadcasters per household ÷ TV	3	D	5	6	0.833	0.500	0.833	90
4.2.2 Mental health support	number of beds per 100 000 population ÷ TV	2	D	69	75	0.920	0.644	0.920	35
4.2.3 Physician access	Number of physicians per population ÷ TV	2	S	2.5	3	0.833	-	-	-
4.2.4 Medical care capacity	Number of available hospital beds per 100000 population ÷ TV	3	D	544	600	0.907	0.635	0.907	35
4.2.5 Evacuation routes	Major road egress points per building ÷ TV	2	S	0.67	1	0.670	-	-	-
4.2.6 Industrial re-supply potential	Rail miles per total area ÷ TV	3	D	5412	6000	0.902	0.631	0.902	45
4.2.7 High-speed internet infrastructure	% population with access to broadband internet service	3	D	0.9	1	0.900	0.450	0.900	300
4.2.8 Efficient energy use	Ratio of Megawatt power production to demand	3	D	0.8	1	0.800	0.160	0.800	25
4.2.9 Efficient Water Use	Ratio of water available to water demand	3	D	1	1	1.000	0.240	1.000	60
4.2.10 Gas	Ratio of gas production to gas demand	3	D	0.1	1	0.100	0.050	0.100	70
4.2.11 Access and evacuation	Principal arterial miles per total area ÷ TV	3	D	172138	200000	0.861	0.602	0.861	45
4.2.12 Transportation	Number of rail miles per area ÷ TV	3	D	5412	6000	0.902	0.631	0.902	72
4.2.13 Waste water treatment	Number of WWT units per population ÷ TV	3	D	3	4	0.750	0.300	0.750	65

* q_{0u} = the initial serviceability; *TV* = the target value; q_0 = the initial normalized serviceability; q_1 = post disaster serviceability; q_r= the recovered serviceability; T_r = the restoration time.

* Source: City Data, Census Data, This Study, City Assessor's Data, Dept of Numbers, SF Indicator Project, Data World Bank, Dot Ca, SF Bos, Arcadis, SF Wáter, Energy Ca.



All components are correctly plotted

LOR Facilities:

$\int_0^{T_r(max)} \frac{100 - Q(x)}{T_r(max)} dx = 31.29\%$

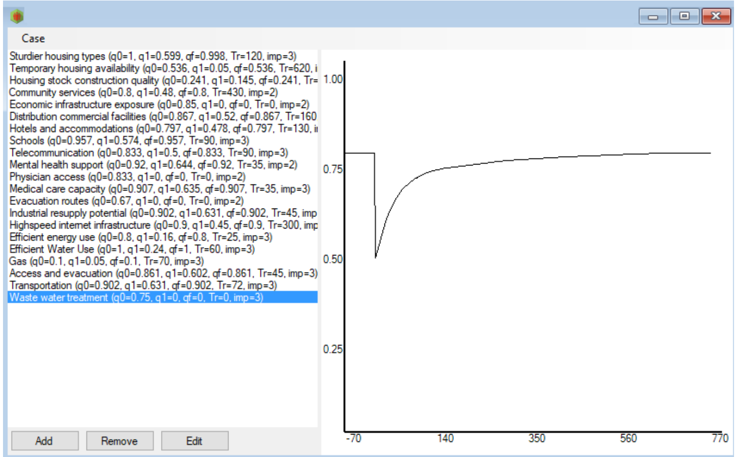
LOR Lifelines:

$\int_0^{T_r(max)} \frac{100 - Q(x)}{T_r(max)} dx = 21.85\%$

LOR All components:

$\int_0^{T_r(max)} \frac{100 - Q(x)}{T_r(max)} dx = 25.63\%$

Figure 7. Serviceability curves of the components “Facilities” and “Lifelines” and the dimension “Physical Infrastructure”



Sturdier housing types (q0=1, q1=0.599, qf=0.998, Tr=120, imp=3)
Temporary housing availability (q0=0.536, q1=0.05, qf=0.536, Tr=620, i
Housing stock construction quality (q0=0.241, q1=0.145, qf=0.241, Tr=
Community services (q0=0.8, q1=0.48, qf=0.8, Tr=430, imp=2)
Economic infrastructure exposure (q0=0.85, q1=0, qf=0, Tr=0, imp=2)
Distribution commercial facilities (q0=0.867, q1=0.52, qf=0.867, Tr=160
Hotels and accommodations (q0=0.797, q1=0.478, qf=0.797, Tr=130, i
Schools (q0=0.957, q1=0.574, qf=0.957, Tr=90, imp=3)
Telecommunication (q0=0.833, q1=0.5, qf=0.833, Tr=90, imp=3)
Mental health support (q0=0.92, q1=0.644, qf=0.92, Tr=35, imp=2)
Physician access (q0=0.833, q1=0, qf=0, Tr=0, imp=2)
Medical care capacity (q0=0.907, q1=0.635, qf=0.907, Tr=35, imp=3)
Evacuation routes (q0=0.67, q1=0, qf=0, Tr=0, imp=2)
Industrial resupply potential (q0=0.902, q1=0.631, qf=0.902, Tr=45, imp
Highspeed internet infrastructure (q0=0.9, q1=0.45, qf=0.9, Tr=300, imp
Efficient energy use (q0=0.8, q1=0.16, qf=0.8, Tr=25, imp=3)
Efficient Water Use (q0=1, q1=0.24, qf=1, Tr=60, imp=3)
Gas (q0=0.1, q1=0.05, qf=0.1, Tr=70, imp=3)
Access and evacuation (q0=0.861, q1=0.602, qf=0.861, Tr=45, imp=3)
Transportation (q0=0.902, q1=0.631, qf=0.902, Tr=72, imp=3)
Waste water treatment (q0=0.75, q1=0, qf=0, Tr=0, imp=3)

Figure 8. Serviceability curve the dimension “Physical Infrastructure”

5. CONCLUSIONS

Previous work on resilience evaluation provided several theoretical frameworks that have not been put in practice because no actual tool has been associated to them. This makes it difficult for the user to apply those resilience methods. In this paper, two software tools to compute the resilience of communities are developed. The first is a web app while the second is a portable desktop software. An indicator-based method based on the PEOPLES framework has been implemented as an engine for the tools. This method has been chosen as it has the potential to indicate in details whether the resilience deficiency is caused by the system’s lack of robustness or by the slow restoration process. It also identifies where exactly resources should be applied to efficiently improve resilience. The softwares can serve as an initial tool for decision makers to evaluate the disaster resilience of their communities. The present work contributes to this growing area of research as it provides a universal tool to quantitatively assess the resilience of communities at multiple scales. Future research is aimed at developing similar tools to measure the resilience of specific infrastructures considering the interdependency between indicators to define better weighting factors.

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