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DAMAGE REPORT WITH SMARTPHONES DURING EMILIA EARTHQUAKE, 2012

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Abstract. *On May 20th and 29th 2012, two earthquakes of 5.9Mw and 5.8Mw have struck the Emilia Romagna region of Italy, causing 27 deaths and widespread damage. The epicentres were between Finale Emilia and Medolla. The damage report during the emergency response was managed from the Italian Civil Protection and volunteers, using AEDES hardcopy forms. Since the use of smart phones is spreading among citizens our team decided to develop a smartphone application, which works on Android technology, to record the damage state of residential buildings. This was tested during the emergency response of Emilia earthquake to help the Piedmont Civil Protection on recording the damage report and, moreover, it was compared with the standard procedure based on the use of AEDES hardcopy forms.*

1 INTRODUCTION

The increasing capabilities of mobile communication and computing of handheld devices [1][2][3][4][5][6] are very helpful to provide a damage report after a natural disaster such as a earthquake. Emergency managers have to receive and record the data related to damages of physical infrastructure (e.g. buildings, etc.) and then they have to develop and transmit emergency plans as fast as possible [7]. The acquisition of damage reports starts from the citizens that require a first-level damage report – i.e. certificates of usability made with the AeDES survey form. Then the operative centre organizes many technical teams to evaluate and perform the damage reports that are processed and organized according to their importance. Much of damage reports of physical infrastructure are currently done by the use of hardcopy forms. These are processed step by step and not in real time – i.e. the emergency managers wait for the slow uploading of the data blocks that are acquired in hardcopy forms from the Di.Coma.C. (Operative centre) – loosing the overall view of the emergency. Moreover, the communication system can break off due to the fragility of telecommunication networks, which makes the damage report more difficult. Therefore, the rapid changing of information during a disaster suggests developing a procedure that can acquire in real time the damage reports using a robust telecommunication network.

In the paper, it is proposed a smartphone application *D.A.S.* – Damage Assessment with Smartphones, which works on Android technology, which acquires citizens' requests and assess the damage state of buildings, providing efficient real-time information for the evaluation of emergency plans required after a natural disaster [8]. The smartphone application was tested during the emergency response in Emilia – that was affected by two strong earthquakes on the 20th and 29th of May 2012 – to help the Piedmont Civil Protection with recording the damage reports. Moreover, the proposed procedure was compared with the standard procedure, evidencing the strengths of using handheld devices.

2 EMILIA EARTHQUAKE

A series of important seismic events occurred in Italy in the Po valley, starting from Sunday morning of May 20th, 2012, when at 04:03:53 local time (02:03:53 UTC) a strong earthquake whit magnitude Mw 5.9 struck. The epicentre was located in Finale Emilia (44°50'N 11°17'E) in the province of Modena. On Tuesday May 29th, at 09:00:03 local time (07:00:03 UTC) a new strong earthquake whit magnitude Mw 5.8 occurred in the same seismic region of the previous event (44°85'N 11°09'E) and even this time it was felt throughout northern Italy. The shock of the nine followed three other mayor shocks again on May 29th: one at 12:55 with magnitude Mw 5.4, another one at 13:00 whit magnitude Mw 4.9 and a further one at the same time with magnitude Mw 5.2. The main earthquake of May 20th was anticipated by a first event with magnitude M_w 4.1 in the same place at 01:13 local time on Saturday May 19th. The strong earthquake of 4:03 has begun with a long seismic sequence, which was continued in the following weeks with more than 2200 shocks; seven were with M_w >5 (Table 1).

Date	UTC (local time)	Latitude	Longitude	Depth	Magnitude	Source
20/05/12	02:03:52 (04:03:52)	44.889	11.228	6.3	5.9	iside.rm.ingv.it
20/05/12	02:07:31 (04:07:31)	44.863	11.370	5.0	5.1	iside.rm.ingv.it
20/05/12	13:18:02 (15:18:02)	44.831	11.490	4.7	5.1	iside.rm.ingv.it
29/05/12	07:00:03 (09:00:03)	44.851	11.086	10.2	5.8	iside.rm.ingv.it
29/05/12	10:55:57 (12:55:57)	44.888	11.008	6.8	5.3	iside.rm.ingv.it
29/05/12	11:00:25 (13:00:25)	44.879	10.947	5.4	5.2	iside.rm.ingv.it
03/05/12	19:20:43 (21:20:43)	44.899	10.943	9.2	5.1	iside.rm.ingv.it

Table 1 Main earthquakes with M_w >5 (updated on July 13, 2012).

All of these earthquakes had a devastating effect on the towns near the epicentre, resulting in 27 fatalities. The collapse of industrial structures was the major contributor to life hazard, because most people were working when the second earthquake struck. The most affected town centres by earthquakes were: *Alberone, Camurano (Meddola), Canaletto, Finale Emilia, Galeazza, Mirandola, San Felice sul Panaro, and San Carlo (INGV)*. Many low-rise unreinforced masonry construction and the most vulnerable buildings have suffered major damage that made them unusable. Some monuments have been damaged with huge losses for the historical heritage. Frequently, the fall of chimneys from the roofs occurred in residential buildings, but generally the new buildings have not been damaged, while many abandoned houses in the countryside collapsed.

3 MANAGEMENT OF THE EMERGENCY RESPONSE IN EMILIA

The earthquakes, which have struck the Emilia Romagna region, can be classified as an inter-regional disaster [10][11] – that required coordination at the national level – because it involved more than 80,000 people distributed across 40 municipalities (16 in the Province of Modena, 7 in Mantua, 7 in Bologna, 6 in Ferrara, and 4 in Reggio Emilia) and it damaged historic buildings in the largest towns (Ferrara, Mantua, Modena and Bologna). The civil protection of the Emilia-Romagna region is one of the best-equipped and organised in Italy, with a big headquartered in Bologna and huge number of vehicles, manpower, equipment, and supplies. Moreover, it was one of the first Italian regions to introduce TETRA system (TErrestrial Trunked RAdio, Figure 1), which creates an alternative emergency communication network if the previous one is damaged.

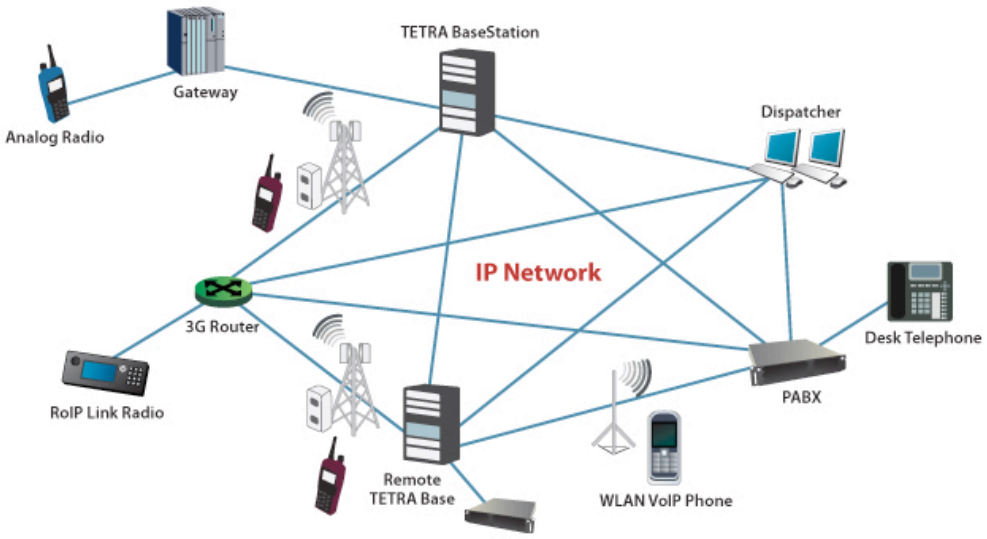

Figure 1 TETRA system (TErrestrial Trunked RAdio).

The Emilia emergency issue was the regeneration of industry and employment. The evacuations were limited to brief exits at the time of the tremors, but anyway, the earthquakes left about 20,000 people in need of shelters (62% in Modena, 30% in Ferrara, 5% in Bologna, and 3% in Mantua). The damage to housing was slight, but the undamaged houses inside the red zones – areas such as the city centres, which were cordoned off in order to maintain public safety – were inaccessible. These buildings needed anyway a first-level damage report to be realised.

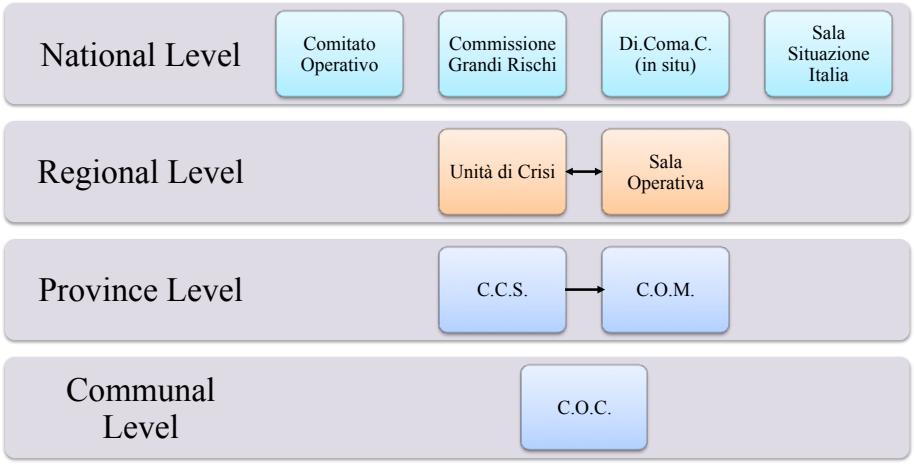

Figure 2 Italian system of coordination.

Figure 2 shows the Italian system of coordination in which resources are managed by sectors from national level (Di.Coma.C.), through regional level (Unità di Crisi) to the larger (C.O.M.) and then smaller local settlements (C.O.C.). One of the competencies managed by the national Department of Civil Protection is to coordinate technical assessments of the stability and usability of residential buildings.

Figure 3 Volunteer technician of Politecnico di Torino.

Volunteer technicians from various regions (Figure 3) have performed the surveys for assessing the damage of residential buildings during the emergency response with the AeDES survey forms (certificates of usability) making 38,726 surveys (3,665 in Bologna, 8,827 in Ferrara, 24,144 in Modena, and 2,090 in Reggio Emilia) from 21st of May until 30th of August (101 days). Also our group of the Department of Structural, Geotechnical & Building Engineering (DISEG) of Politecnico di Torino have participated collaborating with the Piedmont Civil Protection making about 500 surveys.

Figure 4 shows the certificate of usability (i.e., AeDES survey form) that was used in Emilia, which defines six outcomes of building usability: (A) usable building, (B) UNUSABLE building (totally or partially), but USABLE after short-term countermeasures, (C) PARTIALLY UNUSABLE building, (D) TEMPORARILY UNUSABLE building requiring a more detailed investigation, (E) UNUSABLE building, and (F) UNUSABLE building due to

external risk. Moreover, it is composed by nine sections: (1) building identification, (2) building description, (3) typology, (4) damage to structural elements and short term countermeasures carried out, (5) damage to non structural elements and short term countermeasures carried out, (6) external damage due to other constructions and short term countermeasures carried out, (7) soil and foundations, (8) usability judgment, and (9) other observations.

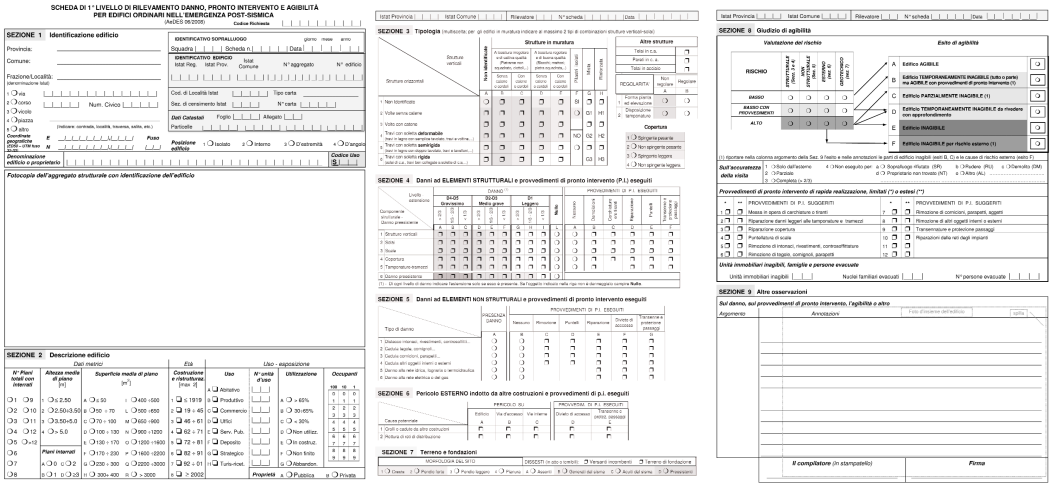

Figure 4 AeDES survey form.

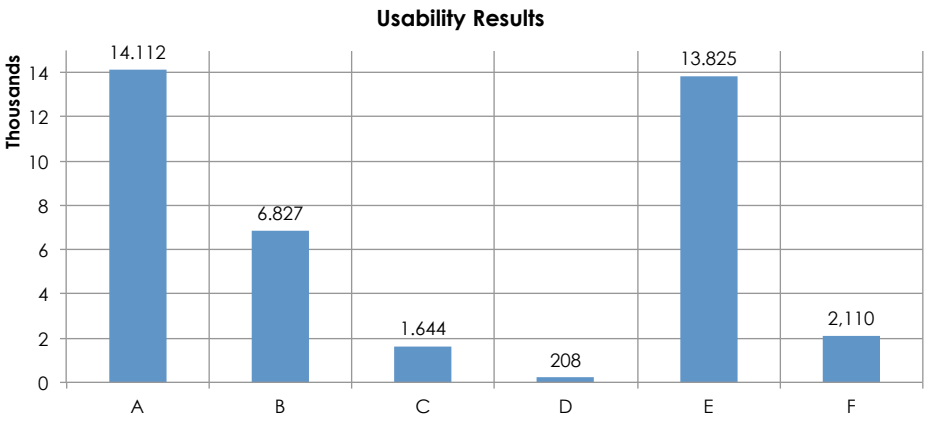

Figure 5 Usability results after 101 days from 20th of May.

Figure 5 shows the results of certificates of usability at the national level, until the 29th of August, which were: 14,112 (36.4%) of A, 6,827 (17.6%) of B, 1,644 (4.2%) of C, 208 (0.5%) of D, 13,825 (35.7%) of E, and 2,110 (5.4%) of F.

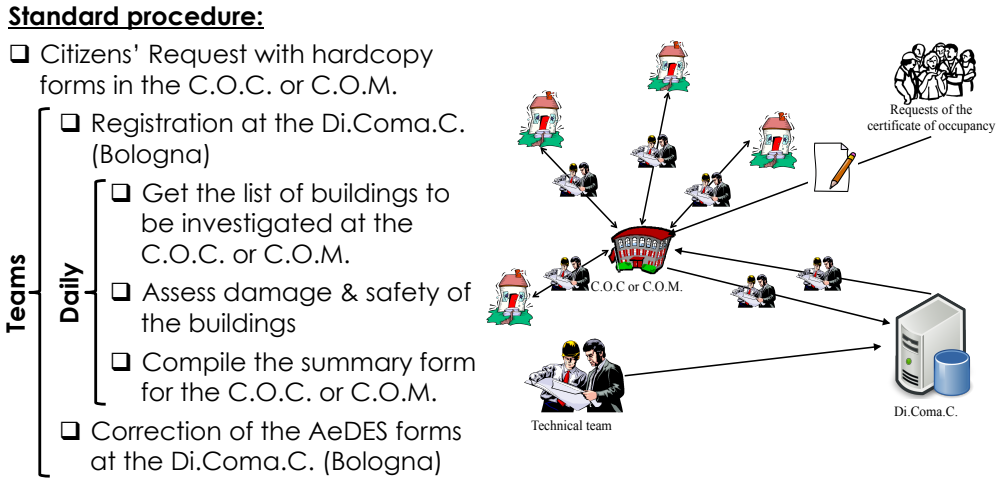

Figure 6 Standard procedure for the certificates of usability during the Emilia earthquake.

As mentioned above, the surveys were made by several technical teams. The standard procedure (Figure 6) for the certificates of usability during the emergency was:

- Citizens' request of certificates of usability with hardcopy forms in the C.O.C. or C.O.M.
- Organization of technical teams

  Then for each technical team:
  - Registration of the technical team at the Di.Coma.C. (Bologna)

    For each day:
    - Get the list of buildings to be investigated at the C.O.C. or C.O.M.

      For each building:
      - Reach the building to be investigated
      - Fill the AeDES survey form (certificate of usability)
    - Compile the summary form for the C.O.C. or C.O.M.
    - Reach the accommodation
  - Correction of the AeDES forms at the Di.Coma.C. (Bologna).

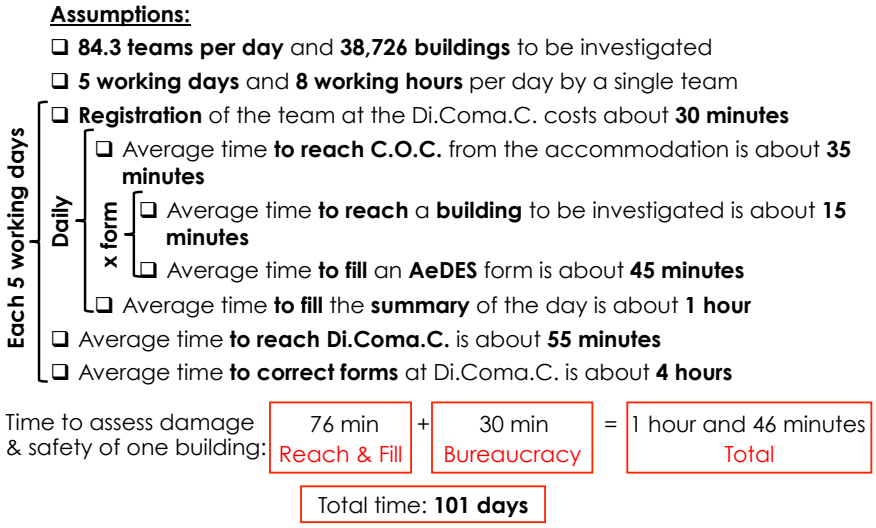

Figure 7 Assumptions and times for the standard procedure.

With the assumptions shown in Figure 7, each certificate of usability has cost 1 hour and 46 minutes, where 30 minutes were lost for bureaucratic procedures. This means that 28% (29

days) of the total time (101 days) for performing the certificates of usability of damaged residential buildings was lost only for the bureaucratic procedures, without considering of the lost time to get the list of buildings to be investigated at the C.O.C. or C.O.M..

4 SMARTPHONE APPLICATIONS DURING EMERGENCY RESPONSE

Since the use of smartphones is gaining interest in people, our team decided to implement the smartphone technology into the standard procedure for making certificates of usability of the damaged residential buildings. During the emergency response, for helping the Piedmont Civil Protection, a smartphone application was developed. This was tested during the emergency response of Emilia earthquake to acquire 24 citizens' requests (Figure 8a) and 70 AeDES survey forms.

Figure 8 (a) Citizens' requests made with application, and (b) graphical interface

The application shown in Figure 8 is a user-friendly and reduces the bureaucratic procedures and simplifies the evaluation and the acquisition of the certificates of usability. The application provides:

1. Registration of the technical team requiring the identification data of technical team – i.e. identification team number, names and signatures of technicians – that are using the handheld device, reducing the time of the registration.
2. Prefilled AeDES survey form, speeding up the acquisition process.
3. Geo-referencing of the forms trough the GPS localization of the device.
4. Sketches and photos of the investigated building that are attached to the certificate of usability.
5. Auto-correction of the survey form, deleting any error.
6. Creation of the certificate of usability in PDF format.
7. Sending of the certificate, photos, and sketches to the operative centre (in our case the Politecnico di Torino), reducing and optimizing the time to perform the damage report.

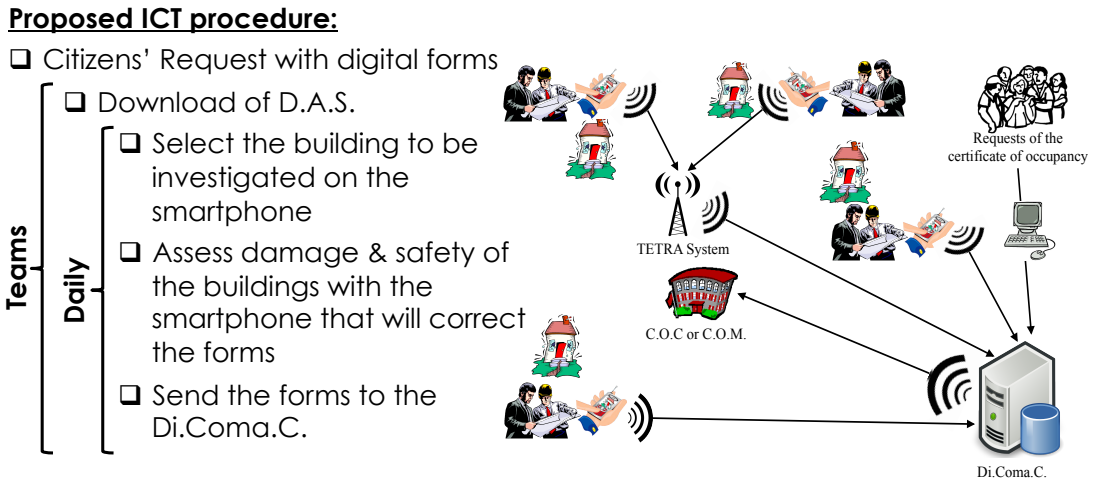

Figure 9 Proposed procedure to make the certificates of usability.

Therefore, our research intends to propose a new procedure (i.e., ICT procedure, Figure 9) to make efficiently the certificates of usability during emergencies: integrating the TETRA system (robust network that permits the use of ICTs), removing all bureaucratic procedures, and reducing detours and missing appointments (giving the routing to the closer and available residential building to be investigated). The proposed ICT procedure is defined as follows:

- Citizens' request of certificates of usability in digital format
- Organization of technical teams

  Then for each technical team:
  - Download of D.A.S. application and registration of the technical team

    For each day and each building:
    - Select the building to be investigated on the application
    - Reach the building to be investigated
    - Fill the AeDES form with the smartphone, which is corrected by the application
    - Send the AeDES form to the Di.Coma.C. by internet connection (TETRA system)
    - Reach the accommodation.

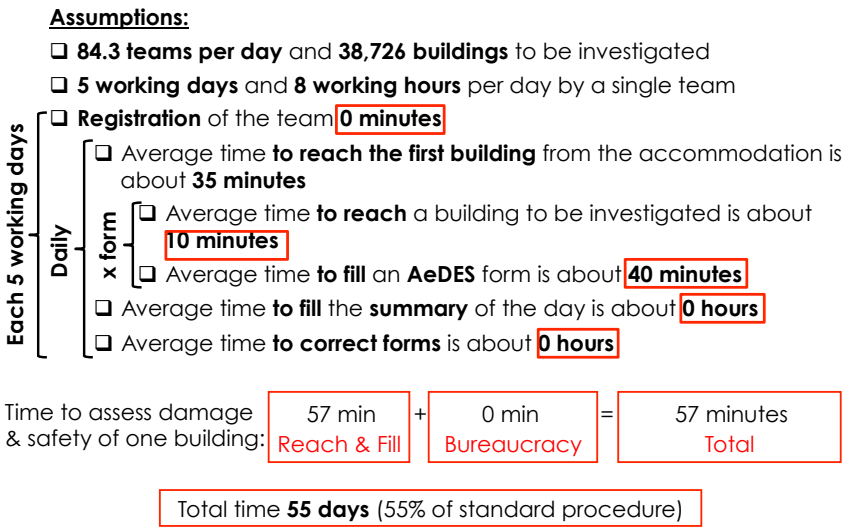

Figure 10 Assumptions and times for the proposed ICT procedure.

In conclusion, with the assumptions shown in Figure 10, each certificate of usability costs 57 minutes. In particular, it doesn't waste time in bureaucratic procedures. This means that the ICT procedure would permit to save 45% (i.e., 46 days) compared to the total time of the standard procedure.

5 CONCLUSIONS

Two earthquakes of 5.9Mw and 5.8Mw, on the 20th and 29th of May 2012, have struck the Emilia Romagna region of Italy, involving more than 80,000 people distributed across 40 municipalities and damaged historic buildings in the larger towns. The Emilia emergency issue was the regeneration of industry and employment.

The Politecnico di Torino helps the Piedmont Civil Protection, with a series of volunteer technical teams, to assess the damage status of the residential buildings and produce the damage report during the emergency. Hence, an application for assisting technicians and engineers was developed in order to improve the speed of producing damage reports for buildings during catastrophic events. The procedure uses a robust telecommunication network (i.e. TETRA system), it reduces the bureaucratic procedures and simplifies the compilation of the first-level damage reports required to assess the stability and the usability of the investigated residential buildings. The smartphone application was tested, during the emergency response of Emilia earthquake, to acquire 24 citizens' requests and 70 AeDES survey forms. The proposed ICT procedure, which works more efficiently during emergencies, was simulated and applied to the case of Emilia earthquake, showing the advantages with respect to the hardcopy standard procedure.

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