Systemic approach to the management of infrastructure safety: Organizational items

Systemic Approach to the Management of Infrastructure Safety: Organizational Items

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Abstract. This study deals with the organizational items within a systemic approach finalized to make the safety management of road infrastructures more sustainable at a scale of territory. In fact, the infrastructure safety is a very relevant topic in many states with structural systems built some decades ago. Beyond the inherent structural problems, other items are worthy to be investigated, such as, social, economic and organizational aspects. With this aim, the study describes a systemic approach finalized to make all the public and private stakeholders active actors in the management process by improving the organizational items: interaction and mode of governance. In detail, regarding a case study in an Italian region, the authors propose to take on the satellite-based information to investigate the structural safety problems of the infrastructures at a scale of territory. Along this issue, risk or alert maps are properly defined. Successively, useful suggestions are discussed with the focus to increase the interactions between the different actors for a better management of the safety. The recommendations are able to improve the governance mode and decision process with a more all-inclusive level of organization.

INTRODUCTION

This study deals with the organizational items within a systemic approach finalized to make the safety management of road infrastructures more sustainable at a scale of territory. In fact, the infrastructure safety is a very relevant topic in many states with structural systems (e.g., roads, bridges, viaducts and highways) built some decades ago. Beyond the inherent structural problems, other items are worthy to be investigated, such as, social, economic and organizational aspects [1-5].

With this aim, the study describes a systemic approach finalized to make all the public and private stakeholders active actors in the management process by improving the organizational items: interaction and mode of governance. Several literature studies describe plans and policies aimed at ensuring the protection of the infrastructures against natural or anthropic events [6-10].

In fact, the research [6] discusses that an increasing number of planning activities by public authorities and governments are more and more devoted to guarantee a protection of urban communities, including all the infrastructures, from tidal rise, flooding and storm surges consequential to climate changes [7] as well as from geological phenomena, e.g., liquefaction events caused by earthquakes. Other researches (e.g., [8]) have provided improvements to the planning of territories, affected by natural hazards (i.e., landslides), considering the risk perception of the citizens by means of surveys.

Some approaches are based on risk maps elaborated through the Geographical Information System (GIS) technique [9]. A framework with integrated and systemic features for safety and security management of road infrastructures is described in [10].

Similarly, “Bridge Management Systems” (BMS) strategies have been developed [11] with various degrees of success around the world as commented in the next.

Two BMSs have been adopted in the U.S.: PONTIS and BRIDGIT. PONTIS is probably the most advanced BMS and with its top-down approach can be finalized to optimize bridge funding for rehabilitation, maintenance and repair as well as also for improvements to bridge structures at the network level.

In Europe, a program known as “BRIdge Management in Europe” (BRIME) has been assumed by the member countries of the European Economic Community with the focus to develop a comprehensive BMS able to meet the specificities of the European Road Network.

In Italy, different BMSs have been proposed by public and private agencies having the responsibilities of bridges and infrastructures [12].

All the above-mentioned strategies employ different Structural Health Monitoring (SHM) techniques: in-situ sensors or remote sensing, i.e., the Differential Interferometry Synthetic Aperture Radar (DInSAR) as commented in [13-14].

Regarding a case study in an Italian region, the authors propose to take on the satellite information to investigate the structural safety problems of the infrastructures at a scale of territory. Therefore, risk or alert maps referred to natural or time-dependent phenomena (e.g., seismic events, slow landslide events, subsidence or temperature or soil-structure interaction effects, deterioration/degradation phenomena, seasonal effects) are properly defined at a scale of territory.

Successively, useful suggestions are discussed with the focus to increase the interactions between the different actors for a better management of the safety. The recommendations are able to select the most appropriate governance mode and improve the decision process with a more all-inclusive level of organization.

THE SATELLITE DInSAR MONITORING

The DInSAR data [15-16] are achieved by means of a satellite constellation (e.g., the Italian COSMOSkyMed) to quantify the movements on the topographic surface, within a timeframe of interest, as a consequence of different possible phenomena as previously commented. The data are received from the sensors along the Lower Earth Orbits, which are placed between 500 - 800 km from the Earth and follow the polar orbits.

The DInSAR-derived data can be characterized by a high accuracy that depends on some parameters (e.g., coherence) [15-16]. As explicated in [15-16], the accuracy varies in a range between 1 and 2 mm/year as for the average velocity and between 5 and 10 mm as for the single displacement time series.

These data can be elaborated in the GIS environment with the focus to illustrate the displacements acting on the infrastructures through specific thematic (alert or risk) maps. Therefore, it is possible to have a spatial view of the infrastructures safety in a context of territory. More details may be found in [17]-[18].

The growing interest for the DInSAR data has led to an increasing their diffusion with several applications in as many projects and case studies focused on the detection, mapping and monitoring of ground displacements after the occurrence of hazardous phenomena [19]. This large diffusion is due to several advantages: the large spatial coverage achievable through the SAR images; the subcentimetric accuracy for the measurements in terms of displacements; the sustainable cost-effectiveness of the satellite monitoring in comparison to the traditional in-situ sensors.

It is noteworthy to specify that, beyond the monitoring results, the judgments of expert engineers are always necessary to assess the structural criticisms and their impacts on the infrastructures safety.

ORGANIZATIONAL ITEMS IN THE INFRASTRUCTURES SAFETY

The abovementioned thematic maps permit to identify the stakeholders directly involved in the different issues and modify the interactions between them to improve the organization mode in the management procedures of the territory.

Figure 1 shows the organizational environment with the technical elaborations. In fact, management improvements can be obtained by improving the relationships between the different actors and the various levels of administration as well as defining the priority of the interventions. Along this issue, appropriate governance modes can be selected to improve the decision process and delineate the investment plans in consideration of both the different competences and criticisms [20-21].

Specifically, it is possible to recognize a sub-system of infrastructures having mainly functionality connections with similar characteristics [22]. Then, the alert or risk maps can provide useful provisions in terms of interventions

priority. It follows that two different governance modes can be chosen: fragmentation and coordination [23-24]. The first one can de adopted, for example, for infrastructures characterised by a similar alert or risk without emergency. Differently, infrastructures characterised by different alerts or risks with emergency require the second mode of governance. More details may be found in [17]-[18].

The right selection of a governance mode ensures a better and more sustainable administration of the safety by the actors.

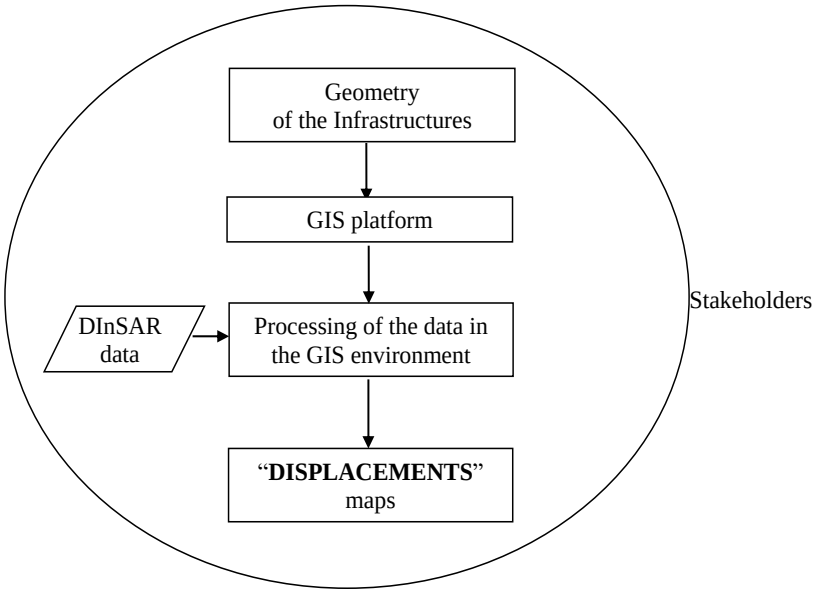

FIGURE 1. Organizational environment.

CASE STUDY IN AN ITALIAN REGION: MAIN RESULTS WITH RELEVANT IMPLICATIONS

Considering the Rome Municipality (Italy) within the research project [19], a group of road infrastructures has been identified and classified as a sub-system, since characterised by similar traffic flows, as can be seen in Figure 2. Specifically, Figure 2 is a thematic map in GIS showing the territory of the Rome Municipality with the selected infrastructures.

TABLE 1. The stakeholders jointed to the selected infrastructures.

Road infrastructures	Actors
"A1 - Autostrada del Sole"	"AutoStrade Per l'Italia - ASPI"
"A12 - Autostrada Azzurra"	"AutoStrade Per l'Italia - ASPI"
"A91"	"ANAS S.p.A."
"A24"	"Strada dei Parchi S.p.A."
"Grande Raccordo Anulare"	"ANAS S.p.A."
"SP 216 - Maremmana"	Province
"Lungotevere"	Municipalility
"Circonvallazione"	Municipalility

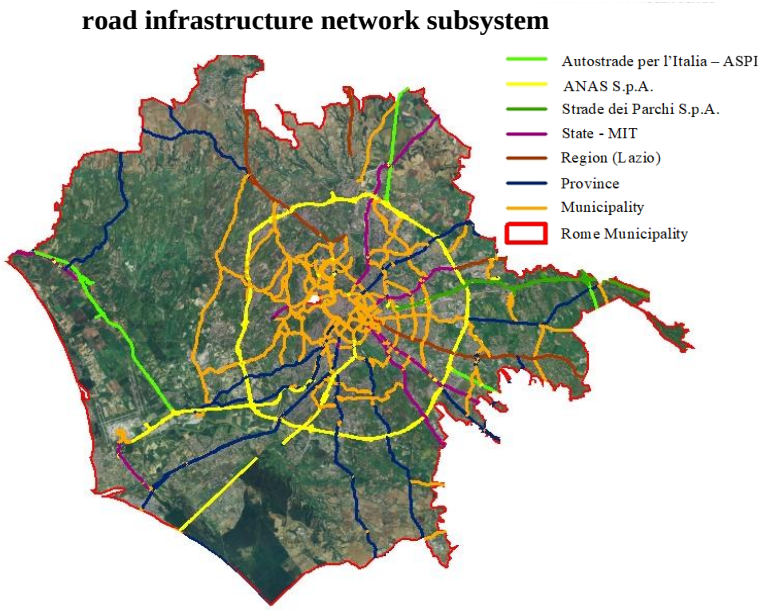

FIGURE 2. The sub-system of infrastructures.

Table 1 presents the list of the stakeholders who have safety responsibilities: "ANAS S.p.A.", "Strada dei Parchi S.p.A.", "AutoStrade Per l'Italia - ASPI", Province and Municipality.

The elaborations described in Figure 1 have been applied developing a DInSAR-based analysis at a scale of territory, as explicated in the next.

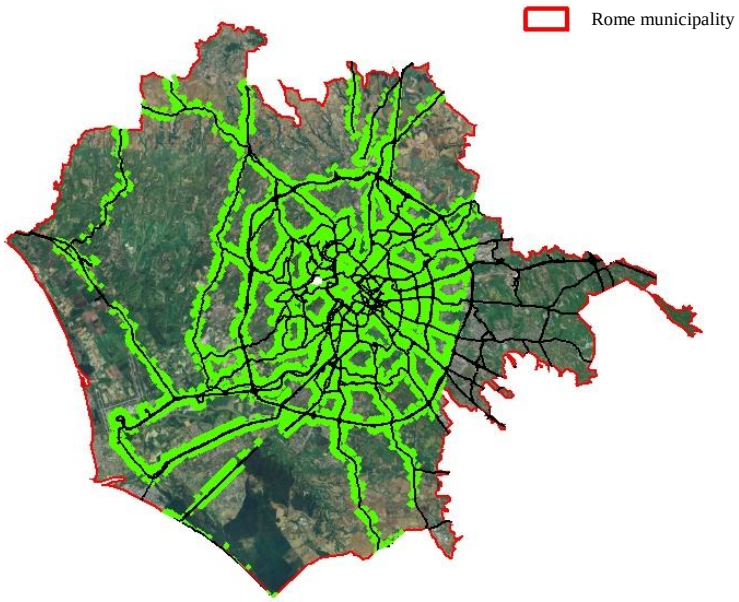

FIGURE 3. The monitored points along the descending orbit.

On the thematic map of Figure 2 in GIS, we have imported the DInSAR data derived from the SAR images (COSMO-SkyMED) of the descending orbit during the last 8 years. After that, these data have been properly

elaborated imposing 0.6 as coherence value [20]. This latter permitted to identify the monitoring data referred to quite 6 millions of points (see Figure 3).

With the scope to compute the displacements, "cells" characterised by a dimension of 50x50m [15,26] have been adopted to divide the infrastructures. Successively, the data have been processed to compute the vertical displacements, as illustrated in Figure 4, in agreement with [15,26].

The thematic map of Figure 4 represents a kind of alert map and can be employed to define a risk map by means of further and more detailed analyses to assess the safety conditions in consideration of specific damage thresholds [5], as developed in [17]-[18].

The results indicate low intensities of the displacements with few potential damages in terms of high intensities of the vertical displacements affecting a group of infrastructures, managed by the following actors: ANAS S.p.A., Municipality, Province and "AutoStrade Per l'Italia - ASPI". It derives that a common mode of governance based on coordination can be selected by all the actors in the territorial area. Instead, a fragmentation approach has to be adopted by ANAS S.p.A., Municipality, Province and "AutoStrade Per l'Italia - ASPI" to manage the safety of the specific group of infrastructures presenting high movements. Along this issue, interventions have to be scheduled on basis of the priority expressed as the intensity of the displacements.

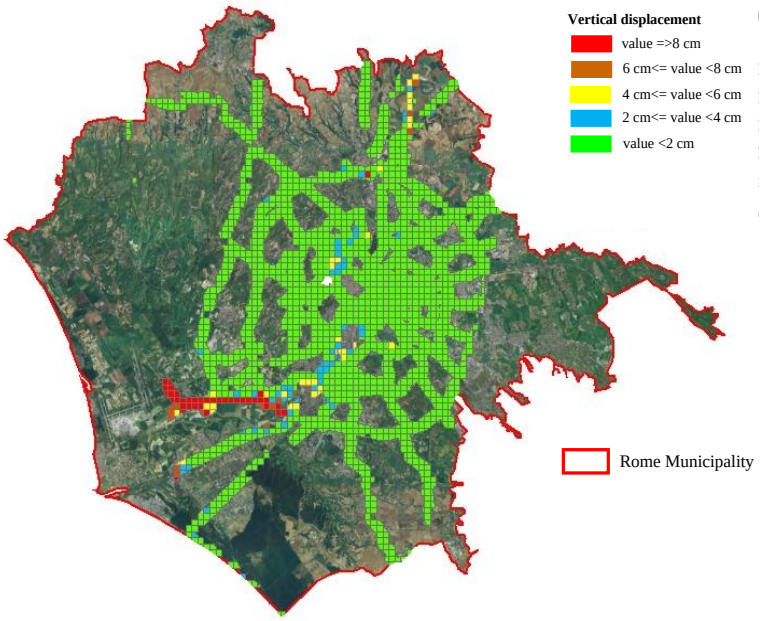

FIGURE 4. Vertical displacements.

The results represent a useful contribution to the field of satellite-based territorial analyses finalised to safety management of the infrastructures. Particularly, this investigation at a scale of territory permits to improve the organizational aspects, achieve an active role of the various actors and delineate the most proper mode of governance. Therefore, it is possible to schedule the interventions and the sustainable and proper investments.

CONCLUSION

The work describes the organizational items within a systemic approach finalized to make the safety management of road infrastructures more sustainable at a scale of territory. Some organizational improvements for this scope are commented. The infrastructure safety is a very relevant topic in many states with structural systems built some decades ago. In addition to the inherent structural problems, other items are worthy to be investigated, such as, social, economic and organizational aspects.

With this aim, the study describes a systemic approach finalized to make all the public or private stakeholders active actors in the management process by improving the organizational items. In detail, regarding a case study in an Italian region, the authors propose to take on the satellite data to investigate the structural safety problems of the

infrastructures at a scale of territory. Therefore, risk or alert maps referred to natural or time-dependent phenomena are properly defined at a scale of territory.

Successively, useful suggestions are discussed with the focus to increase the interactions between the different actors for a better management of the safety. The recommendations are able to improve the governance mode and decision process with a more all-inclusive level of organization. In fact, the case study results evidence that the satellite monitoring of the territorial infrastructures is a technical instrument useful to the proposed organizational improvements. Specifically, the monitoring results suggest that a common mode of governance based on coordination can be selected by all the actors in the territorial sub-system. Instead, a fragmentation approach has to be adopted by ANAS S.p.A., Municipality, Province and "AutoStrade Per l'Italia - ASPI" to manage the safety of the specific infrastructures presenting high movements. Along this issue, interventions have to be scheduled on basis of the priority expressed as the intensity of the displacements.

The right selection of the mode of governance ensures a better and more effective administration of the safety by the actors to schedule the interventions and the sustainable and proper investments.

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