RESilient transport InfraSTructure to extreme events

D2.2 End-User Requirements and Proceedings of the Workshop in Month No 4

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Abbreviations

Abbreviation	Explanation
RESIST	Resilient Transport Infrastructure to Extreme Events
SHM	Structural health monitoring
VMS	Variable Message Sign
RPAS	Remotely Piloted Aircraft System
SoTA	State-of-the-art-analysis

Executive Summary

The Deliverable D2.2 (End-User Requirements and Proceedings of the Workshop in Month No 4) is produced within Work Package 2 (State-of-the-Art Analyses, Threat Scenarios, Metrics, Requirements, Specifications and System Architecture) of the RESIST project, under the Task 2.2 (Development of a User Group, Final User Requirements, Scenarios for the Pilots in WP9).

The purpose of this deliverable is to give an overview of the preparation of the RESIST workshop as well as the outputs. The workshop took place on Wednesday, 5th December 2018 in Thessaloniki, Greece. It was organised by FEHRL. The workshop attracted important end users and external participants that were involved on a discussion on the state of resilience in the European road network as well as gave their opinions on how a system like RESIST can help increase the resilience of the road infrastructure.

The aim of the workshop was to gather input from experts and relevant stakeholders in order to define user requirements and pilots scenarios involving critical road structures. The workshop enabled the RESIST project consortium to liaise with stakeholders and learn how they handle structural inspection/monitoring, cyber/physical attacks and emergencies (including time required for response, the impact of this time, the available information on damage, their ways to achieve smooth continuity of mobility under extreme events). The main outcome of the workshop was the initial user/functional requirements and scenarios for the pilots that are planned later in the project. Additionally, a questionnaire was shared with the participants in order receive more detailed input and more concrete requirements.

The input received from the workshop, the questionnaires and interviews/discussions with road managers and operators, formed the end-user requirements, using the methodology clearly explained in this document, and a comprehensive list of requirements is included.

1 Introduction

RESIST (Resilient Transport Infrastructure to Extreme Events) is a H2020 framework project funded under the grant agreement 769066 that aims to increase the resilience of seamless transport operation to natural and man-made extreme events, protect the users of the European transport infrastructure and provide optimal information to the operators and users of the transport infrastructure. The project will address extreme events on critical structures, implemented in the case of bridges and tunnels attacked by all types of extreme physical, natural and man-made incidents, and cyber-attacks. The RESIST technology will be deployed and validated in real conditions and infrastructures.

In order to better analyse and define the system the consortium organized an end user meeting on M4 planned by FEHRL and hosted by Egnatia odos AE in Thessaloniki, Greece. The external stakeholders invited were carefully selected in order to cover all aspects of RESIST project and to be able to give expert knowledge and guidance to the technical analysis of the project. External stakeholders were invited from different transport modes including road managers, road and railway operators, transport managers, robotic industry, port industry, computer vision, relief unit, IT & solution providers, geotechnical consultancy, academics, experts on resilience of the road and railway network as well as structural engineers.. After the project goals were explained, the participants were engaged to a fruitful discussion with the main goal of correctly and accurately placing RESIST in the resilience of European road network field.

This invaluable knowledge extracted from the interaction with the experts during the M4 meeting was combined with information extracted by the questionnaires provided and with one on one interviews with end users and experts, with analysis of the description of action and with information acquired from the state of the art research in order to extrapolate concrete and accurate user requirements.

1.1 Document structure

This document is structured in the following way:

- Chapter 1: Introduction; purpose of the document
- Chapter 2: Workshop: End-Users & Technical Requirements for the RESIST System
- Chapter 3: Initial requirements
- Chapter 4: Pilots
- Chapter 5: Conclusions

1.2 Purpose of the document

The purpose of this deliverable is to give an overview of the preparation of the RESIST workshop as well as the outputs. The workshop took place on Wednesday, 5th December 2018 in Thessaloniki,

Greece and was organised by FEHRL. The workshop attracted important end users and external participants.

The aim of the workshop was to define user requirements and pilots involving critical structures and scenarios for the field tests planned in the project. The workshop enabled the RESIST project consortium to liaise with stakeholders and learn how they handle structural inspection/monitoring, cyber/physical attacks and emergencies (including time required for response, the impact of this time, the available information on damage, their ways to achieve smooth continuity of mobility under extreme events). The main outcome of the workshop was an initial user/functional requirements and scenarios for the pilots that are planned later in the project.

2 Workshop: End-Users & Technical Requirements for the RESIST System

2.1 Aim of the workshop

The aim of the workshop was to define user requirements and pilots involving critical structures and scenarios for the field tests planned in the project. The workshop enabled the RESIST project consortium to liaise with stakeholders and learn how they handle structural inspection/monitoring, cyber/physical attacks and emergencies (including time required for response, the impact of this time, the available information on damage, their ways to achieve smooth continuity of mobility under extreme events).

In a lively and fruitful discussion, 23 participants from different countries provided valuable input to the work of the project. The main outcome of the workshop was an initial user/functional requirements and scenarios for the pilots that are planned later in the project.

The workshop was divided in 3 sessions:

- Session 1 (Setting the scene) focused mainly on initiatives and projects similar to the RESIST project.
- Session 2 (Technical & User Requirements) was about the preliminary technical and user requirements as identified in the RESIST project.
- Session 3 (Validation & Methodology) focused on the content of the user requirements document.

2.2 Promotion of the event

Given the nature of the workshop, invitation to the workshop was based mainly on personal invitation of project members to specific experts. The first group of experts that were invited were the members of the Advisory Board that confirmed their participation in the project during the proposal stage. Later, invitation was extended to experts identified by project members.

The organisers decided to use Eventbrite (see Annex A)- an event management website - which was used for handling participation. At the same time the event was advertised through the RESIST website (see Annex B) where a dedicated section was created.

2.3 Participation

Overall, 23 people participated in the workshop, out of which 35% were external experts (Figure 1-2).

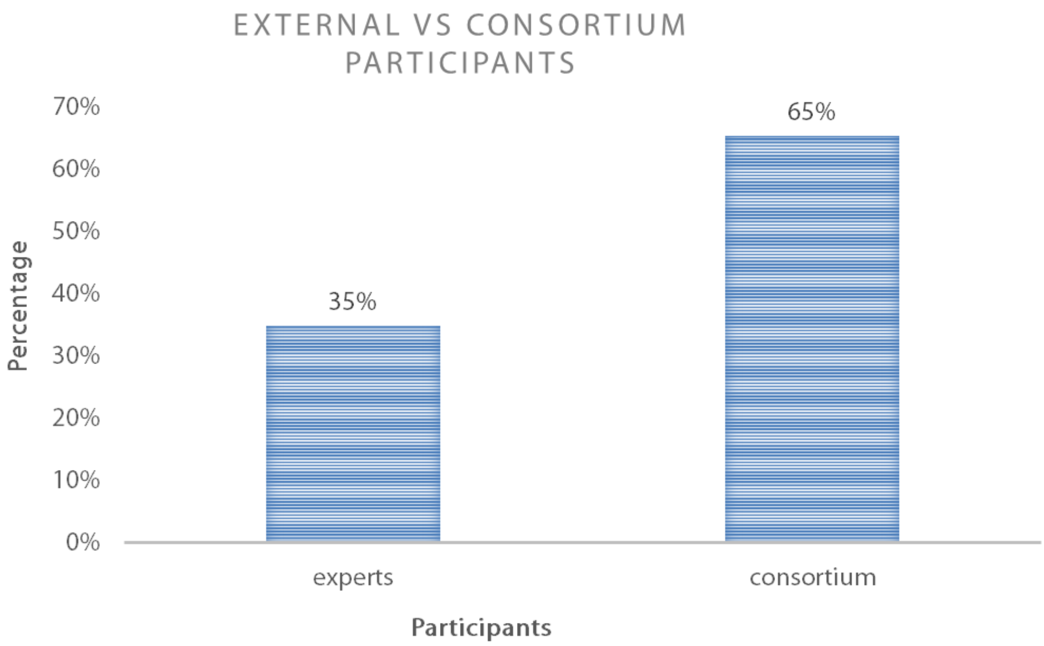


Figure 1: External vs consortium participants

Invitation to the RESIST Workshop was sent to a large number of experts from different countries (Fig. 2), including the Advisory Board of Experts (see DoA). Invited experts were from road, railway, waterway sectors, relief units, computer visions, robotic industry (UAVs) and etc. (Fig. 3). Unfortunately, due to a number of reasons e.g. intense work schedule, flight, personal reasons and etc. not all experts were able to attend the Workshop. However, after the Workshop all the presentations were sent to the invited experts so that they could follow up on the project's activities and main outcomes. The profile of participants cab found in Fig 4.

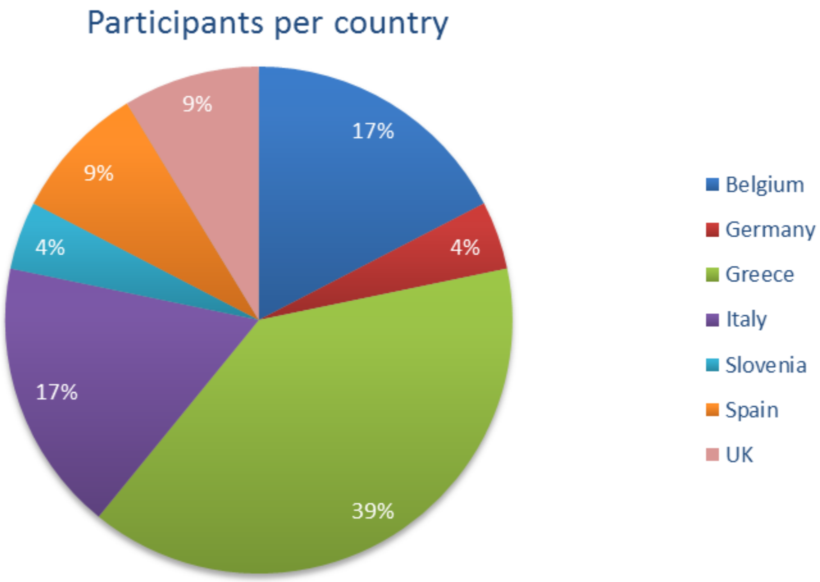


Figure 2: Participants' countries of origin

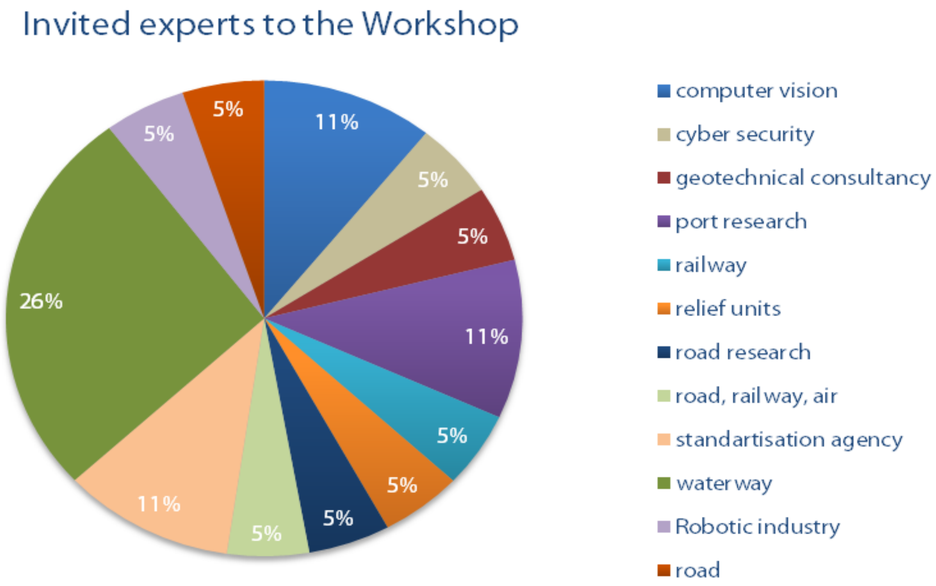


Figure 3: Invited experts to the Workshop

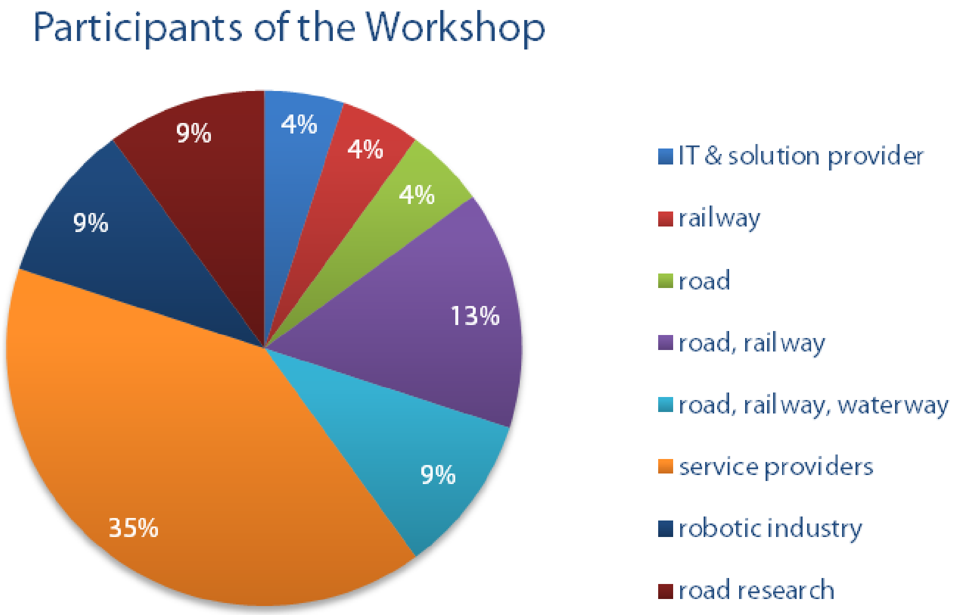


Figure 4: Participants of the Workshop

2.4 Session 1 – Setting the scene

The participants were welcomed by Adewole Adesiyun, Deputy Secretary General of FEHRL, who gave a brief overview and aim of the workshop. He also moderated the first session with 5 speakers.

The first presentation was an opening speech and was given by Thierry Goger, the Secretary General of FEHRL. The speech was titled "Forever Open Road – Resilient Roadmap 2017 Update" and focused on the flagship programme of FEHRL – The Forever Open Road – which consists of the Adaptable, Automated and Resilient elements. Later he focused on the resilient element and the updated version of a roadmap for research published as part of this element. He presented innovation themes of the roadmap which includes among others, vulnerability assessment and identification of adaptation solutions, an area closely linked to what is being done in RESIST.

The second presentation (Infrastructure Resilience - Report of FEHRL Scanning Tour to Asia), co-authored by Jürgen Krieger from BASt - Federal Highway Research Institute Germany and Caroline Evans from ARCADIS, was presented by the former. He started by presenting the many challenges faced by infrastructure owners and operators which include increase in traffic, aging infrastructure, disasters (natural hazards and/or man-made events) etc. He explained the "resilience cycle" which consists of: prepare – prevent – protect – respond – recover. In addition, Jürgen Krieger explained the process of managing and reducing risks (i.e. the various challenges) to an acceptable level. He described the FEHRL organised technical scanning tour of 2016 to South Korea and Japan which focused among others on establishing a dialogue on challenges for implementing more resilient infrastructure as well as establishing mechanisms to share information and experiences regarding the management of resilient infrastructure.

The third presentation titled "Risk Analysis of Infrastructure Networks in response to extreme weather" (RAIN project), was given by Lorcan Connolly from Roughan & O'Donovan (Ireland). The aim of the RAIN project was to provide an operational analysis framework to minimize the impact of major weather events on the EU land. He presented the benefits of providing critical infrastructure protection from extreme weather through the application of the RAIN Risk-Based Decision-Making Framework in the context of two case studies. Lorcan Connolly also presented the emergency management of the case study countries, detailing the response to the extreme weather events upon which the case studies are built.

The fourth speaker was Kostas Bouklas (ICCS) who presented the RESIST project. He spoke about the concepts of the project which includes strengthening solutions of the existing transport structures as well as risk analysis and management to identify suitable adaptation methods. He highlighted the nine objectives of the project as well as the innovations that will be developed at the end of the project.

Panagiotis Panetsos (Egnatia Odos) in his presentation titled "RESIST WP2 Elements of Risk Management of motorway networks", gave a detailed description of the tasks to be done in WP2 of the project. He stressed on the goals of WP2 which include focusing on the needs of road/bridge/tunnel operators to explicitly identify their needs in safety and security under extreme events. Since one of the two pilots where the RESIST technology will be deployed and validated in real conditions, is a bridge operated by Egnatia Motorways (Bridge T9, Peristeri area, Greece). Mr. Panetsos gave a general overview of the motorway bridges under their operation. He also explained the condition ranking system used (based on visual inspection), the deterioration models of the bridges, the structural health monitoring of some of the bridges on the network (e.g. the types of sensors installed etc.). He later explained the monitoring based seismic risk assessment of the T9 bridge. Panagiotis Panetsos explained to the participants the project's expectations of the workshop which include the end-users defining the hazards of their road networks, the effects these hazards have (recorded and predicted), the pre-hazard assessment tools and procedures, the after-hazard assessment tools and procedures, readiness to mitigate risks and reinstate the network etc. At the end of the presentation, he presented the needs and user requirements of Egnatia Odos under hazards such as heavy rain/hail storm, seismic loads, snowfall events and etc.

2.5 Session 2 – Technical & User Requirements

In this session, two presentations were planned, preliminary technical requirements of RESIST project (Kostas Bouklas – ICCS) and User requirements (Panagiotis Panetsos – Egnatia Odos). The user requirements' presentation was given by Mr Panetsos in the 1st session.

In his presentation, Mr. Bouklas presented the requirements regarding the Remotely Piloted Aircraft System (RPAS). These include the ability to provide all necessary measurements for structural assessment, to take measurements of structures like steel and concrete bridges, tunnels etc. In addition, he presented the requirements needed in achieving the objectives of the project in the areas such as:

- Vulnerability Assessment to Physical, Extreme, Natural and Man-Made Events;
- Alternative, Secure and Continuous Communications for Normal and Emergency Operations;
- Cyber Security Management solutions;
- Mobility Continuity Module.

2.6 Session 3 – Validation & Methodology

In this presentation titled Requirements methodology and what comes next, Kostas Bouklas explained the content of the user requirements document that will be prepared in the project. The document will serve as initial terms of reference for the design, development and realization of technical components of the RESIST platform. The document will describe the system specifications from the end user point of view.

The document will be based on the analysis of the requirements already described in the Description of Action of the project as well as feedbacks from consultation of end-users, external experts, technical partners and the stakeholder's community. He also described the methodologies that will be used for the extraction and structuring of the requirements. They include consistency verification, reconciliations methodology, tests for requirements and prioritization.

At the end of the presentation, Kostas Bouklas described the next steps in finalising the requirements for the project. They include:

- Collecting input from all sources like questionnaires, interviews, discussions with stakeholders, end users etc.
- Analysing the input and ensuring that there are no conflicts - that all requirements are testable and there are no overlaps.
- Liaising with the projects end users to validate the requirements.
- Translating of the requirements, by the technical teams, to realistic technical system specifications.

Further to this, the invited experts were given time to complete the questionnaire on requirements which was sent to them prior to the workshop. The results of the questionnaire are shown in the appendix.

2.7 Open discussions

During the open discussion, two scenarios for each pilot were discussed: for the 1st pilot on the T9 Bridge and the 2nd pilot on the Millaures Bridge in case of landslide. In addition, the scenario for the St. Petronilla tunnel in case of the strong earthquake or explosion was discussed as well.

Panagiotis Panetsos from EOAE presented the 1st pilot on the T9 bridge in Greece. The discussion included: test cases, success criteria, necessary equipment and personnel as well as assumption, requirements and procedure. Saverio Mercurio from TECHNOSITAF, one of partners responsible for the 2nd pilot, presented the proposed Italian test site use, the requirements, use cases, procedures and etc.

Discussions later focused on the requirements as seen from the point of view of the experts at the workshop. Some of the points raised during the discussion are as follows:

- The aspect of resilience needs to be looked at holistically and not just technically. There is the need to look at the whole transport network as one.
- The main actors during an event is the control center / infrastructure management, response crews of the end user, 1st responders / civil services (if they are called), users of the infrastructure, civilians living around the infrastructure (if applicable)
- Quantification of the benefits needs to be visible. RESIST project will aim to do what is being done now but faster and cheaper. At the end of the day, the end-user / infrastructure manager requires a price tag on the action he is proposed to take.
- For the infrastructure user (drivers, civilians in general), the main outcome of the project should be a safe, comfortable journey with the least delay possible. Safety of the passengers is always the foremost concern.
- For the use case scenarios, infrastructure managers would like to see "black swan" scenarios (an event or occurrence that deviates beyond what is normally expected of a situation and is extremely difficult to predict. Black swan events are typically random and unexpected). Additionally, it would be useful if combination scenarios are combinational (e.g. earthquake plus icy roads, or tunnel in a fire with workers in the tunnel). RESIST partners noted that from a vulnerability standpoint certain combination of scenarios or black swan scenarios in general might not be possible to be assessed.
- When planning an alternate route and proposing different means of transport (flights, trains etc.) it is important for the user (driver, civilian etc) to know the cost of the route.
- In the case of risk analysis, it would be useful to apply deep learning techniques that could possible replace automation and real time approach.
- For the test cases of the tunnel in Italy the end user (SITAF) proposed the case of fire which is the number one hazardous event. Vulnerability assessment in this case include chemical testing of the affected area and core sampling which, both of them, cannot be tested by RESIST.
- In the case of any event in the tunnel, there are different VMS messages shown inside, outside and in the close vicinity of the tunnel.
- In the case of inspecting the tunnel the drone should be able to operate in the whole length of the tunnel.
- End users from the rail industry noted that cyber security is the most important aspect for them. The drones should be protected from hacking / taking over control that could cause further severe damage. In general, they pointed out that because of this risk some end users might be reluctant in the use of drones without this kind of assurances.
- End user response crews need to be extremely fast in their response. It is important to optimize how the main actors would react to an emergency. The protocols of

communication between control center operators and response teams should be evaluated and to be adapted to RESIST.

- Railway bridges are of great importance as well with fire (on the surrounding area) being the number one hazard. In general railway bridges do not carry SHM systems.
- Railway managers would like to see an IT solution towards the reduction of the response time of personnel. Currently, communication between response crews and control center takes place over the phone. All procedures are old and do not reflect the technology level of the time (for example there is a system that can stop the train remotely on the tracks but there is no system to call response crews to action).

3 Requirements Capturing Methodology

The need for an in-depth knowledge and analysis of the requirements of the RESIST platform is an indisputable fact, especially due to the fact that RESIST platform combines several software and hardware technologies. In order to capture all the requirements of RESIST platform, including also the end-user requirements that is the goal of this deliverable, a specific methodology has been followed. The diagram in Figure 3 presents the methodology to extract all the requirements (functional and non-functional).

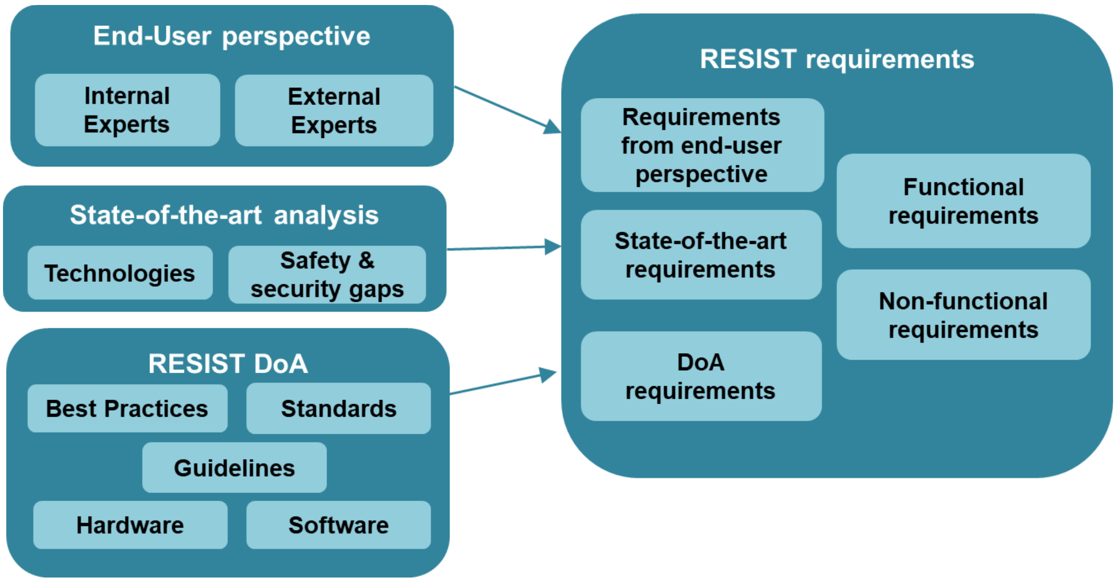


Figure 5. Requirements Methodology Overview

The RESIST system requirements (T2.4 and D2.3) consists of the requirements that come from the end-users (Task 2.2 and D2.2), the state-of-the-art analysis (T2.1 and D2.1), and the RESIST DoA (such as the requirements of Task 2.3 concerning the best practises, standards and guidelines that must be followed as well as the requirements for the hardware and software equipment that will be used in RESIST). The focus of this deliverable is to extract all the end-user requirements that should be taken under consideration for the development of the RESIST platform. Figure 4 describes the correlation/interaction between the deliverables that aim to capture all the requirements of RESIST platform.

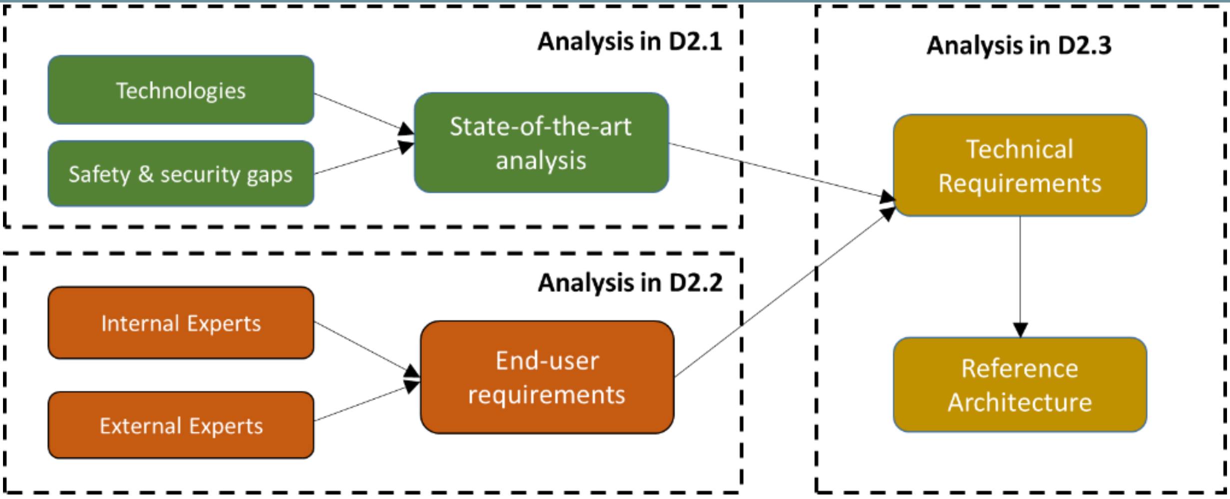


Figure 6. Relationship between D2.1, D2.2, D2.3

3.1 Classification of requirements

Requirements will be classified according to the following general syntax:

While *<optional precondition> <optional trigger>* ***the*** *<actor/system>*
<must/should/could/would> ***be able to*** *<system response> …*

This simple structure forces the separation of the conditions in which the requirement can be invoked (preconditions), the event that initiates the requirement (trigger) and the necessary system behaviour (system response). Preconditions and triggers are optional, depending on the requirement type.

The order of the clauses in this syntax is also significant, since it follows temporal logic:

- Any preconditions must be satisfied otherwise the requirement cannot ever be activated.
- The trigger must be true for the requirement to be "fired", but only if the preconditions were already satisfied.
- The system is required to achieve the stated system response if and only if the preconditions and trigger are true. Other variants of syntax are shown below in Table 1.

Table 1. Requirements Syntax

The <stakeholder type> should be able to <capability>.
The <stakeholder type> should be able to <capability> within <performance> of <event> while <operational condition>. Example: The weapons operator should be able to fire a missile within 3 seconds of radar sighting while in severe sea conditions.
The <stakeholder> shall not be placed in breach of <applicable law>. Example: The ambulance driver should not be placed in breach of national road regulations.
The <system> should <function> not less than <quantity> <object> while <operational conditions>. Example: The communications system should sustain telephone contact with not less than 10 callers while in the absence of external power.
The <system> should <function> <object> every <performance> <units>. Example: The coffee machine should produce a hot drink every 10 seconds.

The detailed system requirements are grouped and presented in structured tables as shown in Tables 2-3.

Table 2. Structure of System Requirement Tables

Column Heading	**Meaning**
Requirement Code	Unique code of the requirement (numerical or alphanumerical)
Requirement Description	Short description of the requirement including the key words for criticality, as shorted by the key stakeholders of the system
Type of requirement	End User requirement, DoA requirement, State-of-the-art requirement
Priority	Priority, as stated by the key stakeholders of the system, is defined by using the following keywords: High (H), Medium (M) and Low (L)
Range	Specific (S) if the requirement is applied on a particular pilot or general (G) if it is applied on all the cases.

In order to prioritise the requirements, the MoSCoW prioritization technique (Clegg and Barker, 2004) has been adopted. Table 3 provides a definition of how priority will be defined using MoSCoW.

Table 3. MoSCow Prioritization Technique

MoSCoW: Requirements Prioritization Technique			
Name	**Definition**	**Example**	**Alternative name**
MUST (M)	Defines a requirement that has to be satisfied for the final solution to be acceptable.	The HR system "must" store employee leave history.	HIGH (H)
SHOULD (S)	This is a high-priority requirement that should be included if possible, within the delivery time frame. Workarounds may be available for such requirements and they are not usually considered as time-critical or must-haves.	The HR system "should" allow printing of leave letters.	MEDIUM (M)
COULD (C)	This is a desirable or nice-to-have requirement (time and resources permitting) but the solution will still be accepted if the functionality is not included.	The HR system "could" send out notifications on pending leave dates.	LOW (L)
WON'T or WOULD (W)	This represents a requirement that stakeholders want to have but have agreed will not be implemented in the current version of the system. That is, they have decided it will be postponed until the next round of developments.	The HR system "won't" support remote access but may do so in the next release.	–

3.2 Resist pilot main actors

Derived from the outcomes of the end user meeting, questionnaires and interviews with the end users the consortium developed a number of main actors. As main actor we characterize a fictional character that represents a group of system users. The main actors are meant to cover all the different user groups of the RESIST platform and are used in identifying and solidifying stories associated with the use and requirements of the system.

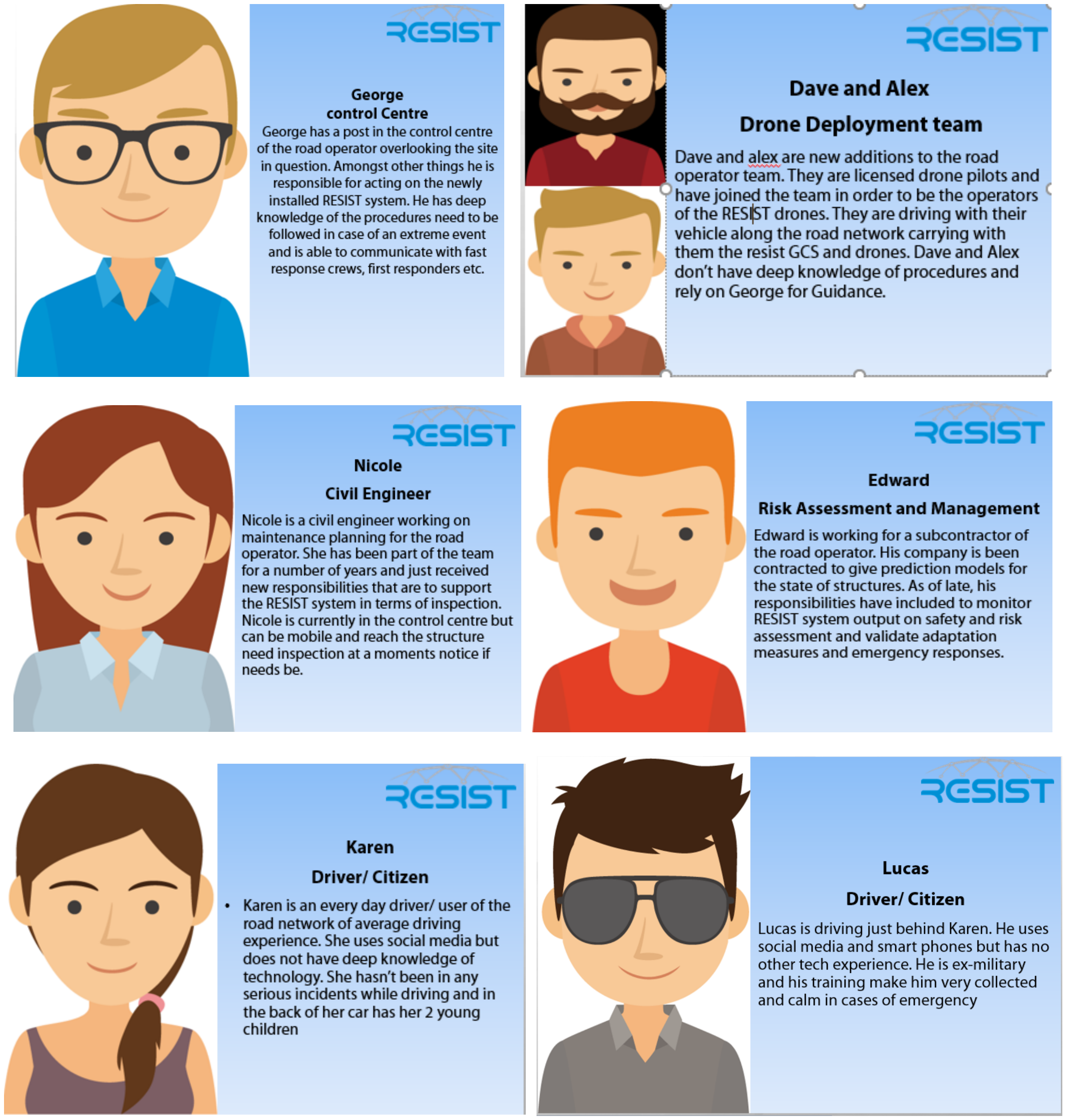


Figure 7. RESIST pilot main actors

3.2.1 Back ground and Setup

The bridge in question is the T9 bridge of the Egnatia AE network. The bridge has its own SHM monitoring system already installed as well as updated, well defined engineering models. Continuous and periodic monitoring of the structure takes place and the current condition is well documented.

After a heavy a rainfall, a landslide takes place. The landslide crashes onto the bridge triggering the existing SHM system which becomes un accessible. The control centre receives the indication from the SHM system as well as from a passing driver which calls in the event.

3.2.1.1 Assumptions:

- The bridge has its own structural monitoring system (sensors are installed, engineering model exists, continuous monitoring takes place and the current condition of the bridge is known).
- Flying permits are available, batteries charged and sensors are calibrated, the drones are already loaded with the payload necessary. Payload includes:
  - Manipulator
  - Sensor suit: stereo camera system for photogrammetric processing and vision inspection, total station prism (to measure the position in terms of the ground station), panoramic view capturing in case the others are not sufficient for gathering the area view, piezoelectric transducers (two kinds), optoacoustic receivers for the crack width.
  - Navigation sensors (internally for the drone safe navigation)
  - Area has been surveyed and is suitable for drone take off.

3.2.2 User storyline, event and actions – inspection

George, is currently in his office in the Egnatia control centre. He sees the alarm from the SHM system about an incident in the T9 bridge. He is then notified that a civilian called in and reported that there was a landslide in the T9 bridge and there is debris on the road. George calls Dave and Alex, a nearby technical patrol crew to check the site and the surrounding area using the RESIST system.

Upon arrival George and Dave setup the Ground control station and get ready to deploy the drones. For the first pass they take panoramic pictures of the affected area and inform George that there is blockage on the road and that there is need for further investigation of the structure.

George consulting with the operational manager of Egnatia Odos AE reaches the decision that the bridge needs to be closed to public until a thorough investigation is carried out to determine its condition. He then contacts Nicole, the structural engineer of the company, to instruct the drone crew about what and where to measure as well as local police to assist with diverting the traffic meanwhile preparing the VMS messages to notify the public.

Nicole takes over communication with George and Dave in order to instruct them on what measurements she needs and in what locations. The first approach measurements are deformation measurements, crack identifications and deflections. These are applied in a preliminary model of the bridge and cross checked with measurements from the existing SHM system. Nicole notices that the SHM system seems to be offline and she has no access. After consulting with George, they decide to deploy the REDCOMM node in order to re-establish communications. Using the satellite link of the REDCOMM node they re-establish connection with the existing sensors and they are able to cross reference the two sets of measurements.

3.2.3 User story line, event and actions – seamless mobility

As mentioned before, when the decision to close the bridge was taken, George notified local police and was getting ready the VMS messages to notify the public.

Karen, approaching the T9 bridge, saw the landslide happening and came to full stop. She has her two children on the back and is feeling extremely anxious. While waiting she noticed the VMS monitors start giving out information relative to the event as well as instructions to keep calm and wait. She had installed the RESIST application in her mobile in order to get more information on what has happened and what she is supposed to do. Being extremely close to the event she cannot be offered an alternate route but receives instructions taking into account her behavioural profile and relative information.

Lucas, also a user of the RESIST app, is driving just behind Karen. He was the one that notified the control centre for the landslide from the contact info that he saw on the RESIST app. He is receiving personalized information from the application as well but different from Karen’s since his stress levels are different because of his background.

Jon and Andrew, the police crew on the scene, help with diverting the traffic away from the bridge. They contact the control centre and ask for the instructions to be visible from VMS messages and the RESIST application.

Citizens, who are driving towards the bridge and are a few kilometres away from the location, notice the VMS signals mentioning an incident on the T9 bridge and they see that the RESIST application is recommending an alternate route with traffic information and expected time of arrival.

3.2.4 Mitigation actions

The measurements taken by the RESIST RPAS as well as measurements from the existing SHM were analysed by the RESIST deterministic structural vulnerability module. The structural model of the bridge was updated using the measurements taken and the local and global condition of the structure was determined.

The drivers on the road were kept well informed and were cleared from the location with the help of response crews and police and further traffic was avoided by giving rerouting options to incoming drivers.

3.2.5 Event outcome

Through the use of RESIST platform, a critical structure was inspected and its condition assessed in a fraction of the time compared to traditional methods and with no danger to human life. Traffic was regulated and civilians were cleared in an orderly calm manner. Communications although affected by the incident remained operational further improving a difficult situation. The infrastructure manager is now able to apply targeted interventions to the structure in order to increase its capacity and longevity.

3.3 Italian Pilot leg 2: St. Petronilla Tunnel

3.3.1 Background and setup

The St. Petronilla Tunnel is located near Bussoleno, 46 km away from Turin, and it takes its name from the area between the A32 motorway "Prapontin" tunnel and the national road SP 24 in the Susa Valley. It is 500m long and it is an escape route for the A32 motorway.

A large earthquake causes rumble to fall on the entrance of the tunnel and the existing systems of the structure to send an alert to the SITAF control center.

3.3.1.1 Assumptions

- The St. Petronilla tunnel is open to the public;
- Tunnel has wi-fi in motion installed;
- Tunnel has RFID sensors installed to identify crews working in the tunnel;
- St. Petronilla tunnel has existing SHM systems;
- Flying permits are available, batteries charged and sensors are calibrated, the drones are already loaded with the payload necessary. Payload includes:
    - Manipulator;
    - Sensor suit: stereo camera system for photogrammetric processing and vision inspection, total station prism (to measure the position in terms of the ground station), panoramic view capturing in case the others are not sufficient for gathering the area view, piezoelectric transducers (two kinds), optoacoustic receivers for the crack width;
    - Navigation sensors (internally for the drone safe navigation);
    - Area has been surveyed and is suitable for drone take off.

3.3.2 User storyline, event and actions – inspection

George in the control centre of SITAF, receives information about an earthquake in the area around Turin. Additionally, he receives an alarm from the existing sensors installed in the tunnel.

George calls Dave and Alex, the nearest SITAF response crew, to assess the situation and provide updates. On first glance, they report that there is rumble in the entrance and exit of the tunnel and that there are trapped vehicles. George, notifies Nicole to assist the crew with the inspection of the tunnel and then notifies the police to help with the evacuation of the trapped cars and the rerouting of incoming traffic.

Dave and Alex, deploy the drones and following instructions from the control center, on the first pass take an overall view of the affected area and notify the control centre.

Nicole, assists the crew by telling them what and where to measure. The inspection, the crew will carry out, is targeted to crack identification and measurement and locations of interest run through the length of the tunnel. The earthquake damaged the local telecommunications infrastructure so the control center decide to deploy the REDCOMM node in order to re-establish communications.

After the crew has finished with the measurements they send them back to Nicole and she crosschecks with the existing SHM system as well as with previous summary reports from routine inspections.

Meanwhile, inside the tunnel two cars are trapped between because of the debris that has blocked the entrance and the exit of the tunnel. George is sending different VMS messages inside the tunnel to keep the trapped passengers informed and different to the ones approaching the tunnel to avoid traffic blocks. The VMS regime is the following:

- ***VMS #1***
  Information to users coming from the national road SS24 - Montgenevre (F) / Claviere (I) / Cesana Torinese or Sestriere (I) towards Oulx
- ***VMS #2***
  Information to users coming from the lowest part of the A32 motorway - Torino / Rivoli / Avigliana / Susa
- ***VMS #3 / #4***
  Information to users in Oulx, the east crucial point of the traffic rerouting “motorway towards national road SS.335”
- ***VMS #5***
  Information to users already engaged in the motorway at the moment of the event
- ***VMS #6***
  Information to users in Bardonecchia, the west crucial point of the traffic rerouting “motorway towards national road SS.335”

Karen and Lucas, the drivers of the trapped cars, use their RESIST applications to receive information about the incident the situation with the tunnel. The messages they receive are personalized according to their behavioural profile and stress levels.

3.3.3 Event Outcome

The vehicles at that moment moving into the segment normally flow away. Once the segment is completely free, the SITAF A32 engineering personnel investigate the potential issue deciding whether reopen the motorway or not. With the assistance of the police crew the trapped drivers are evacuated calmly since they had regular information about the incident and no reason to be stressed.

3.4 Questionnaire

Additionally, to the end user meeting on M4 were the story lines were created and discussed a questionnaire was circulated in order to receive additional input from relevant stakeholders. The questionnaire was created by combining expert knowledge from stakeholders internal and external to the project and can be found in appendix D. Using this questionnaire along side the discussion with stakeholders and analysis from the consortium the following were agreed upon and will be reflected on the requirements as well as technical outcome of the project.

- All participants agreed that the most critical infrastructures are bridges followed by tunnels
- All participants agreed that in today’s worlds cyber security needs to be a priority. Additionally, cyber security will play a major role in the acceptance of drone-based systems from the infrastructure managers/owners as well as from the general public.
- In the case of tunnels, the most serious event that should be checked by the system is earthquakes and flooding’s that cause landslides. In the case of tunnels, it is fire and earthquakes. The standard for inspecting a tunnel is removing a core from the structure and

then doing a chemical analysis so for the case of tunnels the case of earthquake was selected.

- In the case of inspection all participants agreed that the necessary sensors are
    - Accelerometers
    - Strain gauges
    - Tilt meters

  And that the proposed sensor suite of RESIST covers the inspection needs of a structure.
- All participants agreed that in case there are existing monitoring systems RESIST should be able to integrate with said systems. Additionally, since some infrastructure managers are still carrying out visual inspections RESIST should be able to use data from these inspections as well
- In the case of an extreme event relevant stakeholders include
    - Road manager and road manager respond crews
    - 1st responders (police, fire departments, civil protection)
    - Power company
    - Emergency telephone lines (if not part of the 1st responders)
    - Drivers
    - Local citizens

3.5 RESIST State-of-the-art derived requirements

Based on the state-of-the-art analysis, regarding detection, prevention and response for both physical and cyber risks, the basic requirements from the end user points of view are derived. It is worth to be mentioned that these requirements coincide with the requirements derived from the questionnaire, interviews and discussion taken place in the M4 meeting. So according to the SoTA analysis the technical work on the project needs to answer the following:

- Increase the efficiency and the time needed for the detection of unfavourable changes in the structural and functional condition of the road infrastructure, by upgrading the current procedures, with the supplementary use of new technologies, such as terrestrial, aerial, satellite observation and inspections in combination with unmanned autonomous inspectors. In parallel, by enabling more frequent inspections of ageing infrastructure and thus reduce the respective costs (personnel and access equipment costs) and the impact/interruption to traffic (traffic lane closures etc.)
- Increase the interoperability and the accuracy of the inspection, findings, by integrated methods by analysing and evaluating information of various sources and of different nature (images, notes, readings, measurements etc) in order to directly relate inspection results to quantifiable states of damage, structural reliability of the critical road infrastructure. By doing this, the cost of assessment and the time to carry it out will be reduced while the ease and accuracy will increase. Finally, the extent and the quality of the information both regarding the excitation and the structural response, can optimize the determination of the vulnerability of the infrastructures under natural or cyber hazards.
- Finally, the responsiveness of the road operators to natural and cyber disasters shall be optimized by developing a decision support system that will receive all the information

needed on time, by a variety of sources, devices, technologies, in order to accurately detect the critical points of the road network, to autonomously and automatically assess the condition of the infrastructure and to decide on whether and when actions are required for the recovery of the structure to the pre-disaster status.

3.6 RESIST End-User Requirements

The functional and non-functional requirements are best defined as required functions of the system and are grouped in:

- End-user requirements (internal, external experts)
- State-of-the-art analysis requirements (technologies, safety and security gaps)
- Requirements coming from the RESIST Description of Action

The next table presents the end-user functional requirements of RESIST project that is the purpose of this deliverable.

Table 4. Functional requirements of RESIST project

Require-ment Code	Description	Type	Priority	Range
	RESIST system requirements			
1	RESIST must be able to contribute to the resilience of infrastructures, when an emergency event occurs (manmade or physical). RESIST must be therefore able to correlate the condition of the infrastructure before an event with the condition after the event and prepare a plan to repair the caused damages in the most cost and time efficient manner, and to ensure the mobility continuity.	DoA, End User Requirement, SoTA	H	G
2	RESIST must be able to inspect before and after the occurrence of an extreme event on demand in shorter time and with better accuracy compared to the traditional approaches (human inspection), such as to provide a good insight on the condition of the affected structures	DoA, End User Requirement, SoTA	H	G
3	RESIST must combine/evaluate available data from inspections and SHM (if available) such as to assess the actual structural performance of the structures	End User Requirement	H	G
4	RESIST must provide accurate analytical predictions for the ultimate performance of the structures under severe catastrophic events	End User Requirement, SoTA	H	G
5	RESIST must carry out hazard analysis, such as to quantify in a probabilistic manner the expected location, return period, intensity of the various hazards, for the selected pilot infrastructure area	End User Requirement, SoTA	H	G

6	RESIST must carry out vulnerability assessment, such as to determine the most critical structures of the selected infrastructure area, based on a proper hazard analyse	End User Requirement	H	G
7	RESIST must carry out risk assessment of the pilot area infrastructure, based on the results of the hazard analysis and vulnerability	End User Requirement	H	G
9	RESIST must be able to relate analytical predictions of the performance of the structures under catastrophic events to the response parameters monitored by the existing or/and the new sensors (to be installed by the RPAS)	End User Requirement	H	G
10	RESIST should gather periodically data from the fixed existing sensing system of the infrastructures. Fixed measurements are defined per pilot.	End User Requirement, SoTA	M	G
11	RESIST must facilitate gathering of data on demand by specific sensing systems integrated on the RPAS at near real-time (immediately when the RPAS returns to the ground station).	DoA, End User Requirement, SoTA	H	G
12	RESIST must ensure seamless continuity of transport in the affected area.	DoA, End User Requirement, SoTA	H	G
13	RESIST must support decision making by humans with proposals for maintenance tasks.	End User Requirement, SoTA	H	G
14	RESIST platform must provide single point of access to all services provided.	DoA, End User Requirement	H	G
15	RESIST operators should be able to instruct the required inspection points to the RPAS operator.	End User Requirement	M	G
16	RESIST must assess the remaining capacity of the structure under question (e.g. number of remaining lanes of a bridge) after the occurrence of an extreme event.	End User Requirement, SoTA	H	G
17	RESIST should be able to be integrated with existing SHM systems	End User requirement	H	G
RPAS requirements				
18	RPAS should be able to mount new sensors on the infrastructure in environments with or without GPS for bridges and tunnels, respectively.	DoA, End User Requirement	M	G
19	RPAS should be able to carry out contact/non-contact inspections with the use of a robotic manipulator in environments with or without GPS for bridges and tunnels, respectively.	DoA, SoTA	H	G
20	RPAS must be able to operate in a GPS denied environment	DoA / End user Requirement, SoTA	H	S
21	RPAS and sensors carried by the RPAS should be able to detect cracks wider of 0.3mm and localize them.	End User Requirement, SoTA	M	G

22	In the case of tunnel inspection, the RPAS must be able to operate through the length of the tunnel. This includes being able to • Take high resolution images and / or video • detect cracks • measure width and depth of cracks in conditions of low light.	End User Requirement, SoTA	H	S
23	RPAS should be able to achieve contact with existing SHM acquisition units, before and after a catastrophic event and transmit records to the Control Centre	End User Requirement, SoTA	M	G
24	RPAS should be able to map the structures of the affected area – after a catastrophic event – with an accuracy of 1cm, such as to enable the detection of obstacles, failed elements, rock falls' items, landslide's soil masses (cover the pavement), standing water on the motorway, banks' erosion etc such as to support DSS	End User Requirement, SoTA	H	G
Sensors requirements				
25	Sensors in the case of bridges should measure: <u>Infrastructures sensors:</u> • Inclination of the structures to which they are anchored (by tiltmeters) • Oscillations (by servo-accelerometers) • Displacements (by joint-meters) • Depth and width of cracks (by crack meters) • Strain (by strain gages)	End User Requirement, SoTA	M	S
26	The access of sensor data must be reliable, accurate	End User Requirement, SoTA	H	G
27	The transmission of the SHM records must be seamless after a catastrophic event	End User Requirement	H	G
28	Sensors measurements should be stored periodically	End User Requirement	M	G
29	The SHM records from the critical structures, must be gathered, processed and analysed in a faster manner than from conventional systems, after a catastrophic event.	End User Requirement	H	S
Communication & Cybersecurity requirements				
30	RESIST communication system must ensure continuous communications even in the case of an extreme event. In case of an incident that compromises the telecommunication network of the infrastructure the end user must be able to re-establish connection to the structure as fast as possible.	DoA, End User Requirement, SoTA	H	G
31	In case of an extreme event, communication with the public must be ensured using the mobile application and the social media.	DoA, End User Requirement	H	G

32	RESIST will connect control centre with 1st responders/ response crews. Communication to take place through VHF/UFH.	End User Requirement	H	G
33	Authentication attempts must be logged.	End User Requirement, SoTA	H	G
34	The interface of the RPAS with the RESIST platform must be secured (against jamming and control takeover attacks).	End User Requirement, SoTA	H	G
35	RESIST communication system should provide capabilities of 112 calls in case of emergency and communication loss.	DoA, End User Requirement	M	G
36	RESIST should replace cellular communications in case of failure due to an extreme event.	End User Requirement	H	G
37	Communication with public, 1st responders and the transmission of measurements should utilize redundant communication channels	End User Requirement, SoTA	H	G
38	RPAS must be protected from hacking /control take over.	End User Requirement / DoA, SoTA	H	G
39	Data transfer from/to the GCS should be secure/encrypted	End User Requirement / DoA, SoTA	H	G
40	Transmission of measurements need to be secured / encrypted	End User Requirement / DoA, SoTA	H	G
41	RESIST system should be monitored and protected against cyber attacks	End User Requirement / DoA, SoTA	H	G
42	Data transfer to/from mobile application will be secure/encrypted	End User Requirement / DoA, SoTA	H	G
43	System and data exchange availability. Providing access to the system, data and assessments at all times to the end users (under attack, crisis, and normal conditions). Only authorised users access the system for the specified purposes. Also, only authorised users receive the information that are specified to.	End User Requirement	H	G
	Mobility Continuity Module requirements			
44	In case of an extreme event in an infrastructure, RESIST must keep the users away or lead them to safety by using very specific messages on the VMS and instruct to move safety barriers of the road network for rerouting.	End User Requirement	H	G
45	VMS messages must be different for specific zones around and on the structure (E.G inside the tunnel outside the tunnel, few kilometres away from the tunnel)	End user requirement	H	G
46	Mobility continuity module must be aware of the traffic info and other info such as speed, blocked roads etc.	DoA, End User Requirement	H	G

47	Mobility continuity module must be aware of the passengers' stress level.	DoA, End User Requirement	H	G
48	Alternate routes should be predefined, to be used in case of extreme event.	End User Requirement, SoTA	M	G
49	When creating alternative routes for highway users, affordability of that alternate route should be considered, including different modes of transport and the inherent socio-economic aspects.	End User Requirement	M	G
50	Communications relevant to the event should include road users, local community, businesses and government	End user requirement	H	G
51	Communications relevant to an event should be based on a multichannel mechanism that include social media	End user requirement	H	G
Mobile App requirements				
52	Mobile app must communicate with registered end users, and public including any social media interactions	DoA, End User Requirement	H	G
53	Mobile app must direct end users to alternative routes.	DoA, End User Requirement	H	G
54	Mobile app should be able to collect data for the evaluation of stress levels and users' behaviour.	End User Requirement	M	G
55	Mobile App could be developed for iOS/Android operating systems.	End User Requirement, SoTA	L	G
56	Mobile app should support user roles and be able to serve different messages per role	End user requirement, SoTA	M	G
Vulnerability Assessment Module requirements				
57	Vulnerability assessment module must provide early and accurate reliability estimations ideally depicted on the 3D model of the infrastructure.	End User Requirement	H	G
58	Vulnerability assessment module should be directly related to the structural condition based on gathered SHM/inspection measurements.	DoA, End User Requirement	M	G
59	Vulnerability assessment module should be supporting the fast evaluation of the remaining structural integrity of the monitored structures.	DoA, End User Requirement	H	S
60	Vulnerability assessment module must provide options for structural strengthening interventions (repair plans) and prioritize them in terms of severity.	DoA, End User Requirement	H	G
61	Vulnerability assessment module options should be accompanied by a price estimation	End User Requirement	M	G
Risk Assessment & Management Module requirements				
62	Risk Assessment & Management Module must be able to assess the severity of the damages and the capacity of the infrastructure.	DoA, End User Requirement, SoTA	H	G
63	Risk Assessment & Management Module must provide the first assessment of the infrastructure directly after an extreme event occurs by correlating the condition of the infrastructure right before the event and the	DoA, End User Requirement, SoTA	H	G

	knowledge of the expected impact of the event (prediction service).			
64	Risk Assessment & Management Module must include a catalogue of possible solutions with a cost benefit ratio and severity priorities. End users would always be interested in quantifiable solutions. Method A or action B for the end users need to be followed by a cost benefit analysis.	DoA, End User Requirement, SoTA	H	G
65	RESIST should include a Risk analysis and management matrix supported by the IT system for infrastructures	End user Requirement	H	G
Photogrammetric Computer Vision System requirements				
66	In case the 3D model does not exist, the photogrammetric module should ad-hoc develop a really close model.	End User Requirement	M	G

4 Conclusions

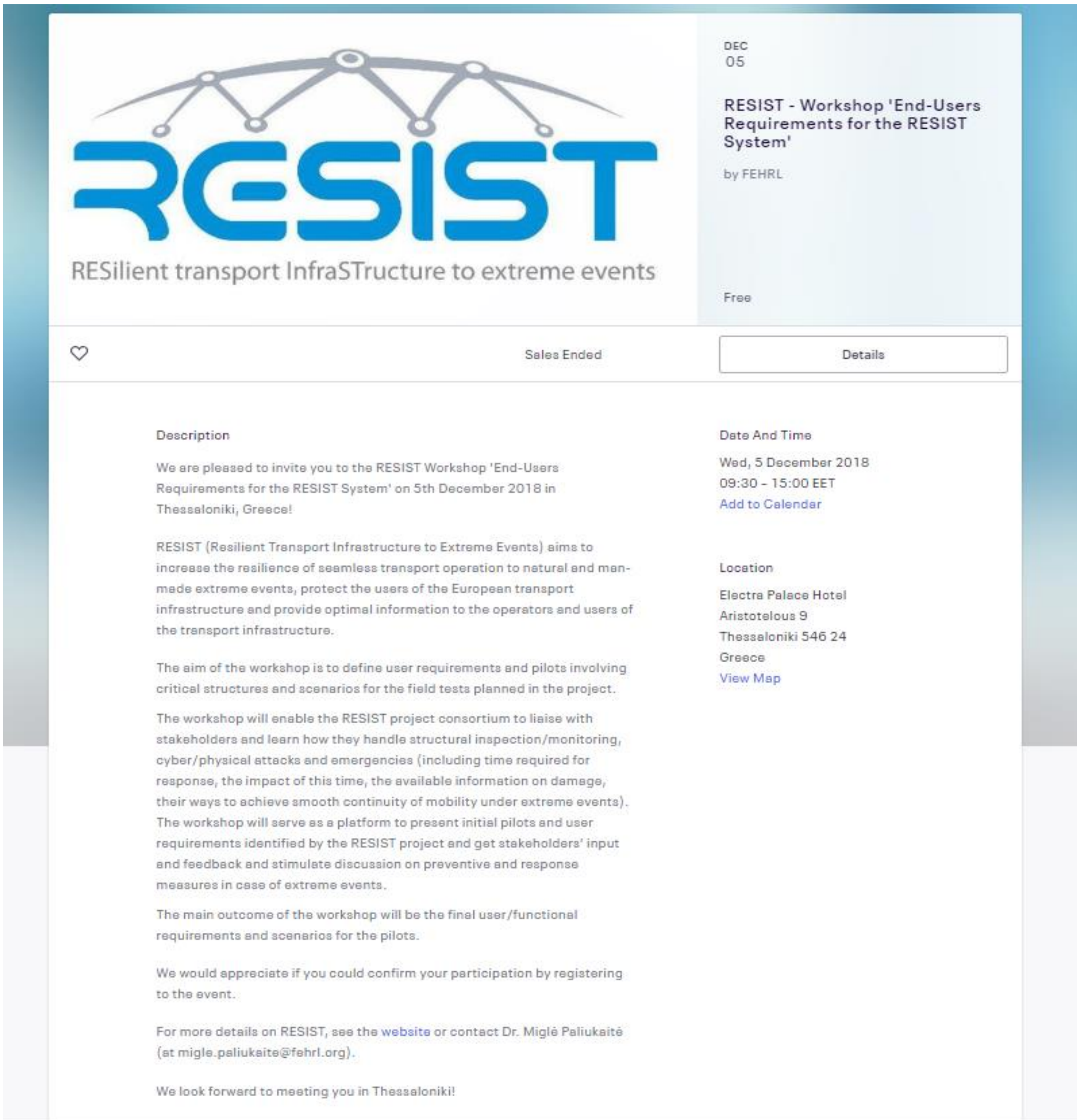
This report detailed the proceedings of the workshop on month 4 and explained the approach followed by the consortium in order to approach and liaise external stakeholders and industry experts. It explains the methodology used in order to format the end-user requirements as well as presents the user stories that were created in order to make extraction of requirements easier and more engaging.

The discussion that took place during the M4 meeting was extremely engaging and provided an abundance of information. The visitors were interested in the project and very willing to point out strengths and weaknesses of the design thought process and to steer the project on a more realistic market relevant approach.

The complete comprehensive list of the RESIST end – user requirements is been presented and it includes unique identifier per requirement, description, source, priority and range. Additionally, the list is being organized by thematic section that the requirement refers to.

These requirements have been shared, discussed and agreed by the consortium and will be the driving material to be used by Task 2.3 in order to create the full specification set for RESIST system and ultimately create the technical frame of the project. Both deliverable D 2.2 and D 2.3 will be kept as live documents to be updated as new information, needs and challenges are presented during the technical work on the project. Any change to this document will be kept consistent to the format presented in the document and with adequate tracking so any change can be easily identified and monitored.

Annex A: Eventbrite page for the RESIST Workshop



RESilient transport InfraSTructure to extreme events

DEC
05

RESIST - Workshop 'End-Users Requirements for the RESIST System'

by FEHRL

Free

Sales Ended

Details

Description

We are pleased to invite you to the RESIST Workshop 'End-Users Requirements for the RESIST System' on 5th December 2018 in Thessaloniki, Greece!

RESIST (Resilient Transport Infrastructure to Extreme Events) aims to increase the resilience of seamless transport operation to natural and man-made extreme events, protect the users of the European transport infrastructure and provide optimal information to the operators and users of the transport infrastructure.

The aim of the workshop is to define user requirements and pilots involving critical structures and scenarios for the field tests planned in the project.

The workshop will enable the RESIST project consortium to liaise with stakeholders and learn how they handle structural inspection/monitoring, cyber/physical attacks and emergencies (including time required for response, the impact of this time, the available information on damage, their ways to achieve smooth continuity of mobility under extreme events). The workshop will serve as a platform to present initial pilots and user requirements identified by the RESIST project and get stakeholders' input and feedback and stimulate discussion on preventive and response measures in case of extreme events.

The main outcome of the workshop will be the final user/functional requirements and scenarios for the pilots.

We would appreciate if you could confirm your participation by registering to the event.

For more details on RESIST, see the website or contact Dr. Miglė Paliukaitė (at migle.paliukaite@fehrl.org).

We look forward to meeting you in Thessaloniki!

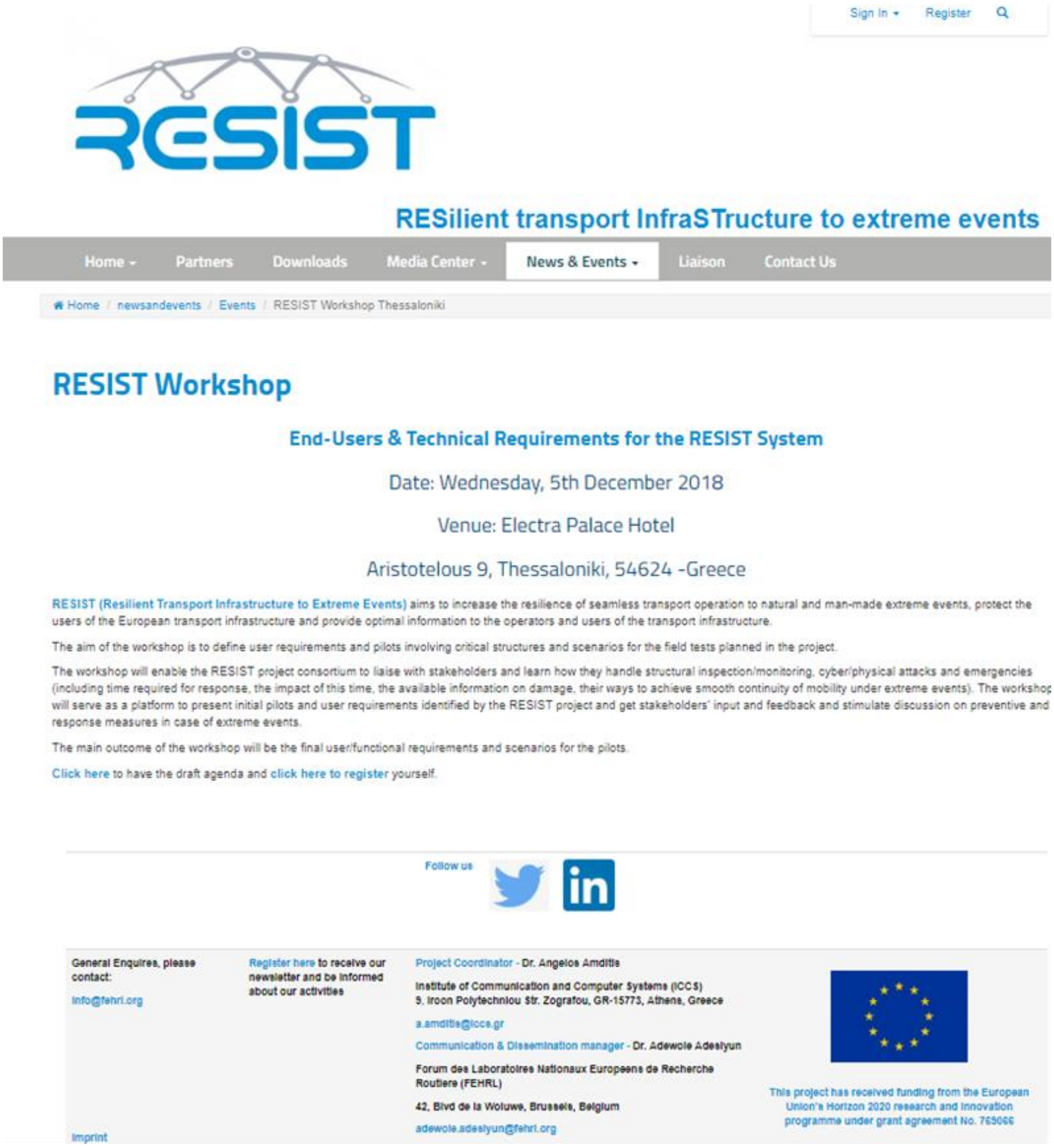
Date And Time

Wed, 5 December 2018
09:30 - 15:00 EET
Add to Calendar

Location

Electra Palace Hotel
Aristotelous 9
Thessaloniki 546 24
Greece
View Map

Annex B: Section dedicated to the workshop on the RESIST website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RESIST Workshop

End-Users & Technical Requirements for the RESIST System

Date: Wednesday, 5th December 2018

Venue: Electra Palace Hotel

Aristotelous 9, Thessaloniki, 54624 -Greece

RESIST (Resilient Transport Infrastructure to Extreme Events) aims to increase the resilience of seamless transport operation to natural and man-made extreme events, protect the users of the European transport infrastructure and provide optimal information to the operators and users of the transport infrastructure.

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The main outcome of the workshop will be the final user/functional requirements and scenarios for the pilots.

Click here to have the draft agenda and click here to register yourself.

Follow us

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info@fehrl.org

Register here to receive our newsletter and be informed about our activities

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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 769066

Imprint

Annex C: Final Workshop programme

RESIST Workshop

End-Users & Technical Requirements for the RESIST System

Date: Wednesday, 5th December 2018

Venue: Electra Palace Hotel

Aristotelous 9, Thessaloniki, 54624

Greece

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End-Users & Technical Requirements for the RESIST System

Programme

9h00 - 10h00	Registration and Coffee	
9h30 – 9h40	Welcome and aim of workshop	**Adewole Adesiyun** (FEHRL, Belgium)
Session1: Setting the Scene **Moderator: Adewole Adesiyun**		
9h40 – 9h50	Opening speech	**Thierry Goger** (FEHRL, Belgium)
9h50 – 10h05	Infrastructure resilience Report of FEHRL Scanning Tour to Asia	**Jürgen Krieger** (BASt, Germany)
10h05 – 10h20	RAIN project Risk Analysis of Infrastructure Networks in Response to Extreme Weather	**Lorcan Connolly** (Roughan & O'Donovan, Ireland)
10h20 – 10h50	Introduction to RESIST project	**Kostas Bouklas** (ICCS, Greece)
10h50 – 11h10	State of the art technologies and processes for minimising impact of extreme events. Expectation of workshop	**Panagiotis Panetsos** (Egnatia Motorway, Greece)
11h10 – 11h30	*Coffee break*	
Session2: Technical & User Requirements **Moderator: Kostas Bouklas**		
11h30 – 11h50	Preliminary technical requirements of RESIST project	**Kostas Bouklas** (ICCS, Greece)
11h50 – 12h15	User requirements	**Panagiotis Panetsos** (Egnatia Motorway, Greece)
12h15 – 13h00	Discussions	**ICCS & FEHRL**
13h00 – 14h00	*Lunch*	
Session3: Validation & Methodology **Moderator: Panagiotis Panetsos**		

14h00 – 14h20	Evaluation demonstration and benchmarking	**Panagiotis Panetsos** (Egnatia Motorway, Greece)
14h20 – 14h30	Requirements methodology and what comes next	**Kostas Bouklas** (ICCS, Greece)
14h30 – 14h50	Feedback from stakeholders - Questionnaire	
14h50 – 15h00 Closing Remarks (ICCS & FEHRL)		

Annex D: RESIST questionnaire

FRAMEWORK OF RESIST PROJECT

RESIST project has received funding and is part of the European Commission's H2020 research & innovation programme. The overall goal of RESIST project is to increase the resilience of seamless transport operation to natural and man-made extreme events, protect the users of the European transport infrastructure and provide optimal information to the operators and users of the transport infrastructures. RESIST aims to develop an integrated interoperable and scalable safety/security platform to offer high levels of resilience and secure nearly seamless transport operation in the event of critical structures suffering all types of extreme physical, natural and man-made incidents and cyber-attacks. It will network, in a unified manner, the targeted group: transport control room operators, first responders and citizens to enable gathering, processing and disseminating information for alternative planning in order to speed up communication in real time, a factor that contributes to the seamless transport operation. The following technologies will be implemented in the RESIST platform:

- Vulnerability assessment to physical, extreme, natural and man-made events: Strengthening/repair needs and cost, loss of operational capacity
- Remotely piloted aircraft system (RPAS) for inspection and sensors mounting to critical transport infrastructures
- Cyber security management solutions
- Alternative secure and continuous communications for normal emergency operations
- Highway users' psychological and behavioral dimensions of safety and its impact on the effective operational capacity and communication of the control with the users
- Mobility continuity for passengers and freight under extreme events in the Highway transport Mode.
- Mobile application for end users
- Risk assessment and management involving critical highway structures under extreme events.
- Integrated RESIST platform
- Validation demonstration and benchmarking of the RESIST solutions in real conditions and infrastructures

The RESIST integrated platform (and its sub-modules) will be tested in real life structures in Greece for the case of bridges and in Italy for the case of tunnels.

In case of questions, you can contact us:

- Mr. Konstantinos Bouklas, ICCS (Greece): kostas.bouklas@iccs.gr
- Mr. Panagiotis Panetsos, EOAE (Greece): ppane@egnatia.gr
- Dr. Adewole Adesiyun, FEHRL (Belgium): adewole.adesiyun@fehrl.org

QUESTIONNAIRE TO INFRASTRUCTURE MANAGERS / END USERS

IDENTIFICATION OF THE RESPONDENT

- **What type of organization do you represent? In which country?**
- **What is your organization function or user group?**
- **What is your role within the organization?**

IDENTIFICATION OF CRITICAL ROAD INFRASTRUCTURE ASSETS

1. **List the critical infrastructure assets (primary and secondary) included in your road(s) corridor(s), and under the Road Management Plan. Some examples are given in the table below.**

Primary Infrastructure assets (highway Network)	Secondary network/assets
• Bridges • Culverts • Tunnel • Cut and cover • Overpass • Underpass • Road surface: pavement & asphalt • Retaining walls • Slopes • Buildings (Traffic Control Center, Tolls) • Drainage systems • Load safety barriers • Road gutter • Bridge sidewalks • Other geotechnical works: high embankments, big cuts, rockfall protection barriers, retaining walls, slope geogrids drainage tunnels etc	• Transmission power lines • Communication towers • Lightning posts • Sign gantries (VMS) • Monitoring equipment • Road fence

IDENTIFICATION OF CRITCIAL RISKS

2. **Please, in reference to the identified infrastructure assets in question 1.**
    - **Describe identified hazards/risks affecting your infrastructure by using the table below. You can propose new hazards if needed.**

- **Explain how the hazard affect the IR asset (impact on operations/maintenance): e.g.** ***strong rain can affect the structural stability of slopes and embankments, even produce rock falls, causing traffic accidents/ cuts)***
- **Express the frequency/exposure of the hazard: low, medium, high.**
- **Specify if you are already using any numerical model**

E.g.

Hazard/ Risk: physical existence	Affected Infrastructure Asset (from question 1)	Impact on RI operations/maintenance	Frequency of hazards	Existence of numerical model (YES/NO)
• Storm, flooding, torrential floods	• Culverts • Tunnel • Cut and cover • Road surface: pavement & asphalt • Slopes • Road gutter • Drainage systems	• Failure of infrastructure embankments • Friction loss • Blocked culverts, drainage pipes, gutters • instability or settlements of slopes	Low	NO
• Abrasion, erosion due to water, scour	• Bridges	• Exposure of Bridges foundation, piers, abutments	Low	yes
• Strong wind and storms	• Communication towers • Sign gantries	• Loss of stability of towers and signs	Low	NO
• Increasing precipitation intensity	• Culverts • Slopes • Road gutter • Drainage systems	• Blocked culverts, drainage pipes, gutters • unstable slopes	medium	YES
• Hail storms	• Slopes	• Abrasion, erosion	medium	NO
• Extreme heat	• Road surface: pavement & asphalt	• deterioration of pavement	medium	NO
• Extreme cold & increased freeze thaw cycles, snow	• Bridges • Overpass • Underpass • Bridge sidewalks	• Concrete spalling, exposed reinforcement	high	NO

Hazard/ Risk: physical existence	Affected Infrastructure Asset (from question 1)	Impact on RI operations/maintenance	Frequency of hazards	Existence of numerical model (YES/NO)
• Earthquakes	• All Primary and secondary Infrastructure assets		high	YES
• Landslides, settlements, rockfalls	• Road surface: pavement & asphalt • Retaining walls • Slopes	• Erosion of slopes • Deterioration of pavement and walls	high	Yes
• Fires	• Road surface: pavement & asphalt • Tunnel • Cut and cover	• Abrasion of the pavement • Tunnel failure	Low	NO
• Fogs	• Lightning posts • Sign gantries	• unclear vision	high	NO
• Man-made events: oversize, overweight vehicles, terrorism, accidents	• Road surface: pavement & asphalt • Bridge • Tolls • Tunnels	• Additional deterioration and ageing factor for asphalt pavement • Effects (strees/strain) on bridge superstructure • Destruction of equipment of tunnels and tolls	medium	YES

IDENTIFICATION OF MONITORING EQUIPMENT

3. **List the current monitoring/ sensing equipment available in your road(s) corridor(s).**

4. **Specify where/how they work, time history, frequency of measurements and if they have remote connection capabilities or they are offline.**

- Currently used damage detection techniques.

Monitoring and/or sensing equipment	**Where**	**How**	**When (Frequency)**

- The type of sensors that are being used.

- The types of maintenance vehicles that are being used.

- Existence and frequency of punctual inspection or monitoring actions (for example, visual inspections).

- When such inspections take place, how long do they last

5. **From the list below, select the monitoring and/or sensing equipment that you would like to integrate in your management/monitoring system. In case you already use one, please indicate.**

Monitoring and/or sensing	Interests
• Images: ○ RPAS with cognitive computer vision for crack inspection (concrete and steel). ○ 3D measurements from images	
• Sensing of infrastructure (bridges and tunnels): Vibration sensors, radiometric sensor, ultrasonic sensor, GPR.	

IDENTIFICATION OF EXPECTATIONS AND REQUIREMENTS FROM END-USERS: NEEDS FOR IMPROVEMENT IN CURRENT MONITORING/ DECISION MAKING PRACTICES:

HOW RESIST TOOL CAN HELP END-USERS?

6. **What is missing, what is already available in terms of workflows and IT-support?**

7. **List requirements / needs that you would like to cover with the RESIST project, in relation to the RI strategic and operational management procedures currently applied, including:**

    - **Routine maintenance**
    - **Risk Analysis**
    - **Monitoring systems and processes (including adoption of new technologies/ improvement of existing ones)**
    - **Assessment of early detection of damage/degradation,**
    - **Rerouting traffic in case of structure closer**
    - **Sync. - and post-hazard event damage inspection and RI performance.**
    - **Efficient, immediate communication with the public in case of an event**

    Use the table below to provide the information.

⚠ **Note that the table contains some examples to help you understand how to fill it. These examples might not apply to your case. They are only guiding examples. Please remove them, and complete according to your case.**

Hazard	**Affected Critical infrastructures**	**Current detection mode/ monitored parameters**	**Current protocol applied**	**Problem/Gaps**	**End user requirement**	**Desired monitoring technique (if any)**
Seismic loads	Bridges, overpasses, tunnels, lost of stability Slopes and embankements lost of stability	**Pre-hazard (Routine monitoring and early detection of damage/degradation)**				
		• Bridge equipped with vibration, tilt, sensors • geological measurements	"Tuned" dampers, fuses	When intensity Ritster scale higher than XX, stop traffic, protect bridges	Calculation of stability of structures (foundations, slopes and retaining structures) under the effect of different and synergetic hazards Model of ground surface deformations and slope displacements	Geotechnical Analysis tool connected to ground sensors
		Sync-Post Hazard: damage assessment				
		Post Damage assessment	After-incident impact assessment based on visual analysis and XX techniques.	• Tracking from National Geological Institutes (during accident) • computer vision and Machine Learning (ML) damage diagnostic, • mobile mapping making use of Unmanned Aerial Vehicles (UAV) technology in non-accessible regions	Calculation of stability of structures (foundations, slopes and retaining structures) after incidient	
Heavy rain/ hail storm	Overloading of drainange systems Scouring in roads, bridge decks and support structures Threat to stability of slopes and embankments (including mudslide) Damage to signs, lighting, fixtures, and supports	**Pre-hazard (Routine monitoring and early detection of damage/degradation)**				
		• No current hail prediction • Announcement National Meteorological Agency • Alarm in SCADA system, associated to	Monitoring of amount of waterfall + wind	• Lack of accurate prediction of hail • Lack of precise long term predictions to adapt maintenance plans • Lack of synergetic risk models, to analyse various scenarios/ multi-hazard assessement		Geotechnical Analysis tool connected to ground sensors Advanced meteorological models, coupling insitu sensors data

Hazard	**Affected Critical infrastructures**	**Current detection mode/ monitored parameters**	**Current protocol applied**	**Problem/Gaps**	**End user requirement**	**Desired monitoring technique (if any)**
	Deterioration of structural integrity of roads, bridges, and tunnels dut to increase in soil moisture levels (only if increase in frequency)	Traffic Control Centers (TCCs)				
		Sync-Post Hazard: damage assessment				
		• Tracking from National Meteorological Institutes and in situ sensors. Owned model. (during accident) • Post Damage assessment	Post damage impact assessment of structures, slopes, etc. (visual, and using ground vehicles equipped with XX technique)	• Lack of erosion control measures • Lack of assessment of structural/geotechnical impact in structures	Structural and geotechnical analysis of structures after hazard event Model of ground surface deformations and slope displacements Improved damage mapping techniques Use of drones for non-accessible areas	Use of drone-based sensors coupled with satellite observation
Fog	Traffic Accidents in Motorway, main road network	**Pre-hazard (Routine monitoring and early detection of damage/degradation)**				
		Sync-Post Hazard: damage assessment				
		Pilot installation in one Toll station (outdoor sensor)	Connected to Special lighting system			
Snowfall event	Main road collapse, traffic accident susceptibility Deterioration of pavement due to increase freeze-thaw conditions Structures corrosion (salt penetration in bridge decks reaching the reinforcement) Lost of stabiliy in slopes	**Pre-hazard (Routine monitoring and early detection of damage/degradation)**				
		• Announcement from Road Weather Information Systems (ice warning meteorological station) • Early Alarm in SCADA	• salt spreading • Corrosion of reinforcement cannot be predicted. Only detected by visual inspection. • In case of poor visibility (ice, ground blizzard, accident)	Currently protocols are based only in Temp. Sometimes fail to predict reliable levels of ice, and salt is wastely used (environmental and economical cost). Corrosion of reinforcement is not predicted, Very high costs associated.	Improve decision-making tool, coupling wider range of variables (including salt amount, costs), to optimize operations. Advanced decision tool based in multi-hazard scenarios	Improved models, Implementation of networked sensors Decision support tool

Hazard	**Affected Critical infrastructures**	**Current detection mode/ monitored parameters**	**Current protocol applied**	**Problem/Gaps**	**End user requirement**	**Desired monitoring technique (if any)**
			and on command of Police→ cut traffic:			
		Sync-Post Hazard: damage assessment				
		• Own tracking, visual follow-up, owned meteorological models, • Salt spreading vehicles equipped with sensors sending data, to follow up event	• Salt spreading vehicles measures Temperature with IR, coupled with meteorological models, can predict the amount of salt to spread in function of meteorological predictions	Need for automated communication among different stakeholders (RI managers, RI operators, salt operators, traffic authorities) Need for more accurate impact assessment tools (effect of corrosion of structures)	Model to predict/follow-up the effect of salt in reinforcement corrosion. Integration of sensors in asphalt to monitor salt filtration + other auscultation measures Produce more accurate very short-term icing-prediction models based in Temperature and Humidity in-time measurements. Accuracy in icing prediction can lead to significant savings (environmental and economic) due to optimization of salt use. Not to mention benefits in traffic management, and prevention of accidents and cuts. Advanced decision tool based in multi-hazard assessement Improved communication with police, traffic regulators	Implementation of networked sensors Decision support tool Common operational picture with other stakeholders
time and load deterioration	Pavement	**Pre-hazard (Routine monitoring and early detection of damage/degradation)**				
		Sync-Post Hazard: damage assessment				

Hazard	**Affected Critical infrastructures**	**Current detection mode/ monitored parameters**	**Current protocol applied**	**Problem/Gaps**	**End user requirement**	**Desired monitoring technique (if any)**
		visual inspection, instrumental measurements	data processing, evaluation report by experts, rehabilitation proposal	traffic assessment for visual and instrumental inspection	special software, hardware for photographic data collection (high definition cameras on vehicle)	

8. **Describe the communication with the police/firemen/traffic agencies and actuation protocol in case of incidents occurrence (fire). Include traffic rerouting methods you might use (pre-defined, dynamic etc.) How could this communication be improved? Automation? Access to a Common Operational Picture (COP)?**

9. **Do you keep statistical data for the infrastructure users?**

Stakeholder	**Region** (culture, percent of locals vs tourists or non-native drivers)	**Public transport modes** (distribution of different types of vehicles)	**Road users' Parameters** (demographics; e.g., education, age, gender, driving experience)

LEGISLATIVE FRAMEWORK

10. **Detail legislative requirements regarding service levels. E.g. - If there are any limitations on the usage of drones (legal regulations): especially with respect to weight restrictions and flying outside line of sight.**

11. Identify stakeholders who play a key role in the road corridor and its surroundings. E.g. who is responsible for monitoring and maintaining road corridor assets?

Stakeholder	Asset	Monitoring responsibility	Reporting responsibility (if yes, to whom)	Maintenance responsibility (financial, operational)