To better understand the evolution of the project, all the research lines will be developed following the three activities (Planning, Selection and Evaluation), which are described in the following. Each activities is related to the above mentioned research lines as indicated in the table.

Activity 1 **Planning**

No.	Title	Description
1.1	**Kick-off meeting in Molise RL1 - RL2 – RL3 – RL4 – RL5**	First meeting will be held in Molise, to agree on common procedures and present each partner's assets concerning equipment and staff members assigned to project. This meeting is also important to establish personal contacts between project managers and create positive atmosphere. Determining of joint procedures for field tests and survey.
1.2	**Review of existing literature RL1 - RL2 – RL3 – RL4 – RL5**	Preliminary bibliographical review will be executed, in order to collect all the most recent documents of the technical literature in the field and proposed methodologies will be compared.
1.3	**Defining guidelines RL1 - RL2 – RL3 – RL4 – RL5**	Defining working methodologies that will constitute the index and the chapters of guidelines for seismic risk mitigation in cities and industrial areas. Defining measures in the world concerning methods of seismic hazard/risk evaluation (latest accomplishments in researched and in codes). Defining measures concerning methods of seismic hazard/risk evaluation in the Adriatic Sea region.
1.4	**Mid-term meeting RL1 - RL2 – RL3 – RL4 – RL5**	Mid-term meeting will be held in Croatia. While exchanges of ideas and cooperative works will be done throughout the project for single topics, this meeting will give the opportunity to all the researchers to evaluate the project activities and eventually correct the procedures for accomplish all the tasks.

Activity 2 **Selection**

No.	Title	Description
2.1	**Testing sites selection RL1 - RL2 – RL3 – RL4 – RL5**	Selecting the testing sites where proposed methodologies will be applied. In this activity all researchers involved in the project will cooperate. The testing sites should be representative of the main typologies that can be found in the periadriatic zone

Activity 3 **Evaluation**

No.	Title	Description
3.1	**Seismic source characterization RL1 - RL2 – RL3 – RL4 – RL5**	Once chosen the sample area for the project, it ought to be defined a seismological scale, that should involve all potential seismic source, using geological and seismotectonic features and damage distribution to define source parameter. In Italy, recently earthquakes in the south-central Apennines is often constituted of multishock sequences, with at least two main earthquakes of similar magnitude, showing a complex dislocation time history. The synthetic acceleration field produced by each source models proposed will be compared to macroseismic intensity map by using empirical relationship. Finally, a reasonable seismic large scale source characteristics (fault size and position, average slip, mechanism) of the target earthquake will be proposed for each seismogenetic structure.
3.2	**Historical seismicity RL1 - RL2 – RL3 – RL4 – RL5**	For the selected test sites, earthquake history will be record and a connection with potentially seismogenic sources will be applied. All available information will be collected,

		including maps, literature data, reports, and boreholes
3.3	**Seismic wave propagation characterization** **RL1 - RL2 – RL3 – RL4 – RL5**	The upper crustal structure of the sample regions will be investigated analyzing all available seismic, stratigraphic, gravity, etc..data, to reconstruct a more reliable seismic velocity model
3.4	**Estimation of the expected seismic motion** **RL1 - RL2 – RL3 – RL4 – RL5**	Numerical methods for computing synthetic time series to be used for the prediction of strong motion parameters of moderate to large earthquakes will be implemented for the evaluation of scenarios for strong motion parameters (peak values, spectral ordinates, signal integral quantities...) associated with the occurrence of a "characteristic" earthquake. The earthquake scenario will be represented by two maps, one describing the spatial distribution of the mean value of the considered strong motion parameter, the other representing its expected variability, through a statistical parameter (CoV= Coefficient of Variation) which is measured from the set of available predicted values.
3.5	**Collecting historical data and results from prior testing** **RL2 – RL3 – RL5**	Gross geotechnical characterization of the main formation in the study area. All available data will be collected, selected and analyzed: boreholes, piezometric data, in situ and laboratory geotechnical tests. This activity will be carried out in tight collaboration with the group of geology involved in the project. This activity is particularly critical because of conditioned collaboration of the authorities and agencies that are in possession of the information. Once the data is collected, it is of great importance to perform careful selection, and elimination of those considered in lack of reliability.
3.6	**Geological characterization and mapping** **RL2 – RL3 – RL5**	This activity will include: • detailed geologic survey: including litostratigraphy of all the units emerging in the study areas • meso and macro structural analysis and evaluation of the regional extension of the found structures; • comparison with deep subsoil data; • interpretation of aerial photos, geomorphological analysis and location of the shapes of geomorphological failures; • creation of the geologic model that is the definition of the geometric relationships between the different recognized geologic bodies (with particular detail to the first 200m under the ground level) • redefinition of the database for geological data
3.7	**Execution of ad hoc geotechnical investigation** **RL2 –RL3–RL5**	Once geologic and geotechnical characterization of the area is obtained, next is analysis of seismic response with aim to define the most hazardous areas in terms of: - amplification of seismic motion; - eventual liquefaction phenomena; - eventual slope instability phenomena. "Dynamic" characteristics of the soils will be derived: • indirectly and in an approximated way, using literature correlations with the physical and "static" mechanical properties; • directly through a series of surveys in laboratory For the latter aspects, the project will take advantage of collaboration with centre AMRA "Analysis and monitoring of the environmental risk (www.amracenter.com), that it is

		highly qualified centre for analysis of environmental risk in general and seismic risk in particular, having several state-of-art devices for characterization of soils under seismic impact. During phase of on-situ testing, five researchers from Croatia will study visit Molise University and participate in activities.
3.8	**Preparation of seismic zonation maps (motion amplification, liquefaction, slope instability) RL2–RL3 – RL5**	Sites that were soil was tested will be mapped, where motion amplification, liquefaction, slope instability elements will be graded, after that a geological and geotechnical model of the subsoil was defined.
3.9	**Integrated geophysical surveys by means of a multi-sensor system RL4**	Today the four main methodologies used are based on ground penetrating radar (GPR), seismic, geoelectrical, and electromagnetic prospecting. Depending on the kind of survey the abovementioned methodologies allow to detect the presence of objects below the surface or buildings through not-invasive survey. Nevertheless, these show intrinsic technical limitations, in terms of size of objects detected, image resolution, range of depth analysable, thus making hard to draw accurately the overall status of the area under analysis. This limitation is more evident in presence of external noises (anthropogenic and geological) which cause a reduction of the image resolution.
3.10	**Application of algorithms for simultaneous processing of data RL4**	The algorithms are coming from the multi-sensor acquisition and for 3D image reconstruction, which allow the estimation of material properties from geophysical data and consequently the achievement of precise images of the survey
3.11	**Use of a topographic imaging RL4**	The method is based on the concept of anomaly source occurrence probability. The rationale of the method is the search of similarities between the measured data sequence and the surface signature of the geophysical signal generated by a scanning elementary source with unitary strength. The elementary scanner is ideally moved within a selected cross-section through the target-space and a regular 2D matrix of anomaly occurrence probability values is thus obtained. A sequence of parallel 2D tomographic slices if finally elaborated in order to outline the 3D anomaly source geometry within the explored structure. It must be stressed that this tomographic approach tough following the same high-resolution strategy as other current methods, differs from them in that it does not require any fundamental a-priori information. The proposed method deals uniquely with the pure physical aspects of the interaction of the impressed geophysical field with the buried features.
3.12	**Behaviour of geotechnical structures under seismic loadings RL1-RL2-RL4**	After defined the most seismic hazard zones, the last activity will be pivoted on the complete analysis of single buildings and industrial systems, toward which the methods of mitigation of the effects of earthquakes will be proposed. The activity of geotechnical engineering will be to study the retaining structures and the foundations under seismic loads, using methods that move typically from simple approaches proposals in the seismic codes to more sophisticated approaches that simulate in more realistic way the behaviour of the geotechnical structures under seismic loadings. The guide variable guide will be, in such case, the performance class required for the structure.
3.13	**Shear strengthening of masonry panels with**	Tuff stones represents the main volcanic product widely spread in Southern Italy, where seismic hazard is relevant

	advanced composite materials (FRP) **RL4**	and represents a crucial aspect in the preservation process of historical constructions. Typically, tuff masonry buildings built over the last two centuries usually are 3-4 storeys high, with bearing wall (including both faced and solid arrangements) regularly spaced, regular openings and orthogonal inner walls. From a seismic standpoint, the analysis of such structures is a complex task due to poor quality and inadequate resistance of masonry buildings to in-plane and out-of-plane loading. The visual observation of earthquake damage on masonry structures were usually denoted by shear cracking through units and mortar. Mode II shear sliding failure along the unit/mortar interface may occur in masonry panels, particularly for low levels of vertical loads and/or low friction coefficient. For this reason, it is important to analyze the shear response of masonry walls that is also critical for the selection of reliable strengthening techniques. Among the innovating techniques to retrofit and repair existing tuff masonry structures, there has been an increasing interest in composite fibres materials (FRP). These materials present several advantages, as low specific weight, corrosion immunity and high tensile strength. Their flexibility and somewhat easy application allow a wide range of intervention scenarios. However the knowledge about use of these systems for shear strengthening of tuff masonry is still lacking. Therefore, a comprehensive experimental research on full-scale tuff masonry strengthened panels with FRP fabrics and subjected to in-plane cyclic loading will perform. The research will be intended to investigate the role of various parameters as the level of the vertical prestress, the masonry texture and assemblage, the FRP pattern (cross or grid), the type of fibres, the number of layers. In particular, specimens will build up in order to reproduce typical masonry texture observed in buildings of South-Central Italy historical centres. The experimental investigation will be supported by the review of the most recent technical literature. The tests will be performed under displacement control so the post-peak softening regime could be fully detected. The instrumentation will be designed in order to monitor the change in geometry, loads, and strain profiles of the fabrics. The overall performances of the strengthened panels will be compared with those of as-built ones in order to evaluate the effectiveness of the strengthening technique. Particularly, failure modes, shear strength, ductility and the post-peak behaviour will be discussed both for as-built and strengthened panels. In addition, the debonding process of FRP will be analysed in terms of load-strain profiles. Moreover, basic design requirement such as high bond properties between FRP and masonry substrate, and proper mechanical anchorages of plies were taken into account. Finally, a finite element analysis will be performed to model the non-linear behaviour of strengthened panels using a commercial FEM package. The approach toward its numerical representation will focus on both the simplified micro-modelling of the individual components, i.e. unit and mortar, and the macro-modelling of masonry as a composite. Clearly, macro modelling is more practice-oriented, and results very attractive when a compromise between accuracy

		and efficiency is needed. On these basis, a simplified analytical model will be proposed as a worthy tool for an approximate assessment of the in-plane seismic capacity of strengthened masonry panels, and also as support for the design of retrofit interventions by means of FRP materials.
3.14	**Strengthening of masonry arches and vaults with advanced composite materials (FRP)** **RL4**	As part of the widespread Italian cultural heritage, historical masonry constructions, namely arches and vaults due to their structural significance, deserve particular attention because their preservation is a current issue since the majority of them are of considerable architectural and historical importance. Ageing effects, movements in the piers or other accidental factors (like ground motion) can cause structural damage on elements belonging to arches, thus affecting their global stability that could lead to either local or global collapse of the masonry building. In order to appraise maximum resistant loads, deformation patterns and collapse mechanisms of masonry arches, a good understanding of their structural behaviour is required. Because strengthening measures might be needed especially to prevent seismic collapse, a significant concern in actual research is the need for efficient strengthening techniques to re-establish or enhance the performance of these structures and preventing their brittle failure when subjected to ultimate state limits. In order to evaluate the effectiveness of different FRP strengthening proposals of masonry vaults and arches, a combined experimental and numerical research activity will be performed. Masonry specimens will reproduce typical vaults and arches of historical centres in Southern Italy, and will be reinforced on the intrados or extrados surface with FRP sheets. The specimens will be subjected to vertical and horizontal loads under displacement control up to failure. The horizontal loading will reproduce earthquakes effects and displacement of piers. The variables of interest included the FRP types and amount, the load carrying capacity, stiffness, displacement capacity, failure mechanism of masonry arches, strain profiles of FRP plies and mechanical anchorages to masonry support. Besides, full and partial length reinforcement with FRP plies will be considered (at the intrados or at the extrados); additionally partial length strengthening could be considered simultaneously at the intrados and at the extrados. In order to provide a structural description of the arch–pier interaction effects, numerical analyses will be performed with a non-linear finite element program. The approach followed will be based on the micro-modelling strategy, where the discontinuities will be concentrated in the interfaces between the units. The properties used to simulate the unit-mortar and masonry-FRP interfaces could be obtained also from mean values of literature studies. On the base of the previous results, a simplified procedure will be proposed as guideline for the seismic assessment of the mechanical behaviour of arches and vaults, and for the selection and design of appropriate FRP materials for their structural restoration and retrofitting.
3.15	**Masonry columns confinement with advanced composite materials (FRP)**	Many contributions are available in the scientific literature for quantifying the confinement effect in terms of both strength and ductility increase of concrete members. On the contrary, despite the urgent need to develop effective methods of

	RL4	masonry confinement as a means of preventing catastrophic failures, for example, during earthquakes, no studies have been reported in this area, namely, masonry confinement through Fiber Reinforced Polymers (FRP) wrapping. It is this gap that the project would intend to fill, through a comprehensive experimental program on FRP-confined masonry columns made of 'leccese' tuff stones and clay bricks. Masonry structures have been built assembling natural stones and clay bricks since ancient times in countries located in the Mediterranean areas, and they represent a significant part of the existing masonry building inventory including historical architecture of Central-Southern Italy. In particular, the 'leccese' tuff represents a very attractive natural stone from a technological point of view due to its outstanding workability, low cost, good mechanical and physical (i.e. thermal and acoustic insulation) properties, as well as availability. It has been widely used in order to build solid and/or faced structural walls having different textures and shape of units. The characterization of base materials will be carried out first, followed by tests of masonry piers. Finally, circular and rectangular masonry columns will be tested under axial load applied cyclically under displacement control. In such a way the overall performances of the strengthened columns will be fully detected, including the post-peak softening regime. Confinement will be obtained by wrapping masonry with continuum or discrete CFRP and GFRP fabrics applied though the use of epoxy adhesive, or with FRP jacketing. Configuration of masonry columns will allow investigation of the role of various parameters in the effectiveness of the proposed confining techniques. These parameters include the wall geometry, the confinement pattern, the type of fibres, the number of layers, the stiffness/strength characteristics of the jacket. Strain profiles in the FRP layers will be measured in order to estimate the ultimate strain under the confinement-induced lateral pressure. Finally, the experimental investigation will be followed by the FEM analyses of the FRP-confined masonry. In addition, an analytical model for the prediction of confined strength and ultimate strain will be proposed and compared with those suggested by literature review and by modern strengthening and rehabilitation code provisions.
3.16	**Definition of the layout of the industrial plants and the actions** **RL1**	The research program will start from the definition of the outlines and the type of petrochemical systems and extrapolation of the critical structural typologies under the seismic loadings. For every typology (distillation towers, rack of tubes, etc.) it will defined the design and the construction data with reference to Italy and Croatia. Standard type in Italy and in Croatia of the stocking systems and their mechanic-physical characteristics will be defined. At the same time data for the curves of "fragility" of the constituent members the systems in Italy and in Croatia will be collected. The characterization of the details of seismic input that is critical for the various typologies of the plants will be made providing of the following information:· • 1° level information for risk evaluation: PGA maps , PGA-Magnitude correlations… • 2° level information of for determinist evaluation of the structural behavior of the structural typologies in linear field (acceleration and displacement spectra)

		and in non-linear field (synthetic accelerograms and so on.)
3.17	**Behaviour of industrial plants under seismic loadings** **RL1**	Specific models for the analysis in non-linear field for steel structures with concentrate or suspended loads (typical of the distillation towers) and for buried or external tanks containing hydrocarbons or gases will be developed including the soil-structure interaction. The use of the models and the seismic input will allow evaluating the vulnerabilities of petrochemical systems by means of the employment of fragility curves and the evaluation of the detailed vulnerability of sampling types. Particular attention will be paid to the evaluation of the contamination scenario due to the release of dangerous substances from the plants. It will be considered the dispersion in the atmosphere with the vapor cloud formation or pools of liquid, by means of the construction of the relevant scenario. Subsequently, they will be considered the ignition phenomena including: outbreak of the cloud, fire of the cloud with damages for effect of the generated thermal radiation, fire of the pool of liquid with damages on the surrounding atmosphere for effect of the thermal radiation, containing outbreaks to chain of adjacent tanks of liquefied gases. The construction of the scenario will be produced by means of opportune models of calculation available in literature and/or commercially.
3,18	**Mitigation of the seismic effects on the industrial plants** **RL1**	Finally, the evaluation of the exposure of the population to the industrial risk is carried out overlapping the analysis results on cartographic maps. In conclusion they will be defined some methodologies and techniques for the reduction of the vulnerability of the tanks based on the employment of the composed advance material for the confining of the structures..
3.19	**Final meeting in Molise and Dubrovnik** **RL1 - RL2 – RL3 – RL4 – RL5**	Two final meetings will take place in Molise and in the city of Dubrovnik where results of research will be presented and disseminated.