1. Final publishable summary report

The final report of the SMARTeST Project, FP7 funded research in the area of environmental technologies for flood protection.

Project details can be found on the website – www.floodresilience.eu

1.1 Executive Summary

The use of flood resilience (FRe) technology has increased in Europe over the past ten years. It is now recognised in some countries as an important means of managing flood risk and minimising damage to buildings and infrastructure. The SMARTeST Project has assessed the next generation of innovative FRe technology, furthered understanding FRe systems and has developed FRe tools. In the process, the project has advanced the road to market of FRe technologies. FRe technology exists in a variety of forms. SMARTeST developed terminology based upon aperture barriers, perimeter barriers and building technology to describe the range of technologies that are available. A number of innovative FRe products were then tested in association with their manufacturers in the test facilities of the project partners.

The research has advanced the understanding of how technologies should be tested with respect to their end uses. There is an absence of national standards that apply to the testing of FRe technology, and therefore the research has aimed to prepare guidance for standards makers. The guidance includes testing and test protocols for the range of FRe technology, but importantly it also sets out guidance on preparing a code of practice for the design, installation, deployment and maintenance of FRe technology as well as site survey. The research has established guidance on standards harmonisation that could lead to a European Standard and CE marking within a period of five years.

A FRe system was a new concept developed by the project to describe the use of FRe technology within complex, multi-scalar urban areas. The research used a case study approach, with all types of flood being considered. The approach demonstrated the importance of having an integrated approach to FRe technology use rather than relying on individual installations. To develop a FRe system the urban environment and the availability of flood management infrastructure (flood alerts/warning, organisation of installations, emergency services, etc) need to be understood. FRe system design must be informed by appropriate modelling using a range of tools. There is no one solution for FRe systems, with the guidance produced covering different scales from individual building level to cities.

A range of FRe models and tools have been developed as part of the project with a view to assisting decision making. These include an overall decision support tool (FVAT) that is designed to help local and strategic stakeholders make the best informed choices when selecting FRe technology. Damage prediction tools have been developed to work at various scales (individual building to community level) and under different flood types. These tools allow users to assess the cost-benefit of installing FRe technology and reducing building damage. A hydrological model (Multi-Hydro) has been developed as a model to show the impact (positive and negative) of introducing FRe technology in urban areas.

The project partners will take forward a range of foreground Intellectual Property and will further develop the technologies, systems and tools that emerged. Innovation in the form of the Basic Barrier Technology and Modelling has been developed and this can be used freely by designers and manufacturers to supply perimeter barrier solutions. Combined with appropriate test methods, the code of practice in a harmonised standard, and further guidance for FRe installation this represents a substantial step forward in the normalisation and integration of FRe technology.

The SMARTeST project will have a visible impact in the years to come. In the scientific literature and amongst industry, where the project has been particularly well received, it will result in greater positive innovation in the FRe sector. The SMARTeST legacy will also include an international competence alliance in FRe, with further dissemination and integration of FRe technologies, systems and tools through this network.

1.2 Description of project context and objectives

The research aimed to improve the Road to Market of innovative FRe technology reducing deficiencies and obstacles to implementation, facilitate holistic flood defence systems and support the EU Floods Directive. The research was undertaken through a collaborative research programme involving leading European institutions in this area. New technology, systems and tools were developed and guidelines for validating their performance developed and applied in experimental studies. The project enabled EU partners to learn from each other and to investigate, develop, implement and disseminate a range of methodologies that will enable more scientifically sound transfer to flood resilient cities.

The project had the following specific objectives:

- Development and enhancement of innovative technology for the protection of buildings and urban infrastructure from flood:
    - to evaluate the reliability and efficiency of FRe technology;
    - to provide cost effective solutions for existing and new structures within the context of safety standards (building regulations) throughout national countries.
- Development and testing of 'smart' flood resilience technology that progresses technology and test methods beyond the current state of the art, including:
    - Innovative products that can respond and react to flood incidents with minimal human intervention;
    - Products for resilience of urban infrastructure, focussing on transportation, bridges and dams;
    - Technology to adapt streets, parks and corridors for conveyance of exceedance storm water.
- Systematically testing the performance of FRe-products with experimental facilities in the hydraulic laboratories of partners and derivation of guidelines for the validation of FRe-technologies and systems.
- Analyse and assess different systems of flood resilience in urban environments according to different flood types (pluvial, torrential, fluvial and estuarial).
- Review of literature and stakeholder interviews in representative cities of Europe to explore the societal and administrative barriers to implement flood resilience measures at buildings and infrastructure and implications for future practice.
- Develop integrative flood resilience system concepts as a 'safety chain', and develop strategies for integration in existing flood defence systems and urban development.
- Development of guidance and best practice examples for public and professional stakeholders to raise their knowledge, and stimulate and guide the implementation of FRe-technology and systems.
- Disseminate the research results at local, national and international level to maximise the impact from the findings.

Drivers such as climate change and rapid urbanisation have resulted in increasing flood problems in urban environments throughout the last century. According to EU policy (EC 2003, EC 2007/60) flood risk *management* is the appropriate strategy to cope with this increasing flood risk rather than traditional flood *defence* strategies which try to reduce the flood risk through blocking the pathway of floodwater using dikes and walls. Flood risk management deals with the flood problem in a more holistic way, namely by considering all components of flood risk. In this context, the flood resilience strategy gains great importance as it seeks to reduce the exposure and vulnerability of the receptors which are the population, the built environment and the urban infrastructure. Resilience measures not only consist of individual technical solutions but they need to be integrated to a 'safety chain' which requires the development of resilience systems and tools (see figure 1). They should facilitate their implementation into practice by improving the decision making and acceptance of communities at risk.

FReM	**Type of measure**	**NS Responses**	**object**
Techniques	Wet-proofing	Traditional	**Built environment**
	Dry-proofing	Emergent	
	Floatable buildings	Emergent	
	Transportable pumps	Traditional	
	Flow resistant objects of infrastructure	Emergent	**Infrastructure**
	Water proof sewers, electrical and telecommunication lines.	Traditional	
	Runoff Conveying streets, parks, corridors	Emergent	
System	Flood proof building	Emergent	**Adaptation of flood prone area**
	Exceeding water conveyance system		
	Flood compartment systems		
	Flood proof infrastructure system		
Tools	Flood proof seal	Emergent	**Capacity building & Decision Making**
	Building codes		
	Financial incentives		
	Insurance service		
	Reserve funds	Emergent	
	Evacuation and rescue plans		
	Decision support tools		
	Learning tools for capacity building		

Figure 1: Flood Resilience Measures (FReM) for urban environment

Flood resilience technologies

At the project commencement some of the Flood Resilience (FRe) Technologies had already been established (traditional measures), but most of them were regarded as emergent as they are at their inception or not yet applied. Knowledge and understanding therefore needed to be improved to establish and adapt technologies to suit the dynamics of the urban environment. As a consequence of the paradigm shift of the EU water policy (Directive 2007/60/EC, EC 2003) from defence to living with flood, the industry has already reacted by researching and developing products and materials enhance building resistance to flood water. The range of vendors offering flood products is already extensive with multiple solutions to adapt buildings from flood (dry-proofing technology) or to adapt their materials and interior to the probability of flooding (wet-proofing). However, private stakeholders and professionals seldom made use of these new opportunities for the following reasons:

- Insufficient transparency of the performance of the products;
- Uncertainty of their efficiency;
- Complex technical solutions may not be easily integrated into decision making processes;
- Uncertainty how to best utilise and assess flood risk data within decision making;
- Inefficient information dissemination according to the great variety of stakeholders;
- Insufficient appreciation of the variety of stakeholders concerns;
- No coherent or comparable information about the new technologies;
- Insufficient capacity of stakeholders;
- Uncoordinated activities and responsibilities of stakeholders.

Flood Resilient Systems

Flood resilience measures for the built environment can achieve deeper integration by: protecting several blocks of properties or city quarters; encompassing all elements of urban fabric such as infrastructure; or by being combined with other non-structural responses such as warning systems and flood emergency services. Such integrated approaches of flood resilience are the key to resilient cities. They have a broad impact on urban structure and thus need the adaptation of the urban system in a holistic way which calls for new concepts and strategies of urban planning. While some engineers want to compensate for the negative impact of climate change on flood risk by rising dykes, new strategies of flood resilience should promote dike reinforcement with adaption of the urban environment to protect against flooding.

Decision making tools

In the past ten years or so many tools for flood damage assessment had been developed. However, they were not sufficient for the decision making process of flood resilience measures as they cannot simulate the damage reduction through resilience measures. More advanced and bespoke tools (models of damage, surface water flows, etc) to support the planning of resilience measures has been a key aspect of the SMARTeST project.

Capacity building has been widely recognized as a component of integrated flood management. The efficiency of a flood resilient system relies on the quality of suitable measures but also on the capacity of the community to accept the system (that is, to have a critical understanding of what the system can do and cannot do and the circumstances under which the system may fail). The creation of favourable conditions needs to be fully comprehended, particularly the way the concerned population perceives flood hazard and its own vulnerability.

There can be no meaningful stakeholder participation effort, unless there is awareness raising and training of participants. This has been acknowledged in the SMARTeST project where workshops with experts and the public displayed the difficulty of fully integrating the approach of technology, systems and tools for flood management.

Flood resilient buildings are generally encouraged by the insurance industry and flood resilient repair is a potential opportunity to reduce vulnerability in the building stock. However, the responsibility and cost for flood resilience generally has to be borne by the building or asset owner. Insurance companies are reluctant to offer flood resilience within their existing policies as this would increase the cost of premiums and would be a form of ‘betterment’. The research has examined the development of the insurance market for resilient buildings. It has also provided evidence of clients’ needs for assistance to build up the financial capacity (or incentives) to invest in FReM. But this is not, in itself, without challenge. Previous initiatives in Germany to give incentives to building owners and occupiers have not been successful in Baden-Württemberg, where in the city Wörth most vulnerable dwellers did not accept the incentives that were offered. But there are also examples where incentives have been more successful. In the UK, government funded schemes for FRe technology(mainly aperture barriers) has resulted in thousands of installations with an increasing number taking place over the period of the project. The production of guidance in the SMARTeST project, including the ‘six steps to property protection’ has high impact potential at implementing FRe technology at this level (returned to later in detail).

In many cases finance has been the reason underlining the risk that these instruments will increase further social inequality. In this respect financial incentives should be developed to support the implementation of the technology.

The project has worked with advisory groups at an internal level (the Application and Implementation Group) and national level (the National Support Groups) in order to identify measures to improve the road to market. Such stakeholder engagement has further idnetified routes to market through financial instruments and legislation.

1.3 Description of the main scientific and technical results and foreground

The overall research strategy involved the combination of the following components:

- Research and development on smart innovative flood resilience technology for the protection of the built environment;
- Development of testing procedures and methods for flood resilience technology;
- Development of draft harmonised international standards for flood resilience technology;
- Undertaking case studies to assess the systems under which flood resilience technology is used in the urban environment;
- Developing implementation tools for flood resilience technology in Europe;
- Integrating the aspects of technology, systems and their implementation;
- Disseminating the results of research to a wide user audience (technical and non-technical), in order to achieve a significant impact on protecting the built environment.

The project strategy used the work package system to address the technology (WP2), systems (WP3) and implementation (WP4) for smart resilient flood protection. The three main strands of the research were brought together in the integration work package (WP5). The research strategy also involved a significant amount of dissemination activity in order to have an impact beyond the project partners and contacts (WP6). Dissemination activities were varied in order to reach a variety of interested stakeholders. Figure 2 shows the relationships between the different work packages, which reflect the strategy of the project.

Case studies were undertaken in the partner countries as a component of the methodology, and these provided the following:

- A wide range of characteristic urban flood situations (pluvial, fluvial, torrential rain and coastal floods);
- Wide range of flood risk management practices;
- Typical topographic situations throughout Europe;
- Typical climate conditions throughout Europe (humid, mild weather, semi-arid and arid weather);
- Different urban topology;
- Availability of data;
- Existing relationships between research and water management authorities.

The case studies were instruments of the research into the systems and implementation challenges related to flood resilience technology.

The success of the project was dependent on good administrative and financial management by the Coordinator, Work Package Leaders and all partners. The management work package (WP1) dealt with the administration, financial management and reporting of the project. The Coordinator was responsible for the organisation of all project meetings. A Steering Group of the principal members of the work package leadership team assisted the coordinator in managing the consortium. Project meetings were held at approximately six monthly intervals over the course of the project. The meetings created strong communication lines within and between work packages, including regular conference calls. The Coordinator operated a web-based project management system in order to monitor the progress of work packages against deliverables and milestones.

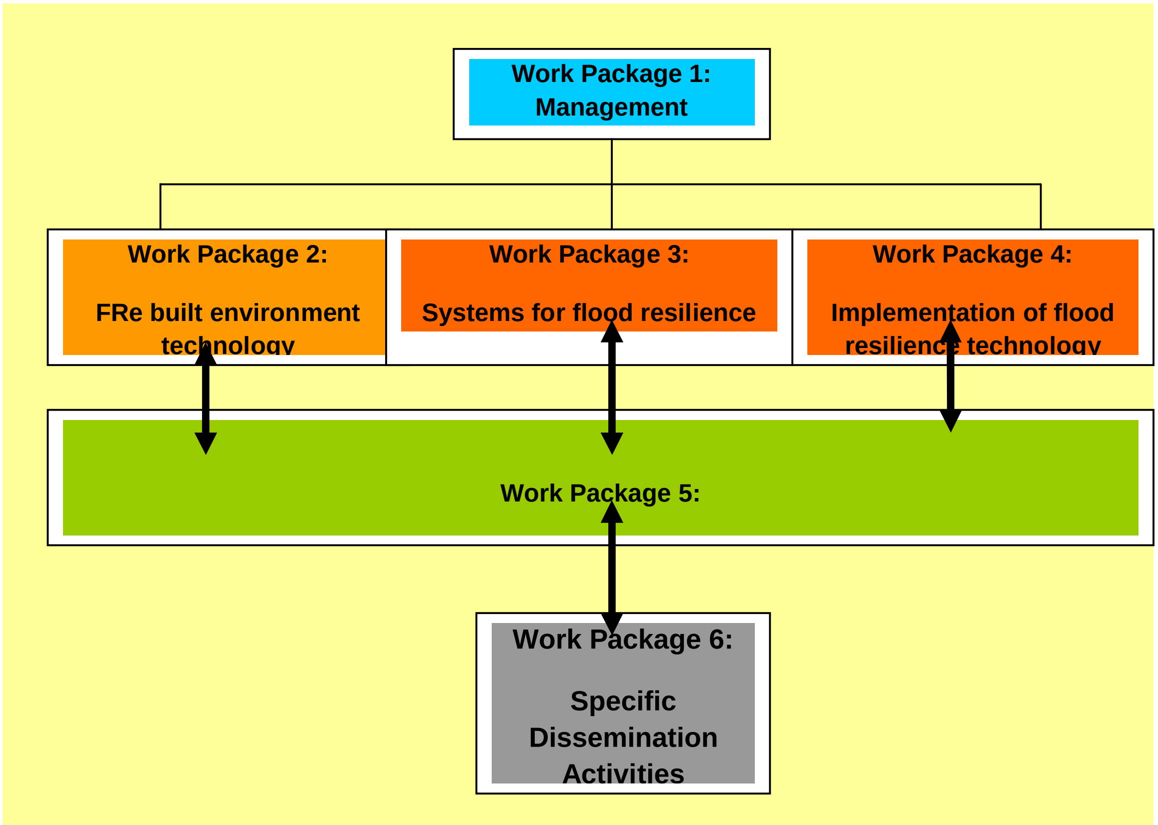


Figure 2: Research components (work packages) and their interdependencies

The main scientific and technical results and foregrounds are described here on the basis of the individual areas (undertaken through work packages) of technologies, systems, tools and integration. The dissemination work package (WP6) also contains results and foreground from dissemination activities.

Work Package 1 concentrated upon project management and as such it did not involve any specific activities that constitute scientific outputs or the development of foreground.

Flood resilience technologies (Work Package 2)

The objectives of the research with respect to flood resilience technologies were as follows:

- To develop innovative and smart technologies to enhance the flood resilience (FRe) of the built environment and infrastructure, with a specific focus on new materials, smart deployment and control;
- To test and assess the performance of FRe-technology (products and materials);

- To develop guidance as the basis of standards for the testing and approval of FRe-products, harmonizing the different European standards on FRe-product and approval procedures.

Method

The project partners identified two main possibilities for innovation in flood resilience technologies. The first was in the use of new materials and components that offered significant benefit over existing products, such as performance, durability and ease of deployment. Secondly, smart technologies that offered the benefits from less reliance on human intervention, particularly important where the type of flood cannot be readily predicted or forecast prior to an event occurring. The SMARTeST project team worked with a range of stakeholders in each country to test and develop innovative FRe technologies. The main output from the research on FRe technologies was guidance that could form the basis of future harmonised European Standard for FRe technology.

The work package sought to develop a more structured and standardised way to test products across the EU. Standards organisations (e.g. DIN, BSI and BWK) and their current test methods were the basis for this work. However, the research also highlighted a deficiency in the standards arena in that no independent and authoritative code of practice was available. Those standards that do exist were typically test standards and lacked guidance on issues such as site survey, installation, maintenance and quality.

As the project partners were predominantly research organisations, and not involved in technology manufacture or supply, a key requirement of the methodology was to work with such industry groups, for instance through the national support groups. A notable exception was the basic barrier, which was developed through a case study approach. This barrier, and associated design (tool) software, was intended to address those countries within the consortium with minimal or no current use of FRe technology. In terms of the consortium, the UK, France, Germany and the Netherlands had varying degrees of industry development with regards to FRe technology, whilst the countries of Spain, Greece and Cyprus had little if any current involvement. The basic barrier has application anywhere as does the associated design model, but represents probably the first indigenous FRe technology barrier in Cyprus.

The first task was the development phase for innovative and smart FRe technology, which had a focus on new materials opportunities and smart systems. Each partner involved in this work brought forward at least one example of each type of innovation. Research with industry and end users resulted in specific product ideas being identified. This included, for example, protection layers for infrastructure, permeable covers for sealed public spaces and drainage filters for basements and ground floors. In addition, smart technology design for buildings and infrastructure (especially transport routes) includes those with multi-functional use (e.g. combined wall insulation properties and FRe performance).

The SMARTeST project developed a number of technology categories, described as follows:

- Building aperture technology: these provide flood protection to openings within a building, such as ventilation areas, entrance doorways and pipework. The specific products could include air brick covers, door guards, building-fixed flood guards and non-return valves.
- Perimeter technology, including:
    - Temporary technology - these provide flood protection away from the building and/or between buildings. They have no permanently-installed elements and are positioned before a flood event occurs. Specific products could include filled tubes and/or containers, and temporary flood barriers with no permanently fixed components.

  - Demountable perimeter flood barrier - they provide a semi-permanent barrier to flood water and can include various elements (both fixed and non-fixed) that can be installed when required.
  - Preinstalled perimeter flood barrier - they provide a permanent flood protection available on site which can be activated when necessary.
- Building technology - there are a range of items that are included in building technology. They include permanently positioned technology used to seal building walls, foundations and floors. Components such as resilient or resistant doors and windows are included in FRe building technology. Resilient building materials that are not significantly affected by a flood should also be considered as FRe building technology. Local warning systems that are integrated at the building level are also relevant FRe building technologies. Waterproofing and anti-corrosion products have been identified within the SMARTeST project as relevant to building technology.
- Infrastructure technology - these provide flood protection to infrastructure components such as roads, rail routes, pathways and permanent flood defences. Specific products could include innovative surfacing materials that resist the potential erosion of infrastructure elements, automatic barriers, and membrane technologies.

SMARTeST deliverable (2.1) contains further information and examples of FRe technologies that are currently available in the European market as products. The project initially collected information in a simple spreadsheet database, which was developed into an on-line Technologies Database currently hosted on the website (www.tech.floodresilience.eu).

The development and description of innovative FRe technologies needed a definition of the key terms associated with this research. Therefore, a glossary of terms was developed largely based on previous research activities throughout Europe, as well as discussions within the project team and associated experts. Key terms and definitions have been written into the SMARTeST Glossary (see www.floodresilience.eu).

In relation to the above, the following approach was taken:

- State of the art – Each country represented within the SMARTeST project identified the FRe technologies currently and historically utilised to provide flood resilience to buildings. This not only involved identifying products, but also giving information on their intended use and deployment.
- Technology categorisation – In order to develop a consistent approach to the discussions on FRe technology, existing products were categorised following desk-based and survey research.
- Identifying failures – The limitations of existing FRe technologies have been investigated by the project team. This has involved a review of these technologies at a national level to identify common weaknesses in performance, operation and deployment.
- Need for innovation – The limitations of existing FRe technologies have been identified within the activities undertaken in Task 2.1. This has allowed the requirements for more innovative approaches to FRe technologies to be reported. This does not provide justification for the development of innovative approaches, but describes how the current limitations have influenced the industry in its own development.
- Innovation in FRe technologies – The development of FRe technologies that provide more innovative solutions to flooding has been investigated. The categorisation of innovative products has also been developed following the PAS 1188 (2009) approach to lend a level of consistency in reporting these products. This has allowed a generic approach to the

description of innovative products, complemented by examples provided by project partners across Europe.

Testing

After identifying a range of innovative FRe technology, they were tested in association with manufacturers and suppliers. For some, this was the first opportunity that such technologies had for assessment. Testing took place through the project partners research facilities, including the large flood test tanks at the TUHH and the smaller test facilities at other partners.

Task 2.2 involved tests on the innovative FRe technology and comparison with established products on the market. Tests were undertaken in laboratory conditions, although at different scales.

National, international standards, protocols and guidance document related to the assessment of the flood resilience technologies were reviewed. Limitations of these standards in the reliability assessment of the FRe Technologies were identified. The testing phase of the FRe products was mainly based on these documents.

Test results of 25 products including perimeter, building aperture, and building and infrastructure technologies are presented in the SMARTeST Deliverable D2.2. The test results enabled the assessment of the functionalities of different FRe technologies with a view to improving their performance by detecting the product weaknesses. Several products in the same resilient technology category were tested to assess if a comparison of performance is possible. Furthermore, the tests indicated that no fixed testing scheme could be defined for the performance assessment of the variety of perimeter technologies available, but a testing matrix could be developed for the set-up of appropriate testing procedures.

The flood resilient product market was also assessed through surveys and a market analysis. Surveys, carried out of members of the various NSG's, show that the scope of the current market of FRe technology generally remains unknown, although estimates made by some members suggest promising potential for FRe products. The performance and function of FRe technologies are not the only important criteria for the selection of the appropriate product. Cost also plays an important role in the decision making process and this was assessed for some types of FRe technology.

SMARTeST Deliverable D2.2 details the test results achieved and the lessons learnt from that test work. Two examples of different innovative FRe technologies are provided here.

Spring Dam

The Spring Dam technology has been designed to protect urban areas and buildings against flood damage. It belongs to the pre-installed perimeter flood barriers category. It is characterised by its two states, as follows:

- A passive state in which case the barrier has no function. This accounts for most of the time. Between two flood events the product is not in use (or at least not as a flood defence, but it may form a walkway or similar). In order to not disturb the aesthetics of the environment the barrier is hidden inside an underground compartment, or attached to an adjacent structure or permanent flood defence.
- An active state when, in case of a flood alert, the barrier is activated automatically or manually to protect the system against flooding.

The main advantage of this category is the speed of installation by reducing the logistical requirements in contrast to demountable and temporary barriers. However, they require preliminary design and installation work and regular maintenance.

The Spring Dam is a manually operated system. Its innovative characteristic lies in the opening mechanism which consists of springs. The barrier erection is made easier by the springs which counter balance the weight of the barrier (see figures 3 and 4). Therefore, barrier sections can be put into place prior to a flood event without the need for a number of operatives. The barrier surface itself is heavy and would not lend itself to easy installation in the absence of the springs.

Figure 3: Spring Dam in the passive (left) and active (right) states

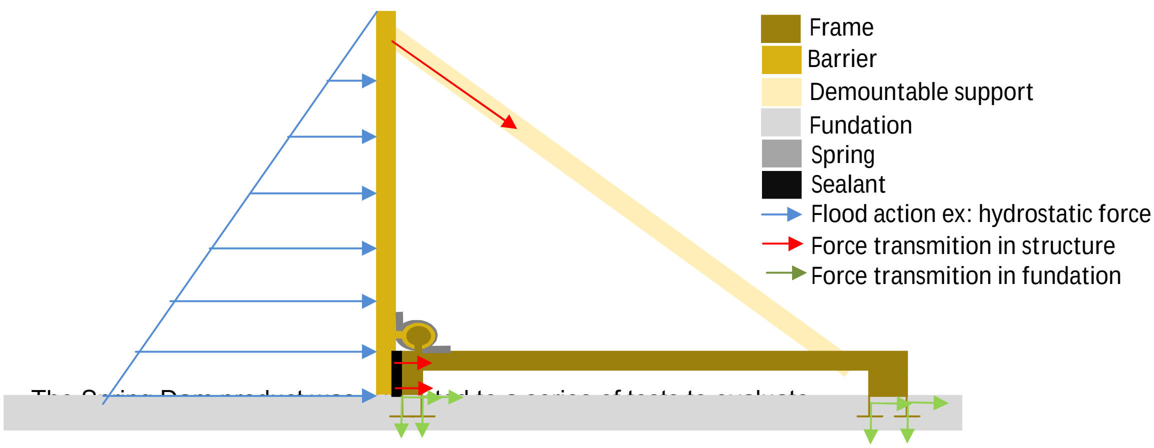


Figure 4: Force transmission principle

The product's performance under different flood conditions was assessed in tests carried out in KLIFF, the research centre of climate change of the River and Coastal Engineering Institute of the TUHH (Hamburg University of Technology).

Tests provided a better understanding on its performance. The hydrostatic-, hydrodynamic- and impact tests did not affect the functionalities in terms of waterproofing and stability. The only leakage found was at a specific location, which appeared to be an installation issue. Although the majority of aspects were satisfactory, some "weak points" were revealed by the wear- and mounting-test. Some improvements were suggested to the manufacturer in order to resolve those issues.

Resilient insulation

Testing of Technitherm® insulation material in-situ in masonry cavity walls was carried out at BRE. Water-tightness tests on masonry cavity walls were conducted to determine the ability of the insulation material to prevent water passing through a cavity wall, compared to the same wall with an empty cavity. The insulation material is a closed-cell polyurethane foam that is pumped into wall cavities as a liquid, which then foams, expands and sets to form a resilient material.

Samples of Technitherm® insulation were also subjected to water immersion and submersion tests to establish the level of water absorption of the material. Further samples were taken from the test wall after water-tightness tests and then carefully dried out to identify water absorption by the material in the flood test.

Further testing was carried out by BRE to determine the capability of masonry walls filled with the material to withstand the ingress of water in a flood situation. For the initial water-tightness testing, a purpose built rig was installed at BRE in East Kilbride (figure 5).

The insulation greatly improved the capacity of the tanks to hold water. In tests prior to the insulation being injected, water had leaked through the walls, below the walls, from tank to tank and from gaps around the pipe. In tests, after the injection of insulation, there was only a small amount of leakage from below the wall in tank 1. This leakage was observed even when the water depth in the tank was only 100mm, so it was unlikely to be due to water pressure. It was possibly the result of the insulation not being injected to the bottom few millimetres due the presence of some limited water amount in the cavity before the installation. The material itself only absorbed a minor amount of moisture, and therefore would have an insignificant effect on the thermal insulation properties.

Tests on flood resilient building materials

A test method and specification of a set of equipment was developed at IOER in order to assess the flood performance and resilience of construction materials. UPM also developed test methods for a range of materials that can be used in the assessment of the ability of sealants and coatings to resist the passage of water through materials in a flood.

The objective of the test runs was to determine the water seepage through the wall and floor constituents. To quantify this effect, the laboratory tests clarify the extent to which liquid water penetrates the materials of each building construction.

The water-tight tank used for the building assembly tests was made of transparent acrylic glass. This allows processes such as seepage flow to be closely observed during the test runs. The specific geometry of the water tank enables the simultaneous examination of two constructions per test run. Its design is presented in figure 6. The inside of the water tank has a length of approximately 200 cm, a height of 50 cm, and a width of 50 cm. Two frames increase the rigidity of the tank construction. The front and back panel of the water tank can be removed for the in-situ construction and deconstruction of the test arrangements.

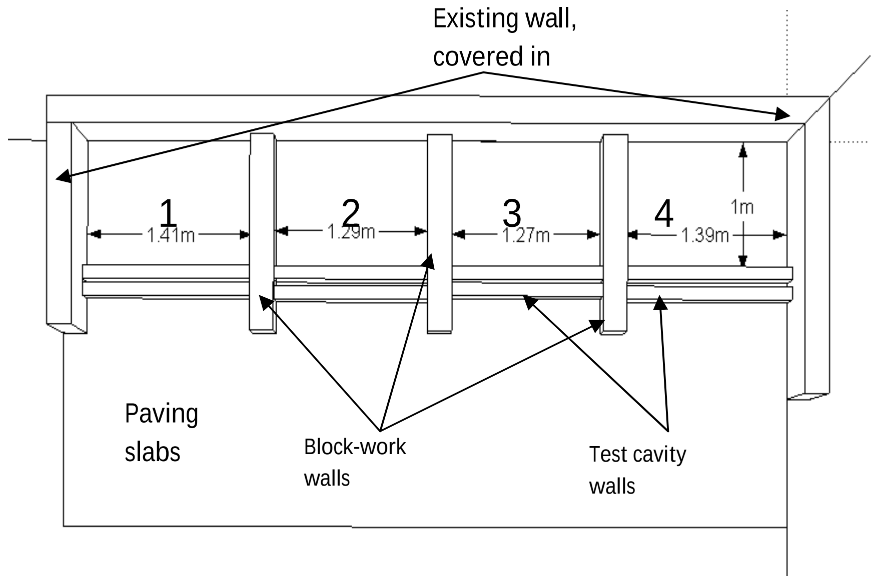


Figure 5: Plan Diagram of test rig

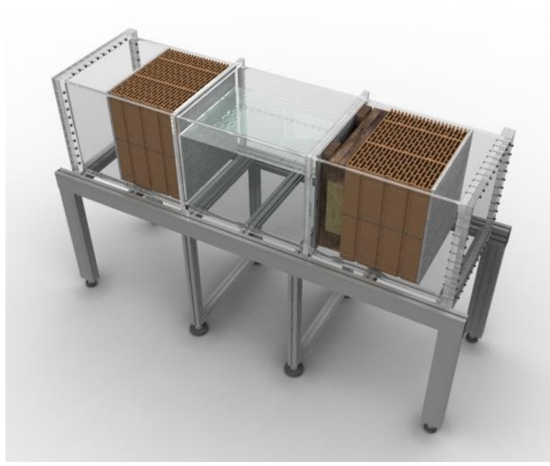


Figure 6: Facility used for flood performance tests of building assemblies

Standards

One of the main objectives of the project was to produce guidance directed at the developers of standards. At project commencement standards makers around Europe generally had little comprehension of FRe technology as there are few national standards. In the UK, the National Standards Body (BSi) has produced a test specification (known as a PAS), but this is not a full standard either for testing protocols or as a code of practice.

The guidance for standards makers was considered to be a practical document outlining the main forms of testing as well as an approach to a technical code of practice. Differences in testing regimes for aperture and perimeter barriers were highlighted. The potential to have different leakage rates on a classification scale rather than a simple passfail value (e.g. as currently used by BSI) was offered. This is in line with other European test standards for construction products. In that way a manufacturer could declare a performance leakage class, for example under hydrostatic conditions, whilst specifiers could then use this to determine what level of leakage might be tolerated by a building over a particular period of time. Table 1 provides the classifications proposed and the limits within those classes.

Aperture barriers		Perimeter barriers	
Classification	Leakage rate range	Classification	Leakage rate range
aL0	≤ 0 lt/hr/m edge length	pL0	≤ 0 lt/hr/m of barrier length
aL0.5	.> 0 ≤ 0.5 lt/hr/m edge length	pL10	.> 0 ≤ 10 lt/hr/m of barrier length
aL1	.> 0.5 ≤ 1.0 lt/hr/m edge length	pL50	.> 10 ≤ 50 lt/hr/m of barrier length
aL5	.> 1.0 ≤ 5.0 lt/hr/m edge length	pL100	.> 50 ≤ 100 lt/hr/m of barrier length
aLmax	.> 5.0 lt/hr/m edge length	pLmax	.> 100 lt/hr/m of barrier length

Table 1: leakage test classification system for aperture barriers proposed by SMARTeST

Work Package 3 – Flood resilient systems

The objectives with respect to flood resilient systems were as follows:

- To explore and describe different systems of flood resilience in urban environments corresponding to different flood types;
- To analyse these systems to identify failure modes, effectiveness and criticality;
- Make a synthesis of these findings in order to prepare guidelines for the design and assessment of flood resilient urban systems.

The FRe systems considered ranged from property and infrastructure-level (one receptor system), to building block and urban development level (group of receptors) and to water basin level (pathway-receptor system). Case studies were used in order to identify failure modes, effects and criticality of the described systems. The case studies addressed the local and national context of building standards, building types and construction methods. This allowed comparison of the performance of the building fabric with FRe technology in different situations of urban development and infrastructure, and development of concepts for resilient buildings and communities.

Inputs from WP2 concerning innovative FRe technologies were considered through the improvement in resilience they offer to the case study systems. Guidance was then prepared on a European level to address the resilience of systems at different scales. The guidance provides information on the preferred options for the built environment, infrastructure and urban development to optimise flood resilience.

FRe systems

In the context of SMARTeST, a “system” is an assembly of elements and the interconnections between them covering urban flood under various flood type scenarios (riverine, pluvial, flash, coastal, groundwater) and embracing all flood management elements (warning appliances, emergency services organisation, drainage networks, flood risk models, protection construction and equipment) and over various scales (from house to street to neighbourhood to city to conurbation to region to country). Figure 7 illustrates an FRe system in the context of a river flood.

Many tools are available that can contribute to the design of such systems (e.g. protection equipment, construction water-tightening processes, urban hydraulic simulation software, damages assessment methods, training, information media, etc.). Some such tools were developed and tested during the course of the SMARTeST project.

The case studies presented in table 2 were used as a generic tool by SMARTeST partners. These case studies were used for two main purposes during the project, as follows:

1. 'Storytelling' and thorough analysis of Flood Resilient Systems (FRe systems);
2. Guidance for flood resilient systems.

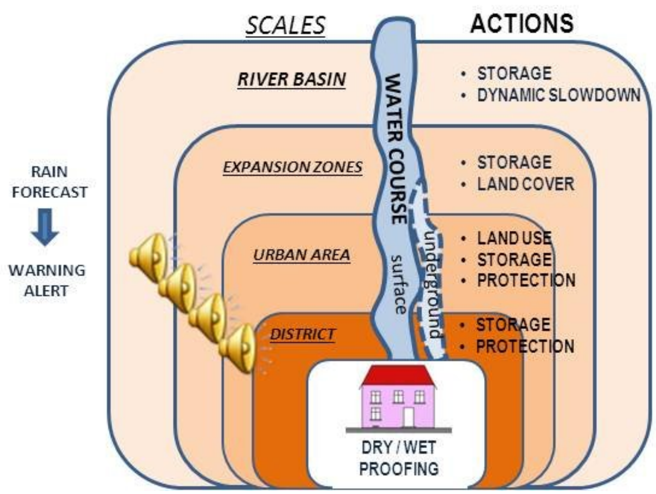


Figure 7: elements of a FRe system (river flood context)

Partner	Partner country	Case study location	Flood type	Story telling	Guidance
TOUM	Cyprus	Paphos	Costal	✓	
ENPC-CSTB	France	Villecresnes	Pluvial	✓	✓
		Jouy-en-Josas	Fluvial + pluvial	✓	✓
IOER	Germany	Dresden	Fluvial	✓	
NKUA	Greece	Athens	Fluvial	✓	
TUD	Netherlands	Rotterdam	Pluvial	✓	
UPM	Spain	Valencia	Fluvial	✓	
UNIMAN-BRE	UK	Heywood	Pluvial	✓	✓

Table 2: case studies locations and use

Task 3.1 required the project partners to explore and describe different systems of flood resilience in urban environments related to different flood types. In order to achieve this, a methodical study of flood resilient systems was undertaken using case study examples. This included:

- Literature review: though the concept of FRe systems is emerging, partners were asked to identify and analyse references which demonstrate this concept and investigate the technology used with regard to flood (protection/resilience) systems. A literature review was undertaken to establish a knowledge base on FRe systems. The term 'flood resilient system' has not yet been widely used across the literature (as confirmed through a web survey). However, relevant literature has been reviewed and analysed in this section. .
- Case studies and storytelling: case studies covering various types of flood pattern were selected in collaboration with Work Packages 4 and 5. . The description of these case studies is used to define the organisation of the existing systems. In order to bring additional information and to create a context for more innovative activity, a storytelling approach was used to describe a real flood event in some of the case studies areas and to imagine the consequences for improvement of the existing FRe system or the implementation of a FRe system.
- Extending the resilience concept to flood resilient systems: Resilience is a concept which impinges on many domains. On a day-to-day basis, society relies on resilient systems which are able to function even in case of failure of one or several system elements. The flood resilient system concept is approached by analysing such examples and the development of methods to design and assess such systems. The adaptation of the resiliency concept to a flood event is thoroughly addressed in all its dimensions.

The SMARTeST project has the premise that innovative FRe technologies were used within FRe systems. The performance of these innovative FRe technologies has been brought together with a range of modelling tools to assess the operation and efficiency of the system under various flood conditions. The case study areas are used as the basis of work on FRe systems.

The following points were concluded from the research carried out in Task 3.1:

- A FRe system contains a number of components that work together to create resilience. The components of the system will vary depending on the nature of the (urban) environment and the type of flooding that is likely to be realised.
- FRe systems within the SMARTeST project have a range of spatial scales and physical forms. The smallest system that can be described is the building level (although this could read 'infrastructure installation'). The system scale builds up to river basin level.
- The other components of a system include physical infrastructure such as transport networks, urban drainage networks and primary flood defences. However, it also includes a range of non-structural measures such as local planning laws, insurance options, local government and central government management, flood warning systems and community resilience measures.
- The literature review has highlighted many studies that address the resilience of different systems in scale and location. These studies do not specifically cover the use of technology at property and community level and its overall role, operation and performance. The role of FRe technology may be viewed as adaptive capacity of the system to cope with extreme events that cause failure of primary flood defences. However, the possibility of their own failure must be considered in order to properly advise stakeholders of potential failure points and to build capacity of communities and individuals.

- In order to fully understand the intervention(s) made by installing FRe technology; the role, operation, performance and indeed overall impact on the system must be addressed.

Task 3.1 analysed information on flood management systems (FMS) and on the emerging concept of flood resilient systems (FReS). The work concluded that successfully implemented FMS are based on a holistic approach:

- FMS encompass multi-scale territories, e.g. river basin/non-urbanised expansion zones/urban areas/quarters/buildings (in the case of river flooding);
- FMS design and implementation is a long lasting process (several decades);
- FMS development requires long negotiations with all concerned stakeholder groups in order to define acceptable downgraded situations in a flood event (as well as possible associated compensation);
- FMS is constrained/guided by a multiplicity of regulations.

Task 3.2 required the analysis of flood resilience systems, a critical analysis using a method based on FMECA (Failure Modes, Effects and Criticality Analysis, including costs) concepts. The case studies cover several types of flood in different locations and these were analysed according to a framework containing eight points as follows:

1. What is the reference situation?
2. What are the objectives of the local FRe system?
3. What are the potential options for FRe technologies?
4. How are FRe technologies planned to be linked to each other?
5. What is the effectiveness of the FRE system?
6. FRe system performances analysis
7. What is the cost of implementation?
8. How can these options be implemented?

Task 3.3 addressed the guidance on flood resilient systems based on the findings of the case studies.

An added-value of the SMARTeST project has been to confirm that the availability of technologies and tools is not enough to ensure that a flood resilient system can be achieved. What is missing is a full comprehension of the scope and the limits of these tools as well as a framework to use them in a consistent way through different spatial and time scales.

The key phrases are associated with this framework:

- Co-ordinated actions: the consequences of actions at a given scale have to be analysed both upstream and downstream in order to assess their impact on the whole concerned area (in order that each can understand the implications of considered alternatives and final decisions)

- Consistency: there is a need for the whole area to check prevention/protection measures are consistent at different scales. No measure should hamper or even cancel the expected effects of other measures at a different location.

- Co-production: this should be organised by all stakeholders belonging to different institutions, geographical or administrative areas (in order to fully accept consequences of measures and to define compensation if needed).

- People resilience should be developed through planned actions aimed at disseminating information on the importance of anticipation, reactions and behaviours before, during and after flood (in order to create conditions for an effective operation of FReS)
  Built environment resilience should be clearly explained (in order to avoid misunderstanding and exaggerated expectations from 'resilient systems/environments'). An urban area is a complex man-made system. The resilient properties of such a system arise from the choices of successive decision makers as well as from the way the urban system is maintained. However, choices can be made to use FRe technology to improve the flood performance of the built environment.

- Innovative FRe technologies have a high potential to support the design, implementation and operation of FReS. They may be essential elements of FReS designed and implemented through a co-production process to develop coordinated actions relying on the resilience of people and of the built environment.

Work Package 4: Flood resilient models and tools

The objectives of the research on FRe models and tools were as follows:

- To develop a range of tools for the implementation of FRe technologies;

- To develop strategies for local and national level implementation within the context of the EU Floods Directive as well as national planning, building regulation and local authority policy;

- To build capacity in stakeholders to support effective implementation of FRe technology.

A range of FRe models had already been developed by the project partners (e.g. HOWAD, GRUWAD and FLORETO). However, these models had been used only for limited situations. The work in the SMARTeST project extended them by analysing a number of case studies, including those used in WP3.

The implementation of innovative FRe technologies needs to consider local, national and EU-wide policy and societal practice if there was to be substantial benefit and impact. Thus decision support that goes beyond current practice is required, which is often on a technical assessment only. Decision support tools were extended to multi-criteria assessment and planning aspects.

In this work package, implementation of FRe technology was addressed from the technology developed and tested in WP2 and the system case studies in WP3. The Work Package used the case study approach with contributions of different national and local contexts and from different flood types.

A models toolkit has been developed within the project (the SMARTeST Toolkit) in order to support the resilient planning on different scales. The toolkit is composed of models which support different planning phases, forming a risk assessment and development of a resilient plan for the built environment. As the requirements of different targeted users on the performance, content and interface considerably vary, an "all-in-one tool" is not seen as a feasible option. The developed toolkit focuses on how to include the outcomes and findings from the performance tests performed on different FRe technologies, adding value to the decision making on FRe technology and systems. The developed tools (figure 8) differ in scope, scales, technology implemented and end users.

Figure 8: SMARTeST Toolkit

Multi-Hydro

The tool Multi-Hydro, devoted to support the flood probability assessment step, is a fully distributed, model developed at the Ecole des Ponts et Chausées (ENPC), ParisTech. It delivers flood parameters for which the damage assessment and FRe planning can be performed.

Multi-Hydro can evaluate the effects of different FRe measures, including any downstream impacts. Indeed, Multi-Hydro has been able to test different floods scenarios taking into account the properties of the protection implemented. The protection measures tested in case studies were the individual barrier, perimeter barrier and retention basin.

Using dedicated GIS software (MH-AssimTool) it is possible to draw barriers and/or storage basins. The software then creates an input file for the simulation. It is thus possible to use the barrier for the whole duration or only for a short period of the computations. The size of these elements can be changed for different scenarios (e.g. a barrier of 1m, 1.5m or 2m).

Multi-hydro has been developed to evaluate the impact of the small-scale changes on the overall behaviour of an urban catchment. In the context of the SMARTeST project, Multi-hydro can take into account the implementation of FRe technologies, simply defined as a particular category of land use at the appropriated (small) scales. Using the model it is easy to implement different types of FRe technologies, such as perimeter barriers, individual barriers or alternative methods such as swales (i.e., surface defined as a soil depression where the infiltration parameters are modified to facilitate the process). As Multi-hydro works on the base of time loops, it is possible to simulate the temporal variation of these devices, i.e. the progressive implementation of the barriers.

Damage models

The emphasis on the project has been to explore and develop efficient damage assessment methods and models, covering different scales of application of FRe technologies and systems and supporting both professionals and the public. Two damage models have been included into the SMARTeST toolkit, HOWAD- Prevent and FLORETO-KALYPSO.

HOWAD- Prevent is a GIS based tool targeting professionals, which can perform damage assessment, flood resilient planning applying different flood resilience technologies and the cost benefit analysis for the defined urban structures and typologies.

HOWAD-Prevent focuses on damage modelling to simulate the effects of FRe technology and includes the following topics:

- The description of flood risk systems and the conceptualisation in flood damage assessment are complex interacting processes. The results provided a sound basis for a broad understanding of systems behaviour. The conceptualisation of flood risk systems follows the source-pathway-receptor-consequence model of risk (SPRC) as a widely accepted, simple interrelation representing the risk generating process. Its integration in damage modelling is shown on the example of large river basins. This is state of the art in damage assessment with a comparison of empirical and synthetic model approaches.

- A short overview is given to flood precaution measures regarding flood resilience technologies and different strategies to reduce the vulnerability of receptors. The classification ollows the consideration and integration of the measures in damage modelling. It links with results of work package WP 2 regarding innovative flood resilience technology.

For the HOWAD–Prevent damage model, developed by IOER, the investigations of different case study areas were an important instrument for the development and the tests of model approaches. The regional characteristics influence the methodology and require further adaptation in generating input data for the damage model. This was a helpful process in the generalisation and enlargement of the methodology. The results of the investigations include detailed information about the study area and a basis for damage modelling other areas of the region. The case studies give experience in detail for every case study area and generalizable knowledge for further development of the approach.

The main emphasis initially was on providing and generating necessary input data. They are a crucial factor for the quality of the outcomes. Three case studies (Heywood, Valencia and Dresden) were used to demonstrate the model within a European context, for instance considering various local and national constraints. The case studies integrated the respective National SMARTeST partners, national support groups as well as local experts. Nevertheless, the options to integrate the FRe technology effects in HOWAD-Prevent show the relevance of the research results in the context of SMARTeST.

The methodology applied in the case studies to analyse the flood vulnerability of buildings at a high spatial and contextual resolution. These case studies were used to demonstrate and compare the inter-relation between the structural design of building types and their specific vulnerability considering various flood types and different national and local contexts. Moreover, the approach provided a sound basis for the simulation of damage reduction through flood resilience technology. The delineation of flood-prone study sites enables the gathering of high quality digital geo-datasets, which contain, among other things, information about expected flood levels, the topography, the building stock etc. In all three case study areas the basic unit of information for the building stock was the building-unit with its attributes of physical extension and special forms of use.

Figure 9 shows the qualitative changes in the course of the depth-damage function for FRe technologies. In Figure 9a, the effects of measures that enhance the resilience of buildings are characterized by the function's diminished slope. The course of the function in Figure 9b shows a reduction of damages due to flooding up to a defined depth by means of measures to enhance resistance, such as building aperture technologies. However, when the defined depth of flooding (the so-called intake threshold) is exceeded, the effects of the measure are lost. Figure 9c illustrates how avoidance works with the changed starting point of the damage function (□), resulting in lesser damage at the same depth. It can be realised in the planning process by, for example, an elevated arrangement of new buildings.

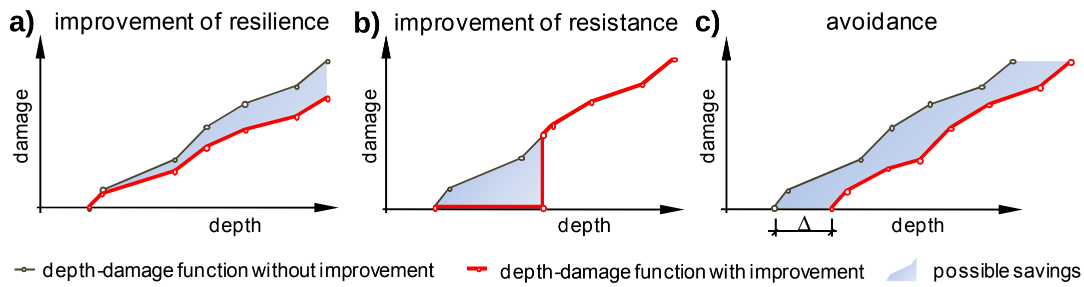


Figure 9: HOWAD model output

Figure 10 shows a possible qualitative course of a depth-damage function by combining resilience measures, resistance measures, and avoidance measures. Erecting a building without a basement, for example, shifts the entire function to the right. If measures to enhance resilience are taken into account, the function also slopes upwards to a lesser degree, and implementing measures to increase resistance and less damage

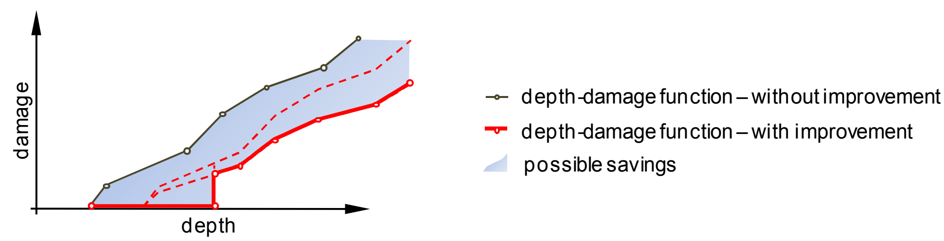


Figure 10: Example of combining vulnerability mitigation measures

FLORETO- KALYPSO (developed by TUHH) is an open source tool that can perform damage assessment and cost-benefit analysis for individual buildings to a high level of detail (description of the building elements and contents), enabling and performing flood resilient planning at the building scale. By consequence, the user is provided with choices of different FRe technologies, which can be considered for implementation and can be processed by the multi criteria analysis. The tool can also be used by homeowners.

KALYPSO is an open source tool, implemented as a family of hydrologic, hydrodynamic models and risk assessment and management models.

FLORETO has been implemented as a web (browser) based open source tool. In the first step, the users can describe the properties/buildings, which are in the next step analysed in terms of the potential damage. In the final step, appropriate resilient plan/system is suggested to the user.

A data collection module has been designed as a graphical user interface, in which data are collected in a step-by-step procedure covering both building fabric and contents. An example of the data collection module interface is given in figure 11.

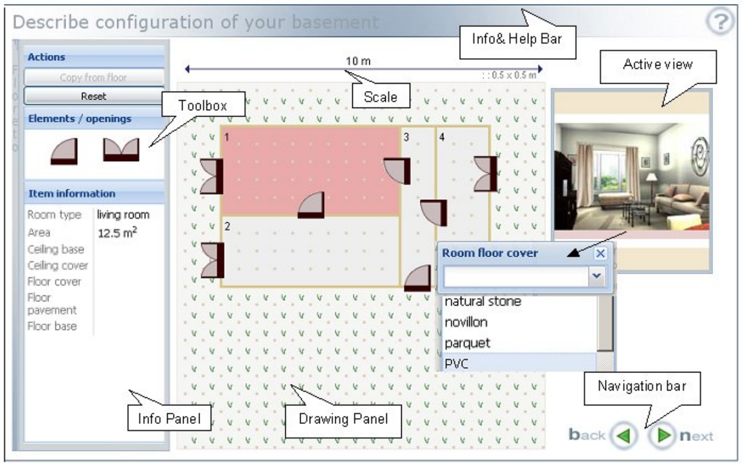


Figure 11: Example of the framework for data collection in FLORETO (Source: TUHH)

RAINS

RAINS is an insurance model developed by TUD, although it should be seen as a framework for insurance modelling, to support the verification process of flood damage models by making use of the data collected by insurance companies. A database containing a series of 20 years records on rainfall-related damage to properties, and content from insurance claims in the Netherlands, has been made available to SMARTeST by the insurance industry. This database has been used to identify explanatory factors of flood damage vulnerability in lowland areas and to establish relationships between rainfall characteristics and damage. The result of the insurance database analysis is the RAINS model that links rainfall characteristics to pluvial flood damage characteristics.

FVAT

FVAT was developed by ENPC and is a web-based system with free access dedicated to the reduction of the vulnerability of urban systems exposed to pluvial or fluvial floods. It extends the above mentioned damage assessment tools by enabling the consideration of non-quantifiable aspects (e.g. ecological, moral or legal) that can contribute to overall damage and vulnerability. The system operates as a check-list of different dimensions of vulnerability (63) that have to be taken into account according to the type of actors, land use, damages and moment of the crisis.

Basic barrier design model

The Basic Barrier design tool is a set of simple to use programs/ spreadsheets that enable the analysis and structural design of flood barriers. It was developed in order to enable consultants to design flood barriers specific to particular project requirements and derive the dimensions of the structural components. It is a basic flexible tool, which can be adapted by industry to fit particular needs, know-how, innovations etc. The spreadsheets of this design tool are available at the link: http://www.diontoumazis.com/Barrier.

The Basic Barrier design tool is a two-step program. In the first step it derives the design loading applied on the main and secondary structural elements. In the second step the minimum strength of each structural element is derived. The user must select one of the two types of loading cases, as follows:

a) River/ still-water floods and

b) Coastal/ wave overtopping floods.

The river/ still-water flood tool computes the loading on a flood barrier for the following load types:

- Hydrostatic loading
- Current loading
- Regular small amplitude wave loading
- Wind loading on barrier above still flood level
- Debris impact loading.

The coastal/ broken wave loading tool computes the loading on the flood barrier for the following:

- Broken wave loading
- Wind loading on barrier above the flood level.

The user selects the loading combinations and the tool derives the final pressure loading imposed on the vertical and the horizontal structural elements of the flood barrier. The results are presented in tables and graphs. The results of the 'Barrier Loading' for both tools are then transferred as input to the structural analysis tool. This tool enables the analysis of two types of elements, as follows:

a) Simply supported elements

b) Cantilever elements

The model derives the bending moment and shear force diagrams for the loading imposed by the user (as obtained in the loading tool).

Within the project, the potential for the integration or successive application of the single tools following the steps of decision making process has been explored. An example of the combined application of Multi-hydro and HOWAD-Prevent at the Heywood case study is given in the WP3 outputs.

The SMARTeST tools address the problem of flood resilient planning at different scales and level of details (property to river basin) and have been applied at different case study areas in Germany- Dresden (HOWAD-Prevent) and Hamburg (FLORETO-KALYPSO), the UK- Manchester (HOWAD-Prevent, Multi-hydro and FLORETO-KALYPSO), the Netherlands - Rotterdam (RAINS and HOWAD-Prevent), Greece- Athens (FLORETO-KALYPSO), Spain- Valencia (HOWAD-. Prevent), France. Villecresens and Bievre (VAT, Multi-hydro) and Cyprus- Paphos (FLORETO- and Basic Barrier).

Capacity building

The capacity building approach within the SMARTeST project aimed to strengthen the skills, competencies, and abilities of stakeholders to develop a better understanding of opportunities and constraints in flood risk modelling. The engagement of all concerned stakeholders involved in flood risk modelling issues encourages effective decision making in flood resilient planning for the built environment. It is evident that the acceptance of smart models and tools in flood risk management requires the availability of comprehensive and profound knowledge about their functionality, their outputs, their data requirements and their ability to facilitate the uptake of FRe technologies.

Capacity building on flood risk modelling addresses at least two different levels: first, the individual level and, second, the organisational level. At the individual level, capacity building typically covers knowledge and skills exchange, via training and other mechanisms such as learning-by-doing, participation and the exercise of ownership. At the organisational level capacity building involves strengthening performance and functioning capabilities through developing tools, guidelines and decision support systems.

Work Package 5: Integration

The objectives of this work package were as follows:

- To develop principles of integration of FRe technology and systems;
- To demonstrate the effect on strategic and local planning by integrating FRe systems within different urban environments and flood risk management frameworks.

This work package addressed the transfer of FRe technology to practice. It involved consideration of both the technical and decision support aspects of the project and those who may use FRe, most notably professionals and community members. Principles of integration were developed that separated out awareness-raising from acceptance (of the technologies) and action (seeing them implemented and used). The decision-making tools and technologies developed in other work packages were shown to a variety of stakeholders in order to assess how they could (or could not) bridge the gap between FRM and FRe technologies. It also considered how integration could be assisted with capacity-building activities at a local level and ascertained how likely it would be that they would adopt new practices.

Deliverable 5.1 developed ‘Principles of Integration’ based on a literature review and conceptual framing. This also drew on cross-national policy and practice review in the seven partner countries which discerned the main regulatory, administrative and societal experiences of flood risk management. Amongst the major findings, 5.1 established the following:

- The use of flood resilience technologies differs greatly across the EU because of regulatory, financial and cultural circumstances;
- The regularisation and harmonisation of technologies may encounter serious challenges because of societal factors;

From this, integration was identified to be an iterative *process* rather than a quantifiable outcome.

Table 3 categorises the barriers to FRe use, was developed in order to delineate the work done for deliverables 5.2 and 5.3.

	Awareness	Acceptance	Action
Technological			
Regulatory			
Institutional			
Cultural			

Economic			
Political			
Social			

Table 3: Analytical framework for FRe technology

Task 5.2 involved the development and coordination of participatory workshops amongst flood risk management professionals (“strategic”) and community (“local”) scales in each of the eight case study areas. Partners were provided with a template to guide these workshops. In addition, the technologies tested in Work Package 2 and the tools developed through Work Package 4 were shown to both local communities and flood risk management professionals. As a result of the workshops, it was possible to obtain an in-depth and comparative analysis of the constraining factors and opportunities in differing Member States that may influence the route to market of the technologies and tools. The main findings to emerge from this work were as follows:

- There was a general lack of awareness of smart and innovative FRe technologies and tools. This was markedly so for Greece, Cyprus and the Netherlands owing to a variety of economic and political circumstances.
- Even so, the lack of awareness indicated that the promotion of FRe technologies and tools and general education on their effectiveness and use (perhaps initially prompted by the insurance industry, national and EU-level institutions) could lead to a better understanding of how flood resilience fits into a holistic flood risk management strategy.
- In all case study countries, it was easy to discern mistrust in the efficacy and performance of new FRe technologies.
- Trust in FRe technology (at all stages such as installation, performance and maintenance) could be assisted through an internationally accepted certification process and the wider dissemination of good practice.
- Decision support tools and models were only of interest to the flood risk management professionals, with the general public preferring to rely on professional independent advice.

Task 5.3 provided an assessment report that drew on D5.1 and 5.2 in order to discern how the constraints on the integration of FRe could be overcome and how the opportunities could be pursued. This led to the development of a series of principles and practical initiatives to support FRe in policy and procedures based on the identification of good practice. These included:

- Standardised and adequate flood risk assessments to identify exactly where the FRe technologies can be most effective.
- Performance standards need to be communicated along with any residual risk of flooding.
- Manufacturers can work with stakeholders in the initial design phase in order to raise the acceptability of the products which should be bespoke.
- Governments, institutions and the insurance industry can support innovation and awareness-raising. For example, the UK government provided some funding for property-level FRe in order to lead to demonstration examples.
- The support of learning and action alliances (flood action groups) could increase the uptake of FRe through demonstration events as well as increasing its efficacy in maintenance.
- There is a need for independent and trusted agencies to support the use of FRe technologies.

The project developed six sequential steps that, combined, will help enable FRe to become an accepted part of a wider flood risk management strategies. The *Six Steps to Flood Resilience* developed by UNIMAN and BRE are depicted in figure 12 and described in greater detail in D5.3.

In order to understand how these might work in practice, and as an added output to WP5, the team worked with the UK National Support Group and other stakeholders from across the industry to hone these steps into good practice guidance reflecting the particular circumstances in England. Two documents were produced for different audiences: a concise version for property owners and an expanded version for FRM professionals, particularly in municipal-level authorities. Though the documents cannot be directly transferred to other countries, the principle of the 'six steps' can. Tailored documents could be prepared for other national or regional contexts based on the methodology described the six steps guides (policy review, literature review, surveys and interviews).

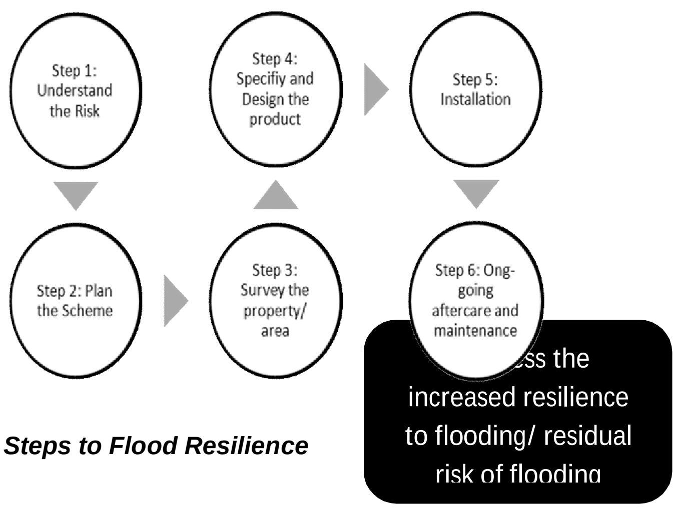


Figure 12: ***Six Steps to Flood Resilience***

Work Package 6: Dissemination

The objective of the work package on dissemination was:

- To disseminate the results of the research at local, national and international levels:
    - At local level, including strengthening target groups' participation, and to expand this to other local and regional authorities.
    - At a national level, including increase of knowledge on risk awareness, adaptation strategies and resilience. This will also encourage the use of innovative strategies and tools within national policies applied by the Ministries of Environment and Sustainable Planning, universities and other public and private national research institutes.
    - At the international level, a European wide competence alliance for FRe technology and systems

- Diffusion of knowledge via a networking of European institutes to exchange scientific methodologies and develop practical elements to cope with sustainable implementation of strategies and tools to other countries beyond project partners.

WP6 was dedicated to dissemination activities which was essential to the success of the project. Dissemination took place on the following levels:

- On a local level, including participation by target groups, local stakeholder groups and regional authorities;
- On a national level, including the increase of knowledge on risk awareness, adaptation strategies and tools within national policies applied by government agencies, planning authorities, universities and other public and private national research institutes and public bodies. Research results are disseminated at local level through national support groups and national workshops held in each member country.
- On an international level, diffusion of knowledge to European counties (including others than those participating) is via the networking of European institutes, the exchange of scientific methodologies and the development of practical elements to assist in the sustainable implementation of strategies and tools. International dimensions of dissemination are assured via the project website portal, the organisation of an international conference and the delivery of the published report/manual.

Summary of scientific and technical findings and foreground

Technologies

A range of FRe technologies exist and are currently being used to protect dwellings, buildings and infrastructure from the effects of flood. A database of FRe technologies has been developed by the project to bring together a searchable source that can be developed for use by clients around Europe and elsewhere (http://tech.floodresilience.eu/).

The existing standards, protocols and guidance documents related to FRe technologies are not sufficient to guarantee a reliable assessment of their performance. FRe products, although present in the market, are not fully trusted by home owners and/or community bodies. Indeed, many of the companies producing FRe technologies are claiming some performances without any third party evaluation.

The test results obtained (in total 25, including perimeter, building aperture, building and infrastructure technologies at five testing facilities) enabled the assessment of the functionalities of different FRe technologies and contributed to the improvement of their performance by detecting weaknesses. These results indicated the strong necessity for appropriate testing procedures of products prior to their commercial use. The tests and the development of appropriate standards have also been assessed as one of the main vehicles to improve the road to market of FRe.

A number of added value areas have been developed with respect to FRe technologies:

- The categorisation of the FRe technology and presentation to the end users in an understandable and easy accessible manner (website-(http://tech.floodresilience.eu/).
- Better understanding of the performance of different FRe technologies (each category has been represented in the tests).

- Draft Code of Practice and testing procedures developed based on the European experience and presented to standards makers, including CEN. It can further be used as a basis to develop regulation on flood resilient technologies.
- Draft Code of Practice and testing procedures have been developed tailored to different user groups (Code of practice mainly for practical workmanship issues in the construction area and the testing protocols for policy development (e.g. CEN)).
- Development of the testing procedures and the Code of Practice for each category of the FRe technology. This was as a result of the exchange with the manufacturers, policy makers, emergency services, practitioners (via NSGs.
- More transparency on the performance of different FRe technology through the testing procedures.
- Intensive collaboration with the manufacturers, using the test results to improve the performance of the product.

Research in the area of FRe technology has shown that the scope and type of the technology are widespread. The market in Europe and beyond (in particular North America) is potentially large, as demonstrated by market research, but there is substantial potential for further innovation in the technology.

Systems

The case studies approach has been used to address the project objectives with regards to FRe systems. The case studies, using an adaptation of the analysis framework to tasks, proved to be an efficient way to collect, organise and connect information in each particular context.

The research developed the new concept of a FRe system. Guidance on how to design a flood resilient system in a particular context was proposed. A key finding was that the barriers to developing FRe Systems in urban environments more often lies in organisation problems rather than in the deficiencies of FRe technology. Achieving the correct balance between organisational and technological aspects is important to FRe system development.

An added-value of the FRe systems research has been to confirm that the availability of tools (e.g. protection equipment, construction water-tightening processes, urban hydraulic simulation software, damages assessment methods), is not enough to ensure that the claimed goals of a flood management system (e.g. limit damages to persons, built assets and goods, anticipate the crisis management, recover “quickly” after flood) can be fulfilled. What is missing is a full comprehension of the scope and limits of these tools as well as a framework to use them in a consistent way through different spatial and time scales.

The added-value of the storytelling activity was to shift from qualitative to quantitative aspects, at least for some of the SMARTeST case studies. The use of simulation models helped to quantitatively assess the impact of FRe measures based on the implementation of FRe technologies and to better appreciate the advantages and drawbacks of projected solutions. This method can be easily reproduced using available simulation models allowing the integration of technologies.

Before SMARTeST, it was known that the design of a system that incorporates FRe technology requires a global approach. What is now better clarified is how ‘global’ the approach has to be in the context of flood. There is definitely no one-fits-for-all–solution. Local factors such as topography, type of flood, surface and underground built environment must obviously be taken into consideration.

Some other aspects are more difficult to define, such as the overlapping, interlocking of local and regional organisations.All these local factors must be mapped when designing a FRe system.

Insurance was a key factor with a great variety existing across insurance regimes in Europe to cover the consequences of flood. The question of the positive, neutral or negative role of insurance on the development of FRe systems must be explored further. Insurers are not only bound to the exposed population by contract, they can also play an important intermediary role between the population and institutional bodies.

Tools and models

The two flood damage assessment models - HOWAD–Prevent and FLORETO–Kalypso - have been extended. These improved models are now suitable to determine the impacts of FRe technologies concerning risk reduction. These efficient models have been tested in several European case studies to consider different local and national requirements as well as various flood types. High resolution modelling results indicate the impacts of different FRe technology implementation and provide an evidence base to identify the most effective resilient solutions. Both models have been integrated in the SMARTeST modelling toolkit that serves as an interface for all SMARTeST tools which support decision making processes. These also cover different scales of FRe technology application and different user groups such as professionals or the public. A web-based platform for the SMARTeST toolkit provides detailed information about each enhanced/developed model (see http://tech.floodresilience.eu).

Although no all-in-one model has been generated due to a broad range of complex constraints, selected models have been coupled for the description and analysis of different processes in flood risk assessment. The approach on linking methods for hydro-meteorological flood hazard determination (Multi-Hydro) with methods for flood vulnerability analysis (HOWAD–Prevent) may support decision making processes in future. For example, based on the results of coupled modelling, the potential of FRe technology implementation in the study area Heywood, Greater Manchester (UK) has been proved for different flood events.

It is evident that the acceptance of smart models and tools in flood risk management requires the availability of comprehensive and deep knowledge about their functionality, their outputs, their data requirements, and their ability to facilitate the uptake of FRe technologies. Hence, guidance has been compiled for stakeholders that cover these issues. A learning alliance, national workshops and conference presentations supported a knowledge transfer process from the current situation to FRe systems.

Integration

The research considered technical, social and decision-support aspects of FRe integration, not least from the perspective of those who may innovate, promote and use FRe. Local and strategic workshops in each project member's country (and associated with case study areas) resulted in a number of empirical observations, as follows:

- There was a general lack of awareness of FRe technologies and tools owing to different regulatory, financial and cultural circumstances.
- The lack of awareness of technologies suggests that the promotion of FRe, and general education on its effectiveness and use, could lead to greater coherency regarding the integration of such technologies into holistic flood risk management strategies. In all case study countries, there was a considerable degree of mistrust in the efficacy and performance of new products.

- Trust in all aspects connected to FRe (such as installation, performance and maintenance) could be assisted through an internationally accepted certification process and the broader dissemination of good practice.
- The development of harmonised standards may encounter serious challenges because of societal factors, including socio-economic status, property tenure, access and availability of insurance, the extent and type of state/ civil society support, and concerns regarding risk literacy.
- Decision support tools and models were primarily of interest to professionals or similar intermediaries, with the general public preferring to rely on professional independent advice.
- Integration was identified to be an iterative process rather than a quantifiable outcome.

A series of initiatives could be implemented to support FRe in policy and practice, including the following:

- More adequate and potentially standardised risk assessments to identify exactly where the FRe technologies can be most effective.
- Performance standards need to be more clearly communicated, along with any residual risk of flooding.
- Manufacturers should work more closely with stakeholders in the initial design phase of products to support acceptability of the products.
- Governments, institutions and the insurance industry to undertake supportive measures that lead to innovation within the FRe sector, and awareness raising with users.
- The support of learning and action alliances (e.g. local flood action groups) could increase the uptake of FRe technology through demonstration events as well as increasing its efficacy in maintenance.
- There is a need for independent and trusted agencies to support the use of FRe technologies.

Reflecting the iterative nature of FRe integration, and the divergence of flood risk management regimes across the partner countries, six sequential steps for FRe integration were developed. Two documents were produced: a concise version for property owners and an expanded version for FRM professionals, particularly in municipal-level authorities. These were based on the UK situation, but can be readily adapted for other countries. The documents were endorsed by a variety of key UK organizations. It is recommended that other EU countries use the guidance documents as a template to produce similar help for the FRe technology sector in their respective countries, and that the EU consider adopting these on a European scale.

Integration concerned the understanding of the 'route to market' of FRe technologies, particularly in terms of catalysts and barriers and the social aspects of technology integration. The decision-making tools and technologies developed in other work were presented to a variety of stakeholders in order to assess how they could (or perhaps could not) meet the complex requirements of flood risk management.

This research into FRe integration has assessed the strengths, weaknesses, opportunities and threats pertaining to FRe. It further considered how integration could be assisted with capacity-building activities at local level and ascertained how likely it would be that they would adopt new practices. By consequence, the research proposes recommendations that are centred upon three distinct though related stages of the road to market, from product innovation, development marketing, and beyond, to encompass issues regarding the installation, maintenance and critical review of technology, system and tool functionality.

1.4 Potential Impact, dissemination and exploitation of results

The SMARTeST project has had substantial dissemination activity throughout the course of the project particularly through engagement with government, local authorities and industry. Certain activities had been planned at the outset of the project and were successful, whilst other opportunities were taken for wide dissemination. The approach to impact and dissemination has allowed the project partners to reach a wide audience and targeted groups.

Impact

Penetration of FRe technology into European markets

The partners in the SMARTeST project covered seven countries and it was evident that there were differences in the penetration of FRe technology into the markets of each. In the UK, France and Germany FRe technology of various types has been present for a number of years, with a number of companies creating an indigenous industry. However, these companies are typically SMEs and the overall turnover and value of the industry is limited. In the Netherlands there is also some development and supply of FRe technology, but there is a public expectation that major flood defence infrastructure is all that is needed. In Spain, Greece and Cyprus there was little or no indigenous industry and only a few projects seemed to have taken place.

In Cyprus the development of the Basic Barrier through the SMARTeST Project represents the first known product of this type to be developed in that country. The basic barrier opens opportunity for impact on the road to market, especially to many coastal floods in those towns that floods have a damaging effect on property and the economy.

In Spain several industry partners have worked with UPM to assess how a range of coatings and sealants can contribute to flood resilient buildings that are better able to resist water ingress. These include some multi-national organisations that are able to develop not only the product, but also have greater impact in the route to market. The situation is, however, unusual for the FRe technology suppliers as many are SME companies.

In the UK, a comparatively developed market, there was clear evidence that manufacturers and suppliers of FRe technology were seeking to develop innovative technologies that addressed the concerns of property owners, government and insurers. Such technologies may be described as ‘fit and forget’, or automatic types. Examples of such innovation have been given above.

The results of the SMARTeST project as set out in deliverables show that FRe technology not only has potential to be part of flood management across Europe, but that its implementation through informed decision making and understanding of flood risk can help to create flood resilient systems that function properly. FRe technology on its own is not a panacea for flood risk management. However, when combined with an appropriate assessment and creation of a FRe system, it has the potential to be used to protect many millions of homes across Europe. No official statistics exist on the number of homes that could be protected using FRe technology, but the Application and Implementation Group (high level advisory group to the project) has estimated that it may be up to 50 million. The number of items of infrastructure that could be protected is also substantial.

Innovation

The SMARTeST project created an environment amongst National Support Group members in which innovation was encouraged. As the majority of the innovation in this sector will come from the SME manufacturers, suppliers and designers, it has been important for SMARTeST to have worked with relevant companies through the National Support Groups. Whilst improvements in existing products or opportunities for new technologies can be readily identified there is an inability for SMEs to support the research and development, and indeed the marketing required.

The extent of the flooding problem throughout Europe is immense and the place of FRe technology has been set out in the SMARTeST outputs. Yet there is insufficient penetration of the technology to protect the built environment and infrastructure. Encouragement has been given to SMEs within the SMARTeST project through the national support groups.

The SMARTeST project has had substantial links with SMEs. Clearly growth in this sector does not just require regulation, but importantly it is about supporting innovation. Promoting innovation is identified as essential practice amongst SMEs manufacturers.

One of the three main objectives of the EU's Climate Adaptation Strategy is 'climate proofing', particularly of infrastructure. Moreover, insurance is intimately involved. SMARTeST has shown that there are possibilities for innovative FRe technologies that are able to meet the challenge of making people and assets more resilient to floods. However, there are still opportunities to ensure that this is adequately reflected in the insurance industry and taken into account.

Innovative technologies will provide enhanced flood resilience performance. This innovation can be measured against the following criteria:

- Control – enhanced control mechanisms to provide greater levels of in-use performance and operation.
- Warning – provides increased warning of rising flood waters or the likelihood of flood events occurring.
- Automation – provides automatic deployment of FRe technology and minimises or removes the need for human intervention.
- Reaction to flood – provides an enhanced performance in reaction to predicted or current flood events.
- Ease of deployment – provides an enhanced system of deployment through practical implementation or automation.
- Durability – provides enhanced levels of durability of materials and components used within FRe technologies.
- Performance – provides enhanced levels of flood resilience through the design of new technologies and use of innovative materials. Improved environmental performance may be viewed as a performance attribute. The properties of materials used in flood resilience technology is also a performance aspect (e.g. for waterproofing materials the cure time might be important).

Standards

The development of the market must also be accompanied by the introduction of harmonised standards that assess performance, that relates to practice, and sets out good practice codes for implementation. At present there has been limited development of national standards, with what currently exists being used to support national certification schemes. The SMARTeST project has set out information for standards makers at the EU level to enable preparation of appropriate test procedures and codes of practice.

SMARTeST has examined both FRe technology and also the standards currently available. Standards in this area directly relate to the Construction Products Regulations and CE marking of products, with respect to the following (http://ec.europa.eu/enterprise/sectors/construction/legislation/):

> *"CE marking enables a product to be placed legally on the market in any Member State. However, as explained below, this does not necessarily mean that the product will be suitable for all end uses in all Member States.*
>
> *CE marking indicates that a product is consistent with its Declaration of Performance (DoP) as made by the manufacturer. The declaration varies according to the particular harmonised technical specification covering the product. In general there are three ways in which information can be presented for each relevant characteristic:*
>
> > *confirmation of achievement of a minimum performance or threshold. This could be by satisfying a Pass/Fail criterion or simply by being eligible to be in the standard.*
> >
> > *the actual performance (a declared value)*
> >
> > *a particular class of performance reached.*
>
> *By making a DoP the manufacturer, importer or distributor is assuming legal responsibility for the conformity of the construction product with its declared performance."*

SMARTeST has highlighted that the testing of perimeter barriers and aperture barriers best fits into the development of performance classes. The performance class primarily refers to the leakage rate under specific conditions of test, i.e. hydrostatic and hydrodynamic actions. There is a strong preference to test under conditions that reflect those likely to be encountered in practice by the technology. If property level protection is involved through the use of aperture barriers then there is no need for impact to be considered, but this is an essential element of assessing perimeter barriers.

The project partners identified that a weakness in current standards was that they focussed upon test methods rather than codes of practice. The result is that the guidance offered sets out a template for a technical code of practice. The project has also seen a template being developed for member countries to adopt guidance for individual property owners and professionals (particularly in municipalities).

The audience identified for the guidance was primarily those involved in the areas of standards. The guidance will also be of use to those involved in the production of FRe technology. There are two groups of users amongst the technology providers. The first are those involved in manufacture and supply of technologies that have the sole purpose of flood resilience and the second those producing construction products that could have innovative uses for flood resilience.

The research identified that there was a focus within the area on test standards related to aperture or perimeter types of barriers, with an absence of information related to either testing flood resilient materials, or indeed to codes of practice directed at designers and contractors. The SMARTeST project has addressed both of these issues through laboratory development and case studies. As a result the guidance comprehensively covers these issues.

Centred on the creation of a Code of Practice (CP) of flood resilience technologies, the guidance sets out good practice and is typically in relation to practical workmanship issues in the construction area. It defined recommendation on three levels, as follows:

- Pre-flood;
  - Survey phases of the flood risk and the site to properly assess the flood resilient requirements;
  - Design phases mainly based on surveys and quality control;
  - Construction phases to properly and safely construct permanently-installed component;

- During flood;
    - Operational procedures to properly and timely install the flood resilient products;
- Post flood;
    - Maintenance, which is a key issue for features that are likely to be rarely installed (potentially several years without being used);
    - End of life of the product.

Performance assessment is primarily based on laboratory based testing of technologies. Review of existing standards and experiences from the testing phase carried out within the SMARTeST project are the basis of these guidance documents. Performance assessment of the three categories building apertures, building technologies and perimeter technologies are further addressed in this report.

FRe systems

The Floods Directive (2007/60/EC) takes a systems approach to flooding by requiring Member States to assess risk in their territory and to take measures to ensure that there is an understanding of the nature of flood and the measures that can be used for mitigation. It also links the system understanding to the protection of the end use, as follows:

> "(Clause 3) It is feasible and desirable to reduce the risk of adverse consequences, especially for human health and life, the environment, cultural heritage, economic activity and infrastructure associated with floods. However, measures to reduce these risks should, as far as possible, be coordinated throughout a river basin if they are to be effective."

FRe technology needs to be part of a co-ordinated regime within a FRe system that can help to achieve the following:

> "(Clause 14) Flood risk management plans should focus on prevention, protection and preparedness. With a view to giving rivers more space, they should consider where possible the maintenance and/or restoration of floodplains, as well as measures to prevent and reduce damage to human health, the environment, cultural heritage and economic activity. The elements of flood risk management plans should be periodically reviewed and if necessary updated, taking into account the likely impacts of climate change on the occurrence of floods."

An understanding of how flood risk management can result in FRe systems is important to the ability of Europe to adapt to climate change. The project has shown through a number of case studies in member states that there is no one solution to link FRe technology to the protection of buildings and infrastructure. To assess the benefits (i.e. FRe tools) of FRe technology in any urban context must be associated to a thorough understanding of how the FRe system works in that specific location. For example the availability of flood maps can help decision makers to identify buildings and infrastructure at risk. However, unless the area is covered by flood warning / alert systems then certain technologies may not be employed in time to protect the asset. SMARTeST has encouraged thinking towards automated technologies of a fit and forget nature and these lend themselves to locations where it is not possible to operate an effective warning system.

The creation of FRe systems that incorporate appropriate types and uses of innovative FRe technology would be a substantial step towards the achievement of the EU policy of 'living with floods' as set out by the Directive. SMARTeST has highlighted two possible ways to think about FReS, and to answer the above questions, namely ‘pragmatic’ and ‘systemic’ approaches. The approach which consists of acting at a limited scale with little (if any) consideration for the consequences of decisions is named ‘pragmatic’ approach. It may be initiated by individuals but also by groups of victims or at the community level. The approach which consists of acting at several spatial scales with a global view on the wider area (e.g. water basin) is named ‘systemic’ approach.

The analysis of case studies confirmed that reducing vulnerability is a critical mile-stone on the way to resilience. Measures have been widely implemented in all case studies areas as well as many other flood-prone areas. The steps that should be taken are as follows:

- define objectives, i.e. priorities in terms of vulnerability reduction;
- select the most promising measures;
- organise/connect these measures (e.g. create a system);
- assess the capacity of the system to fulfil the expected objectives (e.g. by using assessment methods such as FMECA);
- define rules for efficient behaviour of the system (organisation, maintenance).

The case studies demonstrated that real processes cannot be so straightforward. Many intermediate steps and feedbacks have to be taken into consideration to reach the ultimate goal: a ‘resilient’ system. A guide and manual for the development of flood resilience in the built environment has been created from the results of Work Package 3. The case study analysis has ascertained that the availability of modelling tools is not enough to ensure that the anticipated aims of a flood management system (e.g. to limit damages to persons, built assets and goods) can be fulfilled.

The SMARTeST project contributed to the identification, analysis, assessment and development of FRe technology. Flood management systems define measures that aim to:

- limit damages to persons, built assets and goods;
- anticipate the crisis management;
- recover “quickly” after flood.

FRe tools and implementation

Adaptation to climate change, including the increased risk of flooding, requires a range of tools to be available to decision makers in member states and in local authorities. The SMARTeST project has investigated and developed a number of tools and decision support models that can be used to determine the cost-benefit of FRe technology, assess the extent of flooding and to design a universally applicable barrier. The models are linked in a Decision Support Platform, which is now available to the public on the project website (www.floodresilience.eu). SMARTeST workshops demonstrated the limitations of existing tools and models and there is generally a need for expert input. The FRe tools will have greatest impact on those investing in FRe technology. The costs of installation of perimeter barriers can be into millions of Euros, so tools to help designers and contractors are positive. Where there is a single property being protected, the investment is in several thousand Euros, with FRe technology aperture barriers or building technology then tools such as FLORETO-KALYPSO will be more proportionate.

The tools and models of the SMARTeST project link to the Floods Directive and the EU’s climate change adaptation strategy. They allow decision makers to be better informed on risk and impact, whilst determining benefits from using FRe technology. As well as developing a range of models, decision makers are seeking reliable information on the performance of technologies and their limitations. SMARTeST has addressed this issue by creating a database of FRe technology.

The following aspects of the Floods Directive are relevant to SMARTeST tools and implementation:

> "(Clause 11) Flood risks in certain areas within the Community could be considered not to be significant, for example in thinly populated or unpopulated areas or in areas with limited economic assets or ecological value. In each river basin district or unit of management the flood risks and need for further action — such as the evaluation of flood mitigation potential — should be assessed."

Flood damage models can show at individual property level and spatial scale the potential benefits of protecting buildings using FRe technology. This is particularly applicable where there are no major flood defences or they are not effectively maintained. There is, therefore, substantial potential for FRe technology to protect property and infrastructure where the cost-benefit of major defence schemes does not provide a substantial case for support.

> "(Clause 13) With a view to avoiding and reducing the adverse impacts of floods in the area concerned it is appropriate to provide for flood risk management plans. The causes and consequences of flood events vary across the countries and regions of the Community. Flood risk management plans (FRMPs) should therefore take into account the particular characteristics of the areas they cover and provide for tailored solutions according to the needs and priorities of those areas, whilst ensuring relevant coordination within river basin districts and promoting the achievement of environmental objectives laid down in Community legislation. In particular, Member States should refrain from taking measures or engaging in actions which significantly increase the risk of flooding in other Member States, unless these measures have been coordinated and an agreed solution has been found among the Member States concerned."

The tailored solutions in FRMPs could incorporate FRe technology, supported by implementation tools and leading to the creation of FRe systems. FRe technology can contribute to flood resilience in support of other forms of protecting communities (e.g. large scale flood defences) or be the main means of protection, i.e. in areas where it is not feasible to use FRe technology. To effectively use FRe technology within FRMPs necessitates the need for better dissemination of information and availability of tools for decision making.

> "(Clause 18) Member States should base their assessments, maps and plans on appropriate "best practice" and "best available technologies" not entailing excessive costs in the field of flood risk management."

There is a substantial connection between affordability, best practice and emergent FRe technologies that has been examined within the SMARTeST project. FRe technology can demonstrate substantial benefits against the costs of its installation providing that the FRe system is sufficiently robust to allow effective use.

FRe technology also offers potential solutions to the protection of water quality as required by the Water Framework Directive. Further work is required to look at FRE systems that prevent flood water spreading across contaminated areas and then discharging to water courses.

The design tool and the prototype for the basic flood barrier, developed within SMARTeST, have a potential impact in the construction/ manufacturing industry:

- Designers may enter the growing market of flood barrier technology and use the design tool for the basic barrier and design their own flood barriers to satisfy the needs of the particular project requirements;

- Manufacturers may fabricate flood barriers in accordance with the designs produced by designers;

- Contractors may specialise in the installation of purpose designed and fabricated flood barriers;

- Individual components of the basic flood barrier, as well as additional components, provide scope for innovation and improvement of the basic flood barrier. There is scope for more durable, robust and light materials, scope for automatic opening and closing of the barrier (operated manually in the basic barrier), scope for more environmentally friendly finishes/ appearance and numerous other innovations.

There is scope for the establishment of new enterprises which provide the combined services of design, fabrication, installation and commissioning of flood barriers. Such a spin-off is under development in Cyprus. This spin-off enterprise is developing the concept of providing a one-stop-service (similar to the lift industry), namely, the user specifies the operational requirements, the aesthetic parameters, budget range etc., and one company undertakes the responsibility of designing the product, procuring components, bringing together all the trades, commissioning and delivering one product fit for purpose.

This innovation has the socio-economic impact of saving significant amounts by reducing/ eliminating flood damage and at the same time supporting various trades, such as designers, contractors, steel workers, wood workers and builders. The design tool of the basic barrier is available on the project's web page. The prototype was exhibited at the SMARTeST international conference (Athens, September 2012). There are also various examples showing potential applications of the basic flood barrier.

The main contribution of the SMARTeST toolkit beyond the state of the art is in terms of better consideration of FRe technology and systems and their characteristics in the decision making process by: (1) enabling consideration of FRe elements in the hydrodynamic modelling platforms and assessment of their efficiency to mitigate flood risk; and by (2) preparing the basis for a multi-criteria analysis on FRe technology based on their main characteristics assessed during the performance tests. Such an analysis makes use of the repository of different FRe technology types and products stored in the SMARTeST Products and Technology platform (http://tech.floodresilience.eu/flood-resilience-measures) and the associated test results. The tools show a considerable potential for future applications and acceptance by the users in the addressed case study areas. Potential improvements are mostly related to the: (1) User interface design- user friendliness; (2) Time effort-Intensive pre-processing times (e.g. HOWAD-PREVENT), long processing especially for large models (e.g. Multi hydro, FLORETO-KALYPSO); (3) Integration of the models in a calculation chain to improve the efficiency of the modelling procedure by enabling automatic data and results transfer between the models. The SMARTeST Toolkit is made available to public users at the link http://www.tech.floodresilience.eu/fre-models-platform/smartest-fre-models.

If there is to be substantial benefit, it is obviously necessary to increase expertise at least to the following target groups to achieve a resilient culture:

- Professionals in spatial planning and architects;

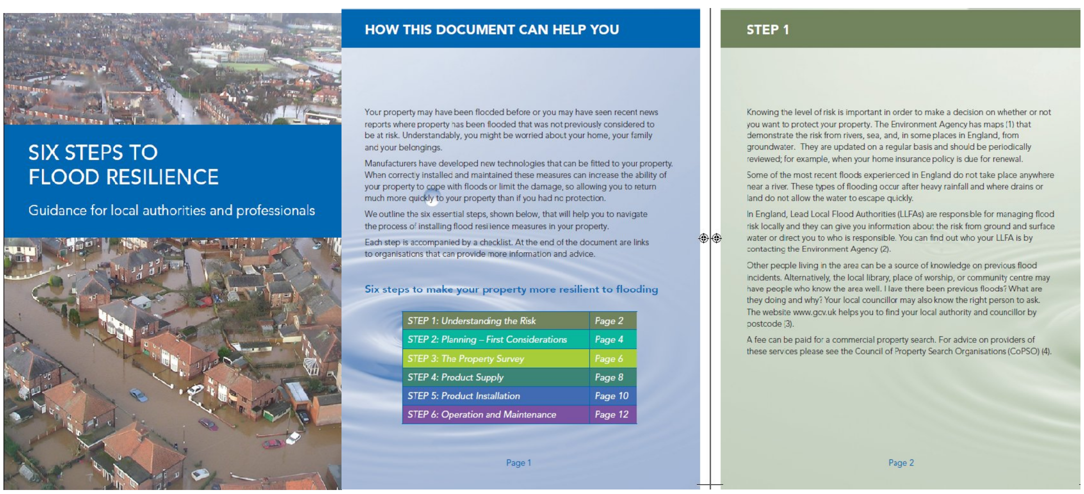
- Administration (local authorities);

- Civil engineers (R&D, consultants, practitioners);

- Insurance industry;
- Private users (homeowners, dwellers).

Crucially, WP5 provided a robust analysis of what might hinder the integration of FRe technologies into Flood Risk Management practice (or, its 'route to market') as well as recommendations as to how these might be overcome. FRe technology procurers and manufacturers can use these to underpin future technological innovation. WP5 also addressed the societal aspects of FRe technologies: that is, the likelihood of uptake and the need for periodic reassessments of the flood risk, the importance of maintenance regimes, and also events in which emergency plans are tested regularly through practice events. Future research could analyse how community groups can best support the integration of FRe into a wider flood risk management strategy.

The guidance documents, Six Steps to FRe technology, are already having an impact in the UK to instil trust in the installation and practical maintenance of technologies (Figure 13). The team worked alongside stakeholders to construct, design and promote the guidance and, as a result, they were endorsed by a variety of key UK organisations such as insurers, government and flood community forums.


SIX STEPS TO
FLOOD RESILIENCE
Guidance for local authorities and professionals

HOW THIS DOCUMENT CAN HELP YOU

Your property may have been flooded before or you may have seen recent news reports where property has been flooded that was not previously considered to be at risk. Understandably, you might be worried about your home, your family and your belongings.

Manufacturers have developed new technologies that can be fitted to your property. When correctly installed and maintained these measures can increase the ability of your property to cope with floods or limit the damage, so allowing you to return much more quickly to your property than if you had no protection.

We outline the six essential steps, shown below, that will help you to navigate the process of installing flood resilience measures in your property.

Each step is accompanied by a checklist. At the end of the document are links to organisations that can provide more information and advice.

Six steps to make your property more resilient to flooding

STEP 1: Understanding the Risk	Page 2
STEP 2: Planning – First Considerations	Page 4
STEP 3: The Property Survey	Page 6
STEP 4: Product Supply	Page 8
STEP 5: Product Installation	Page 10
STEP 6: Operation and Maintenance	Page 12

Page 1

STEP 1

Knowing the level of risk is important in order to make a decision on whether or not you want to protect your property. The Environment Agency has maps (1) that demonstrate the risk from rivers, sea, and, in some places in England, from groundwater. They are updated on a regular basis and should be periodically reviewed; for example, when your home insurance policy is due for renewal.

Some of the most recent floods experienced in England do not take place anywhere near a river. These types of flooding occur after heavy rainfall and where drains or land do not allow the water to escape quickly.

In England, Lead Local Flood Authorities (LLFAs) are responsible for managing flood risk locally and they can give you information about the risk from ground and surface water or direct you to who is responsible. You can find out who your LLFA is by contacting the Environment Agency (2).

Other people living in the area can be a source of knowledge on previous flood incidents. Alternatively, the local library, place of worship, or community centre may have people who know the area well. Have there been previous floods? What are they doing and why? Your local councillor may also know the right person to ask. The website www.gov.uk helps you to find your local authority and councillor by postcode (3).

A fee can be paid for a commercial property search. For advice on providers of these services please see the Council of Property Search Organisations (CoPSO) (4).

Page 2

Figure 13: Sample pages from *Six Steps to Flood Resilience* documents

Dissemination

National Support Groups (NSGs) were set up in the seven national countries represented in SMARTeST. The NSG's focus was on local context and dissemination. Where a country was represented by more than one SMARTeST consortium partner (UK, Germany and France), partners collaborated in the context of organisation of meetings, while one partner acted as the co-ordinator of the NSG.

The NSG's members numbered more than 140 organisations and individuals. The membership included a mix of industrial and other stakeholders including representatives from local governments, national governments, industry (technology providers and building companies), environment agencies, insurers and local flood forums. Details of the NSG membership for each country are included on the project website.

The NSGs led to the creation of an industrial awareness forum, 'the competence alliance for FRe technology and systems'. A campaign was also implemented with the Application and Implementation Group to inform decision makers, planners designers, developers and other building professionals on developments in innovative FRe technology.

The website (www.floodresilience.eu) has had more than 152,000 hits. It is expected that the number of hits will continue beyond the end of the project. The volume and geographical dispersion of hits indicate that the project website is highly ranked with regards to flood resilience and FRe technologies. The website has already achieved its initial goals in terms of national and international dissemination of project results.

National Workshops

As the objectives of the project dissemination activities was focused on disseminating the results of the research at a local, national and international level a national dissemination event was held in each partner country. This included demonstrations of innovative flood resilience technologies and presentation of project results. The national events were held during the final year of the SMARTeST project to maximise the benefits from the research results and outcomes.

National events were held in the language of the country involved, the most logical option with regards to dissemination at a national level. The national events aimed to engage industry and other stakeholders. More than 200 participants attended the national workshop events.

Full details of these events were recorded within a project report (Deliverable D6.4). The aim was to identify the response to the project activities, results and outcomes. It was also an opportunity to gain knowledge related to flooding and flood resilience technologies from other professionals and industry partners.

International Conference

An international conference on innovative FRe technology was held during the project. The SMARTeST International Conference and Exhibition, 'Implementing Flood Resilience', took place on 27th – 28th September 2012, in Athens, Greece. The book of abstracts is available on the project website.

The conference addressed innovative flood resilience technologies and systems, testing standards, damage modelling, decision support mechanisms and discussions of necessary future actions. It was compiled of a total of 34 oral presentations, 12 poster presentations and eight key note lectures. Seven themes were addressed during the conference, linked to the imminent strands of the SMARTeST project. Ninety people attended the conference and exhibition. The conference ran in parallel to the SMARTeST International Exhibition, dedicated to FRe technologies and systems for the built environment. Eleven exhibitors from the United Kingdom, Greece, Cyprus, the Netherlands, Norway, Germany, Belgium and Canada took part in the exhibition which was well received by all participants and visitors.

The location of the conference was deliberately within a country with almost no penetration of FRe technology at that time. The conference and exhibition allowed learning around Europe and opened up potential for manufacturers to sell into new markets and to develop new FRe technology offerings.

SMARTeST research report on FRe Technology

The research report gave a narrative outline of the SMARTeST project, with a description of progress of the state-of-the-art of FRe technology during the project's inception, to the present, noting all key activities and results from the 42 month project lifetime to future goals and aspirations in terms of research.

A SMARTeST Policy Statement has been prepared and placed onto the project website. The policy statement addresses flood related directives and legislation, but it is also relevant to innovation and competitiveness of industry in Europe.

Additional Dissemination Activities

Although Work Package 6 was originally set out with a clear set of aims and deliverables, project partners were also encouraged to communicate the results of the SMARTeST project at any and all given opportunities, relevant to the nature and goals of the project. As such, a vast array of additional dissemination activities has been recorded by all project partners including published articles, oral presentations at conferences, press releases and interviews, workshops and meetings with stakeholders.

SMARTeST was represented with publications in European Goelogical Union 2012 & 2013, Vienna; Urban Drainage Modelling 2012, Belgrade; Hydro-informatics, Hamburg; Water and the City Conference, Delft; FLOODrisk 2012; COST ES0901 FloodFreq Conference 2012, Volos; Symposium 'Flooding and Insurance' 2012, Netherlands; SCUPAD (Salzburg Conference on Urban Planning and Development); ISC2011, Poland; EGU Leonardo Conference Series and CEST 2011, Rhodes; the ICFR Conference, Exeter, UK, 2013, as well as many other national and international conferences and symposia.

Papers deriving from SMARTeST research were published in HESSD (Hydrology and Earth System Sciences), Planning Theory & Practice (special edition on flooding) and Mission Risques Naturels.

Furthermore, the project was represented in national flood relevant events such as at; Lancaster Environment Institute, Climate Change Adaptation workshops, FloodProbe workshops, Climate Change and Urban Governance Master Class, Birmingham Planning Conference, Climate Proof Cities workshops, Heywood site visits, Defra (Department for Environment, Food and Rural Affairs) workshops, ACUF & CEPRI Workshops, AGMA Flood Resilience Officers Group Meeting (UK), Newzeye conference, property claims conference and the Parnassus Project Conference in the UK.

Articles have been published in national newspapers such as El Mundo (Spain), Levante (Spain), Mira Valencia (Spain), VLCiudad (Spain), Iasprovincias.es (Spain), El Periodico (Spain), Kerdos, Eleftheros Tipos (Greece). Television broadcasts have also been incorporated in the project dissemination activities, Canal Nou (Channel 9), Spain; Skai TV (Econews), Greece; Main News programme, Cyprus.