UrbanFlood

Functionality & Architecture of Internet Based EWS and EWS Hosting Platforms

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SUMMARY

This deliverable (2.2) of the FP7 UrbanFlood project describes from a stakeholder (user) point of view, the architecture and functionality of the UrbanFlood Early Warning System (EWS). A questionnaire (described in deliverable 2.1) distributed amongst professionals working in the area of flood safety was one of the inputs of this deliverable. Another source were the EWS specifications of the domain experts of the UrbanFlood project.

As the UrbanFlood project validates the EWS in the context of flooding, the document describes the architecture and functionality of the EWS as, for example, an ICT expert of a dike owner would understand it. This yields a readable and understandable specification of the UrbanFlood EWS. According to the DoW, the development strategy of UrbanFlood is “agile” meaning that in an iterative process the EWS will be improved. A detailed specification is not required; details are left to the developers who will turn feedback from the stakeholders (e.g. the UrbanFlood advisory board) into a change of the EWS.

This deliverable shows that two technical components of the EWS are crucial for the sophistication that an advanced EWS needs to have. One of them is virtualization technology in which computer programs run on an emulated computer (e.g. PC). Virtualisation technology is available from many sources and is the basis of cloud computing services which UrbanFlood extensively uses. Dedicatedly developed, and the basis of all innovations in Urbanflood is the Common Information Space (CIS) technology. UrbanFlood builds the CIS with off the shelf components. The resulting CIS technology is used many times to construct the final EWS platform.

Groningen, 29 April 2010

Acronyms and Abbreviations

app	specialized plug in
CYF	Cyfronet AGH, Cracow, Poland – UrbanFlood partner
CIS	Common Information Space
DoW	Description of Work, annex to the UrbanFlood Grant Agreement
ESB	Enterprise Service Bus
EWS	Early Warning System
GEOSS	Global Earth Observing System of Systems
HRW	HR Wallingford
ICT	Information and Communication Technology
IJkdijk	IJkdijk Foundation, dike testing site in Groningen, the Netherlands
LiveDijk	Test location for sensor technologies at Eemshaven, Groningen, the Netherlands
ODP	Open Distributed Processing
SIE	Siemens, Germany. OOO Siemens in Russia is an UrbanFlood project partner
STOWA	Dutch acronym for the Foundation for Applied Water Research, Utrecht, The Netherlands – UrbanFlood Partner
TNO	TNO Dutch organisation for Applied Research, The Netherlands – UrbanFlood lead partner
UK	United Kingdom
UvA	University of Amsterdam
WP	Work Package (there are 7 work packages in UrbanFlood)

1 Introduction

1.1 UrbanFlood

UrbanFlood develops an online early warning system (EWS) technology for climate induced disasters in urban areas with support for real time emergency management and routine asset management. The technology is widely applicable; however UrbanFlood validates it for the case of flood risk management in urban areas. UrbanFlood is partly funded by the EU 7th framework program. Started in December 2009, the project runs for 3 years. Partners of UrbanFlood are TNO Information and Communication Technology, the University of Amsterdam and STOWA (Dutch acronym for the Foundation for Applied Water Research) from the Netherlands; HR Wallingford in the UK, ACC Cyfronet AGH in Poland and OOO Siemens in Russia.

1.2 About deliverable 2.2

This document is written under Work Package 2 (WP2): Stakeholder requirements. The objective of this work package as stated in the Description of Work (DoW) is to: *Identify typical capabilities, requirements and usage scenarios of the early warning system (EWS) from experts, authorities and citizens. Evaluate the UrbanFlood results.*

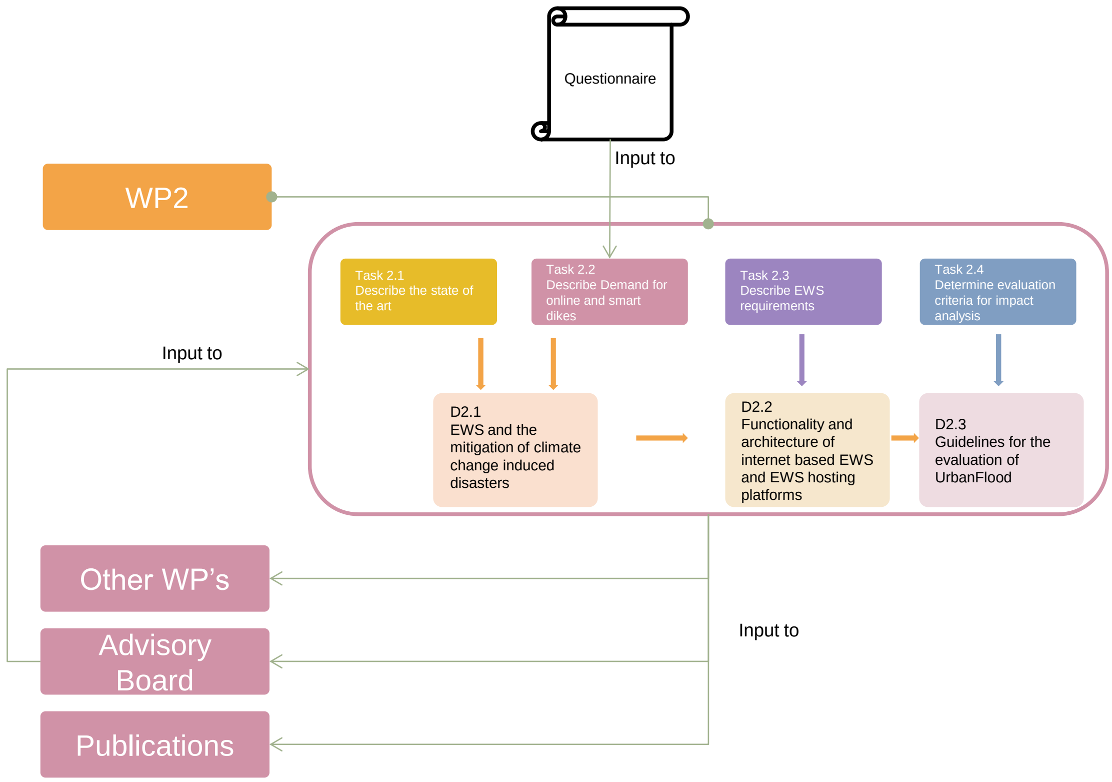

Figure 1 The objective of WP 2 is to set the stage for the UrbanFlood project: describe the state of the art, the needs of professionals that might use a EWS, the specifications of the EWS from subject matter experts of UrbanFlood, and the guidelines for the evaluation. Feedback and experiences might lead to an update, capturing and presenting new knowledge in new versions of the documents.

This report is the outcome of Task 2.3. This task produces a specification, from a usage and benefit point of view, for the EWS platform. Much of the results of this task are based on the expertises of subject matter experts from the UrbanFlood consortium. The results of Task 2.1 and Task 2.2 (and described in deliverable 2.1) are also input. These tasks deployed a questionnaire and interviews with professionals in the field of flood safety to find out their opinions, expectations and concerns in the deployment of EWS for flooding.

The description of an ICT architecture and its purposes (functions) presented in this document is in line with the “enterprise viewpoint” of the Open Distributed Processing (ODP) [1] standard. The viewpoint envisages “architecture” as a model that stakeholders (not necessarily ICT experts) deploy to understand how a distributed system works and “functionality” as a description of what the system does for them.

In Chapter 2 expert insights and the results of interviews are turned into an “enterprise viewpoint” specification of the UrbanFloods EWS. Chapter 3 analyses on which commercial basis the exploitation of UrbanFloods EWS can be successful and how the technology of the EWS should support that. In Chapter 4 the economical basis of the EWS is extended. Chapter 5 presents, from an enterprise viewpoint, the architecture of the UrbanFlood EWS. Engineers turn this architecture and functionality either directly into a (ICT) product, as is typical for the “agile development process”[2], or into more technical specifications, made from other ODP viewpoints[3]. Conclusions are presented in Chapter 6. One of them, which is of course also a starting point of this document, is that

The architecture described in this deliverable meets the generic target outcome of the FP7, 6.4a work programme description:

<u>FP7, 6.4a: ICT for a better adaptation to climate change</u>

Easy-to-use, web-based systems for better preparedness, decision support and mitigation of climate change impact on population, utilities and infrastructures. Special emphasis is on scenario-based prediction, damage assessment, planning and training, 3D/4D modelling, simulation and visualization, as well as sensor networks. Integrated solutions shall be validated in the urban context including for natural disasters, taking full advantage of recent advances in miniaturization of sensors, wireless communications and increased computation power and data storage capacity.

[1] en.wikipedia.org/wiki/RM-ODP

[2] en.wikipedia.org/wiki/Agile_software_development

[3] Other viewpoints are also formalized by ODP. These describe how a system should be constructed (“engineering viewpoint”) and what the logic of interworking components is (“logical viewpoint”) and which data formats and other information structures are deployed (“information viewpoint”). Technical designs of the EWS platform, based on this deliverable are reported in other deliverables.

2 Early Warning System for climate induced disasters

The Intergovernmental Panel on Climate Change writes in its IPCC Fourth Assessment Report that it expects “that climate change will increase the severity and frequency of weather-related natural hazards such as storms, high rainfalls, floods, droughts and heat-waves”. The United Nations organisation ISDR (International Strategy for Disaster Reduction) remarks that extreme weather “coupled with sea level rise will lead to more disasters in the future – unless prompt action is taken”. Over the period 1995-2004, a total of 2,500 million people were affected by disasters, with losses of 890,000 dead and US$ 570 billion costs. Most disasters (75%) are related to weather extremes (ISDR disaster statistics). “Of particular concern is the fact that disasters have been increasing over recent decades, mainly owing to increased populations in hazard-prone locations, unplanned settlements and environmental degradation, but evidence is also mounting that climate change is a factor too, for example in more intense hurricanes, higher rainfall intensities and heat-waves.”

To be better prepared for these types of disasters the UrbanFlood project will provide an online Early Warning Services (EWS) framework that:

- is a generic platform that can be equipped with modules that address specific environmental issues such as dike stability and forest fires (UrbanFlood develops only dike safety related modules);
- includes an online common information space (CIS), allowing the UrbanFlood EWS to interwork with other EWSs as well as to provide services, via the internet, to (web based) applications;
- uses Internet based cloud computing and super computing services to meet higher than average computing demands;
- provides an online visualization, decision support, and public information framework;
- is validated in the context of flooding in the urban areas of London, Amsterdam and St. Petersburg.

Although the architecture will be aiming at EWSs in general, details of the implementation and validation of the EWS technology will be in the context of flooding.

2.1 Flood risks and EWS

Flood hazards exist both in coastal areas as well as from rivers, canals and lakes. Most major cities have been built adjacent to rivers – statistically a very dangerous place. Whilst dikes and levees (earth embankments) protect many of the major cities in Europe and elsewhere, failure of such dikes and levees can lead to significant loss of life and substantial associated economic losses (damage and disruption of economic activities). As the effect of climate change becomes more pronounced, expected effects (such as increases in flood water levels, drought or heavy rainfall) will pose an increasing threat to urban areas as the levels of protection offered by the existing dikes and levees will become increasingly inadequate and inappropriate. Meanwhile, the value of property and business at risk in areas protected by dikes continues to increase steadily worldwide, as protected areas (appear to) offer the most favourable locations for living and working. Unfortunately, the combination of cost, existing infrastructure (adjacent buildings and homes) and local soil properties means that it is often not feasible to strengthen or heighten dikes within the limited space remaining, hence new methods, like EWS, are required to manage the flood risk.

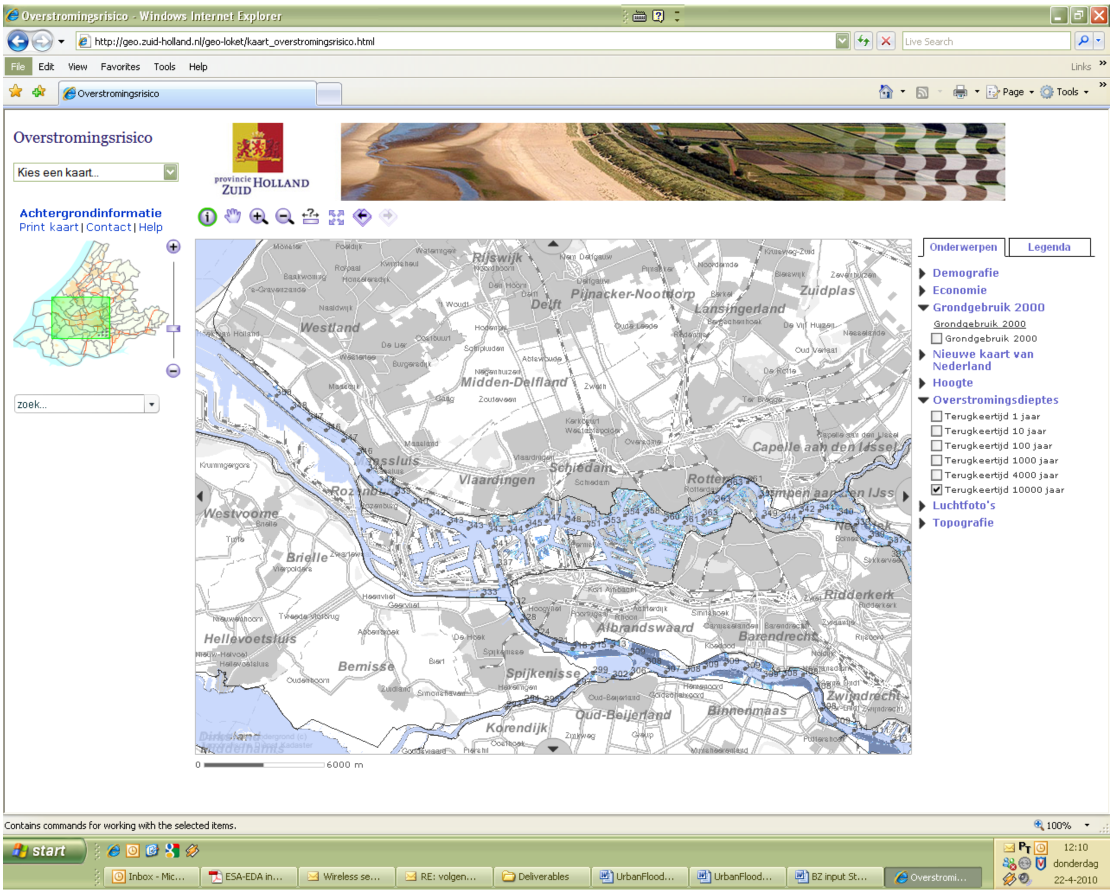

Figure 2. The Province of Zuid Holland (The Netherlands) publishes interactive maps where inundation probabilities are visualized. In the current map the inundation depths for a once in 10000 year event are presented for the city of Rotterdam.

The state of the art of flood risk related EWS is that breaching (dike failure) is forecast on the basis of the dikes composition and flood water level. Potential inundation (risk of inundation; flood risk) is modelled by considering all possible flood defence failures over all possible locations and load conditions. This modelling can take into account the existing condition of the dike, but this data normally relates to visual field observations that can be months or even years old rather than real time measurements of the actual dike body state.

Experiments with sensor systems in dikes by the IJkdijk foundation[4], showed that dike strength can be monitored with in-situ sensors and that EWS based on such sensor systems are expected to decrease the probability of flooding (if, after detection of weak spots

[4]www.ijkdijk.nl. The IJkdijk foundation is stimulation the development of sensor technologies for dikes. Hence, many examples exist only for the Dutch situation, and this reflects in this document. ICT developments like the Urbanflood EWS are out of scope of the IJkdijk foundation. Two of the partners of UrbanFlood, STOWA and TNO, are founding members of the IJkdijk foundation.

countermeasures are taken) at costs often less than those required to implement physical measures. Experiments and pilots, like the ones UrbanFlood will perform, have to establish such as a fact.

Many governmental institutions and specialized companies produce, on basis of models that have the strength of dikes as one of their inputs, the so called flood risk maps. These indicate the *probability* of an inundation, see for example Figure 2. Despite their name, such maps do not map risks. Risk, the quantity that is required for the decision making process, is defined as

*Risk = (probability of a certain event) * (impact of that event in terms of economic loss, deaths).*

Risk varies with time as, for example, the stability of a dike fluctuates as the water height in a river changes. In the case of UrbanFlood, the EWS has the new ability to forecast the reliability of the dike and the potential implications of failure (and hence risk) based upon measurements by sensors buried within the dikes combined with breaching, flood inundation and impact assessment models. The in situ sensors limit the errors in the estimation of actual and future situations (states) of the dike resulting in more accurate risk calculations. If, on the basis of risk forecasts, authorities and citizens take measures to manage flood risk, the more accurate calculations will increase the effectiveness of these measures. For example, an early warning system for dikes gives immediate clues as to the development of weak spots at strategic locations. Instead of discovering that a weak spot existed through the presence of a breach, weak spots can be detected in time for countermeasures to be taken to prevent breach occurring.

2.2 EWS and the Internet

Figure 2 also shows, albeit simplistically, that the internet is used to interact with stakeholders. In general, there is enormous potential in the internet for the interconnection of various computer systems, for the use of specialist on-line computer applications (services, e.g. breaching models, mass communication tools e.g. SMS, Twitter, Email) and for human collaboration and communication. Furthermore, the internet has the ability to connect an EWS to sensors networks are located in other countries and continents.

It is the aim of the UrbanFlood project to use this potential to create a state of the art EWS and to address the expectation of the EU that UrbanFlood is “taking full advantage of recent advances in miniaturization of sensors, wireless communications and increased computation power and data storage capacity”:

- The internet adds reach (sensors can be deployed on almost any place in the world),
- Parts of the EWS can be distributed over the internet and using internet based cloud computing services that greatly enhances the robustness (EWS as multiple locations can monitor the same objects) and scalability (additional computing demands can be acquired over the internet) of the system,

- Parts of the EWS can be provided by specialized third parties – eg supplying specific plug-ins (or “apps”) by specialist companies,
- Authorities, the public and other stakeholders should be able to use the internet to connect to the EWS services, and collaborate on basis of the same shared information and EWS software services.

2.3 General requirements for an contemporary EWS

Summarizing the previous sections and applying it to case of the EWS that UrbanFlood develops the general requirements are:

1. By using modern sensor and internet technologies, the UrbanFlood EWS must allows the estimation of dike reliability and hence flood risk to be much more accurate and timely.
2. UrbanFlood exploits the internet and internet based services to create a powerful yet cost effective EWS.

The UrbanFlood EWS will be validated, through the use of pilot sites, for the case of flooding, monitoring dikes at different locations in Europe. The EWS should have relevance in this context. Hence, trivially,

3. The sensors and the Urbanflood EWS must be able to detect a selection of major failure mechanisms of dikes. The EWS must be extensible to detect others.

2.4 Interacting with an EWS

An EWS supports stakeholders in assessing and managing flood risk. In a minimum scenario, only the risk is communicated to the stakeholders. The risk enables stakeholders to evaluate threats due to the current and forecasted water levels for their dike system. Such evaluations might lead to (computer assisted) decisions ranging from a (just in time) repair of a dike to evacuation of a city.

In simulation mode an EWS allows the stakeholders interact with the system, posing what-if questions. The stakeholders can simulate specific water level conditions or a breach in a dike. This allows forecasting of the impact of different scenarios and this enables the development of appropriate risk mitigation and management strategies. Hence,

4. The EWS should provide a number of functional modes such as routine asset management, event simulation and event management capabilities to assist stakeholders in routine working, event planning and event management.

Even in nonthreatening situations, e.g. a sensor system in a dike in combination with the EWS yield information allowing dike owners to better manage their assets. For the case of dike monitoring

5. An EWS should provide the capacity for automated, round the clock, electronic enhancement of dike inspection processes. (In a most basic form this information will indicate dikes requiring maintenance.)

2.5 Questionnaire

UrbanFlood has sent out about seventy questionnaires to a targeted audience of persons that are professionally involved with flood safety. From them, UrbanFlood received twelve responses from institutions in eight different countries. The responses are reported in deliverable D2.1. The following text snippets, from deliverable D2.1, summarize issues stipulated by these professionals, and which requirement in this document addresses these.

Issue raised in questionnaire	UrbanFlood requirement
The mindset of the water managers in the Netherlands appears focused on the use of smart dikes and early warning systems as a means to prevent a dike failure. Quite literally they sometimes say that the investment for an early warning system to monitor for breaching only is not cost-effective.	2 4 6 7 10 (cost and exploitation related specs)
Application for emergency response alone is not a priority in the Netherlands although such an application may be possible in the future. Still the Netherlands appear to be ahead in application of state of the art sensor technology for monitoring flood defences; at several locations such systems have been installed or will be installed. The justification is often to gain a better understanding of the flood defence structure, in particular earthen dikes. Also, a timely warning may enable the dike manager to temporarily strengthen a given reach, in a much targeted manner.	1 21 (use and science related specs)
All respondents are generally positive on the usefulness of EWS and sensor networks. EWS enable emergency response staff to react quickly and adequately, and a timely warning means that more options are possible, and more measures may be taken.	1
Access to pre-calculated flooding scenarios supports emergency response personnel. Early warning of a threatening dike or flood wall failure can enable targeted responses by the authorities. Overall, EWS are seen to save lives and minimize economic disruption and damage.	14 15
It is critically important that the responsible experts are able to work with the system with a minimum of training.	32 (multi touch table to support experts)
It is also important that the use of the EWS can easily be integrated in the emergency action procedures and decision processes without disruptive changes to these procedures.	30 31 37 (integration specs)
Since flood events are generally rare, the practical use of a Smart Dike EWS in an emergency situation should be part of regular emergency response drills; another option is to integrate the systems used for emergency and regular work (like asset management and audits) as much as possible, so people are familiar with the systems.	4
It is also possible to adapt and use the EWS for non-flood emergencies (multi-hazard) to ensure more frequent use.	3
Integration of EWS with response plans or response planning systems and cell-broadcast or cell-phone warning systems is seen as helpful.	Good idea, however, in UrbanFlood cell broadcast systems are out of scope

Internet access makes relevant information available to both field workers and management. Data should be presented in a form that is useful to the particular user.	**2**
In general respondents are concerned about the cost-benefit ratio of installing sensors in dikes, considering the significant lengths of dikes that need to be monitored. Prioritizing installation at risk hot spots is often suggested.	**6** **(valid for money for every investor in the EWS)**

3 EWS Business modelling framework

A successful EWS has an economic justification if most, if not all organizations that use and fund the EWS can economical justify it – they get enough value (whatever that means for a stakeholder) for costs made. A successful EWS has an architecture and a functionality that enables a business model (cost-benefit model) that is profitable for all stakeholders. More precisely, the generalization of the concept of a single company business model for a concept that applies to describe the business model for a group of companies is[5]: "*the way a network of companies intends to create and capture value from deployment of technological opportunities*". An EWS creates an (electronic) interworking between multiple stakeholders who all have to invest in the use of the EWS. Theoretically at least, an adverse cost-value relationship of one stakeholder can effectively block the introduction of an EWS.

6. The design of an EWS must be such that for every stakeholder the added value has the same relationship to the investment in the EWS.

In this chapter the stakeholders and their relationships for a viable EWS for flooding of urban areas are identified and the cost-value relationships (business case) extracted.

3.1 Methodological Framework for Business Evaluation

In contemporary concepts for business models four domains are identified[6]: value proposition, value network, functional architecture and financial model (Figure 3). The components of the business modelling framework, shown in Figure 3, are:

- **Value proposition**: the value that a provider intends to offer to customers, other parts of the organization or third parties.
- **Value Network**: collection of business actors with reciprocal relationships. Based on certain resources and capabilities, these actors perform value activities together to create value for customers and to realize their own strategies and goals.
- **Functional Architecture**: The technical arrangements that enable the translation of technical resources and capabilities into value creating activities.
- **Financial model**: the financial arrangements between the different actors in the value network. It shows how the value network intends to capture monetary value.

[5] Cedervall, C.,Karlsson, P., Prytz, M.,Hultell, J.,Markendahl, J., Bria, A., Rietkerk, O. and Karla, I "Initial findings on business roles, relations and cost savings enabled by multi-radio access architecture in ambient networks", in Proceedings of the 14th Wireless World Research Forum. 2005

[6] C.R. Casal et al., "The Future of Mobile Communications in the EU: Assessing the potential of 4G", EUR 21192 EN, 2004.

Ballon, P. and S. Arbanowski (2005) Business Models in the Future Wireless World. In: Tafazolli, R. (ed.), Technologies for the Wireless Future: The Wireless World Research Forum Book of Visions 2004. Chichester: John Wiley and Sons Ltd, pp. 90-112.

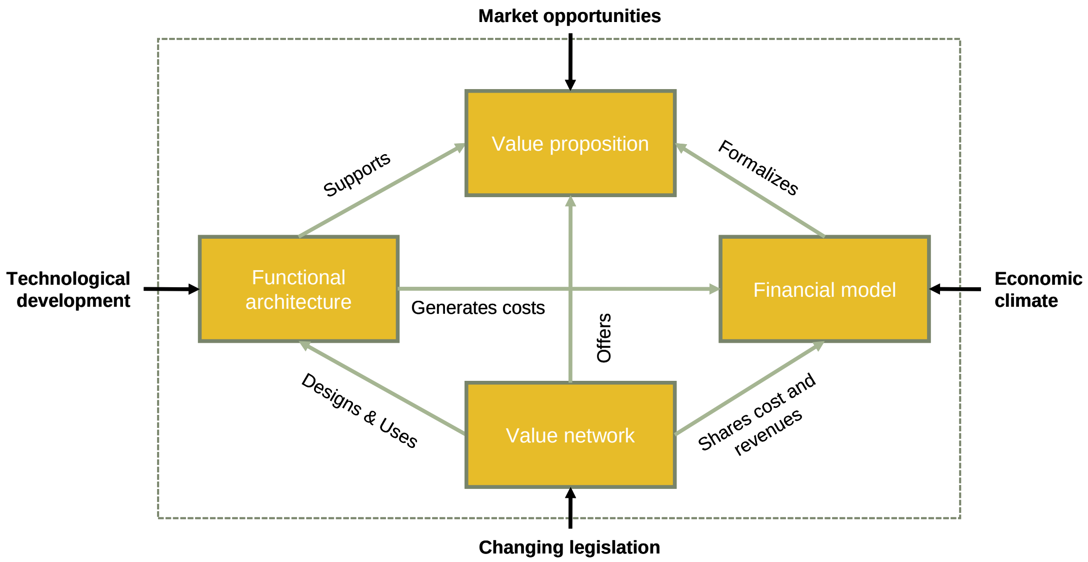

Figure 3 Concept of a framework cable of modelling the value proposition of a group of companies.

On basis of the concept (and accompanying theory) shown in Figure 3 one can perform an analysis of the business model of an EWS. However, given the fact that some stakeholder analysis has been performed in the proposal of the UrbanFlood consortium to the EU, the four domains are elaborated on a general level in the next paragraphs

7. The UrbanFlood EWS should offer stakeholders straightforward economies of scale and scope.

The basis of the business case for EWS is straightforward[7] and exemplified for the Dutch case. However, comparable cost levels are encountered elsewhere in Europe:

> *A new primary dike in the Netherlands costs about 5000 €/m, a physical modification of a primary dike costs on average 1500 €/m (foot of dike widened) to 3500 €/m (height of dike increased) whilst and EWS costs 50 -150 €/m*

Although many dike related improvements do not require the aforementioned adaptations, compared to them, the cost of an EWS is rather low (and some cases[8] the only possible improvement).

3.2 Value network of an EWS

In the UrbanFlood proposal to the EU, and the analysis of deliverable 2.1, the following stakeholders for an EWS were identified, see Table 1.

[7] Values used in IJkdijk business cases

[8] e.g. homes and roads are nearby, there is no room for a larger dike

Stakeholder	At stake
General Public	Flooding risk
Emergency response authorities	Mitigation of flooding effects
Public authorities	Prevention and mitigation of flooding
Service provider	Exploits the actual EWS
Developers	Sales of software parts of an EWS
Manufacturers	Hardware parts, installation work
Government & legislation	Managing risks

Table 1 Stakeholders of an EWS for flooding

In Figure 4 the links between stakeholders are presented in a value network for the EWS. The value network in Figure 4 shows that a central role is fulfilled by the service provider and "public authorities". Interestingly, a single EWS is of interest for multiple stakeholders. For any ICT company it is an opportunity to sell, multiple times, the same product – from hardware to software, service level agreements ... However, this will not happen as potential customers would organize themselves and government would object. A better proposition would be that

8. The EWS should be developed such that it can be offered as a service, and specialized service providers may exploit it as an online service.

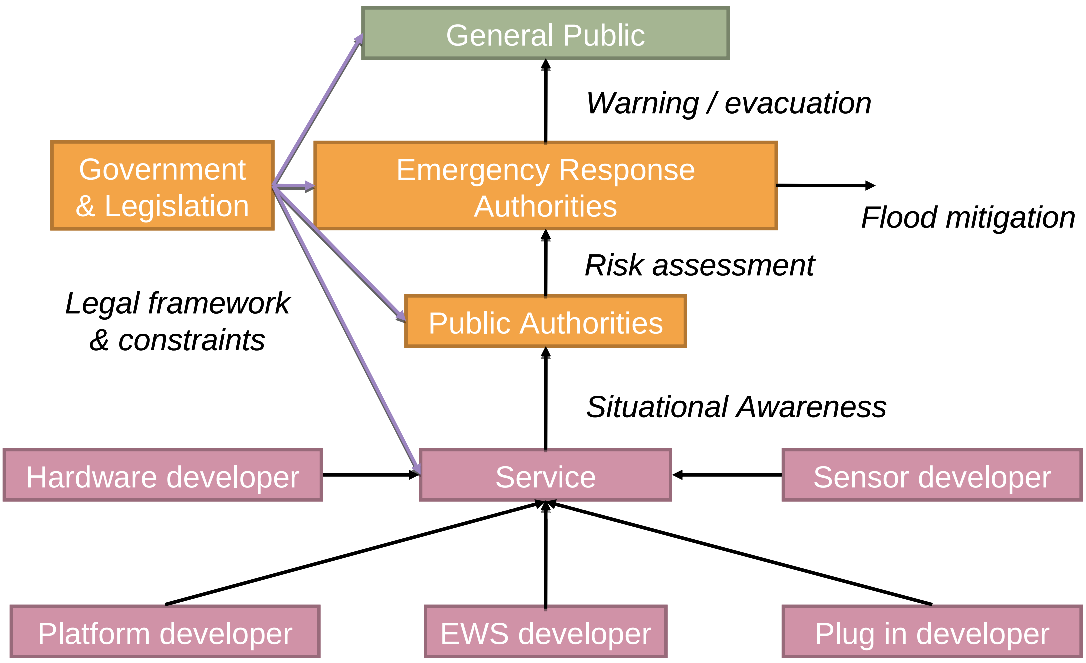

Figure 1 Value web of an EWS (for flooding). An EWS service provider exploiting a platform that hosts multiple EWS offers economies of scale and scope, especially if a single EWS can be used by multiple Public Authorities and organizations that are part of them, e.g. Emergency Response Authorities.

The service provider offers the actual EWS, e.g. that monitors the sensor systems placed (by the authorities) of dikes along the Thames, to several authorities.

3.3 Value proposition of an EWS service provider

The essence of the proposition of the service provider to the authorities (e.g. a water board and a local government) is that the cost of the EWS is shared, that operations and know how is concentrated (economies of scale and scope). Furthermore, the service provider can lower the cost per customer, or increase its profit, by reusing the generic parts of the system over and over again to monitor other dikes or sensors in even completely different environments (e.g. forests, bridges, roads, mountains).

9. The EWS platform should be operated as a shared service.

As the resource usages of all EWSs generally do not peak at the same time, the EWS service provider can optimize this for its own benefit, or that of its customers:

10. Multiple EWS share the same resources.

This only makes sense if the EWS service provider does not have the resources for a peak permanently available,

11. Resources to support EWS operations at peak times should be obtained, via the internet, from cloud computing service providers.

and that not all computing intensive applications run (ineffectively) at all times. The EWS system should support various monitor modes (alerting levels) use computing resources only if the severity of the situation justifies these

Clearly internet connectivity greatly increases the number of objects that can be monitored.

12. The EWS should maximize its market by providing an internet based service.

The government and (its) legislative bodies ultimately define the qualities of the EWS. Part of the value proposition of the service provider is that it interworks with the suppliers of sub technologies to deliver technologies and services that adhere to the norm set by the governmental bodies.
Although the value network of Figure 4 contains many stakeholders and looks somewhat complex, two main stakeholders exists: a group of public authorities that use the EWS and the service provider that operates the technology of several EWSs. Hence, the main value proposition of service providers is to offer an economy of scale in the delivery of “situational awareness” (Figure 4) to authorities. Furthermore, a part of the value proposed by the service provider is its work to organize, construct, innovate and operate the EWD. To do so the service provider maintains business relations to suppliers of sub technologies of the EWS.

13. An EWS should be constructed in such way that several suppliers can deliver, in competition, parts of an EWS.

The service provider acts for multiple (governmental) organizations as a focus point of EWS innovations. The service provide offers economies of scope. However legislation will influence the actual developments.

In Figure 4, the intrinsic product of an EWS is called “situational awareness”. In the context of an EWS for flooding, this means that:

14. The EWS should provide information on the actual condition of the dikes,
15. The EWS should provide information on the risk related to breaching, inundation scenarios and should support the development of evacuation plans.

In terms of risk management, there is a value proposition if and only if a dike with an EWS has less risk then a dike that is as costly but relies on (more) matter. What if the Internet fails during a storm? Or a sensor? The reliability of technologies translates in a probability of not detecting a failure and an impacts the risk of flooding. There are several requirements related to the reliability of ICT (see numbered points 42, 43, 45, 46).

3.4 Financial model

Figure 4 shows that the relation between service provider and a groups of public authorities is dominating the value network, between these parties the dominant cash flow occurs. Many models, ranging from “pay per view” to “safety as a service” can be allied for this. To run the service, the service provider needs all the other stakeholders in the value network. The sensors and other hardware can be purchased in a normal purchase – sales relationship.

The value proposition of the service provider is in essence, see the previous section, that of economies of scale and scope. However, it will deliver these values only if the customers of the service providers can avoid a “lock-in situation”. In that situation the public authorities are, for all practical purposes, forced to continue to use the services of the service provider, whilst the cost-value ratio obtained might become less attractive over the years. Hence Government en Legislative bodies might dictate that the EWS service platform and components must either be ‘open source’ or ‘open’. The ‘open source’ variant means, from a business point of view, that all parts can be reengineered by others and put into service by others. The ‘open’ variant means that products used must adhere to standards and that products must be able to interwork with other products from other suppliers that adhere to the standards.

To avoid lock-in situations, governments other authorities may even be legally bound to use only open source software or software of which they have access to the source code.

The UrbanFlood concept builds upon ‘open source’, but does not explicitly exclude proprietary software and systems. As public authorities are the major (paying) stakeholders,

16. An EWS platform should be open source.

A part of the UrbanFlood EWS cannot be open source. In the case of flooding, some software has been developed over the course of decades. Such software must run on the platform with minimal risk of illegal use or reverse engineering

17. Specialized manufacturers should be able to produce specific modules (plug ins) of the EWS, whist the EWS platform protects the investments made by the manufacturers and buyers of the EWS.

18. The platform should take care that plug-ins, that are not open source, should be replaceable with other plug-ins that have more or less the same functionality.

4 Extended EWS Business case

The basic business case was mentioned in Section 3.1: an EWS can offer the same risk levels as a dike at a fraction of the cost of the creation or strengthening of a dike. However, what if the present risk levels are already acceptable? What if dikes are good enough?

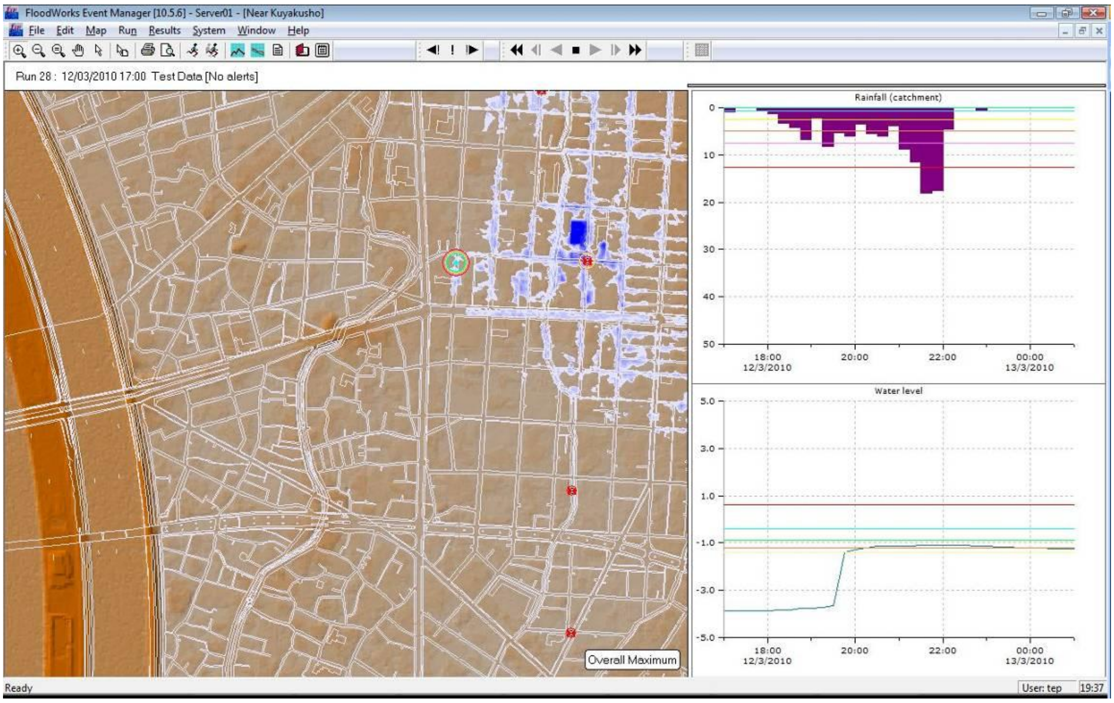

Figure 5 Simulation of an inundation. An EWS that inspects sensor data could also be fed by simulated data. This has many uses, ranging from the development of calamity mitigation strategies to the determination of investment priorities. The technology that created the above picture is based on R&D by HR Wallingford, one of the UrbanFlood Consortium members.

The tremendous impact of the February 1953 disaster in the Netherlands and in the United Kingdom made clear that the consequences of failing flood protection systems are great. These countries have raised the strength of their flood defences ever since to the point that the stakeholders believe that the next big disaster is not due in the coming decades. In the Netherlands the sea dikes are designed for a 1/10000 situation which means for water level and weather conditions that occur once in 10000 years. Other areas are protected for 1/4,000, 1/2000 or 1/250 situations[9]. The creation of a business case is the hardest for countries that have such high standards – if there is a business case here, there is a business case everywhere. In the case that dikes are rather well or even over dimensioned for their task, the value proposition becomes more complex. In this case, the primary value proposition “situational awareness” (Figure 4) becomes less important (why monitor a dike when it is much too strong?) and hence the other benefits of the EWS becomes relatively

[9] Van overschrijdingskans naar overstromingskans. Technische adviescommissie voor de waterkeringen, 2000

more important. These benefits are reported by the IJkdijk foundation[10], for the Dutch situation. For the purpose of finding specifications of an EWS, the generalisation of the (additional) Dutch benefits of an EWS towards a general, European business case is not necessary. The result would be other financial results, on basis of the same specifications. Hence the Dutch example is studied in this section.

4.1 Additional benefits of a Flooding EWS

According to the IJkdijk foundation, an EWS can improve the efficiency of various dike maintenance activities, the EWS can work as an asset management system (AMS).

Inspection

Currently, dikes are regularly visually inspected by inspectors from the water board. They identify situations where damage has occurred and assess if the dike is still functional according to set and agreed standards. Since this inspection is mostly visual, no direct insight is gained into the state of the body of the dike. Application of the UrbanFlood EWS allows for better monitoring of geotechnical aspects of dike behaviour and will supplement visual monitoring by the inspectors and hence makes the process more effective.

19. An EWS should be able to translate sensor data to information that can be used in the maintenance of dikes

The IJkdijk foundation estimates in its business case for large scale deployment of EWS for dikes, that savings of about 20% can be reached in the costs for inspection and maintenance.

Auditing

Taking the Netherlands as an example, dike inspection (auditing) is regulated. All primary dikes in the Netherlands (3600 km) are audited by law for height, strength and stability on a 5-year basis. Currently, an audit scheme for regional dikes (14000 km) is being redesigned. For audits, information on the dikes needs to be collected. This is done through visual inspection and, if this is insufficient, through ground probes and a whole suite of tests. Application of electronic monitoring through an EWS can, according to the IJkdijk business case, reduce auditing cost with 50%.

20. Sensor data, and information that is derived from it, must be protected in order to prevent manipulation.

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[10] IJkdijk foundation, www.ijkdijk.nl, 2010, Business case IJkdijk (internal report). UrbanFlood members STOWA and TNO are involved in IJkdijk.

IJkdijk foundation, 2009, IJkdijk 2010-2010, (internal report)

Efficient approach to reinforcing dikes

A total of €7 billion has to be invested in Dutch dikes. According to the IJkdijk business case, the advance in understanding of the stability of dikes, based on experience with EWSs might "right size the dike" and prevent too much over dimensioning. The more efficient design of dikes could potentially save up to 10% of the total costs of reinforcement.

Hence, this means for the EWS,

21. Data of EWS should be available for the scientific community in order to improve the knowledge of dikes and that of the performance of EWS itself.

4.2 Extended cost – benefit analysis for a Flooding EWS

The costs of installing a sensor network in a dike are estimated at 50.000 to 150.000 €/km[11]. The lifetime of the sensor network is estimated at 10 years. Furthermore, it is currently estimated that about 15% of the dikes must be monitored (the stability of these dikes is such that the water board has doubts about the quality of the dike).

Annual EWS cost for primary dikes in the Netherlands	
Length of dikes monitored	2500 km
Average cost	100.000 €/km
Cost of a 2500 km sensor system	250.000.000 €
Depreciation 10% annually	25.000.000 €
Operational costs	5.000.000 €
EWS annual cost	30.000.000 €

Table 2 Annual costs for an EWS for the Netherlands

For the Netherlands this leads to a total investment between 125M€ and 375M€ to monitor 2500 km dike. In Table 2 this amount is averaged at 250M and the yearly costs for a Flooding EWS is estimated at 30M€ per year.

In Table 3 a rough estimation is made of the yearly savings hat can be reached using a Flooding EWS. From Table 2 and Table 3 it is evident that on the long term tremendous savings can be reached. This however means that the EWS should be able to sustain:

22. An EWS must have the built-in property to accommodate changing technologies and requirements.

[11] Result from the LiveDijk project (www.livedijk.nl). UrbanFlood members STOWA and TNO are heavily involved in LiveDijk.

Field	Term	Annual costs	Annual Savings	%
Inspection and maintenance	short	100.000.000	20.000.000	20%
Safety audits	short	30.000.000	15.000.000	50%
Dike reinforcements	long	800.000.000	80.000.000	10%
Totals	**long**	**930.000.000**	**115.000.000**	**12%**

Table 3 Estimation of the savings, for 2300 Km of primary Dutch dikes, that can be reached in inspection, maintenance, safety audits and dike reinforcements (Source: IJkdijk foundation)

5 The architecture of the UrbanFlood EWS

In this report we describe what is technically is called "the enterprise viewpoint" – the architecture from the user's point of view[12]. Here "architecture" is a concept, a model that stakeholders deploy to understand how an EWS works and "functionality" is the description of what the EWS does for them. This chapter presents the concept of UrbanFlood for the EWS that is expected to meet specifications and requirements described in previous chapters – an implementation has to prove this. A discussion of properties of this concept leads to additional requirements for the "functionality" of the implementation. This implementation is done in other WPs of UrbanFlood.

5.1 Concept of an internet based early warning system

In Figure 6 the UrbanFlood architecture of an EWS, from a stakeholders point of view, is shown.

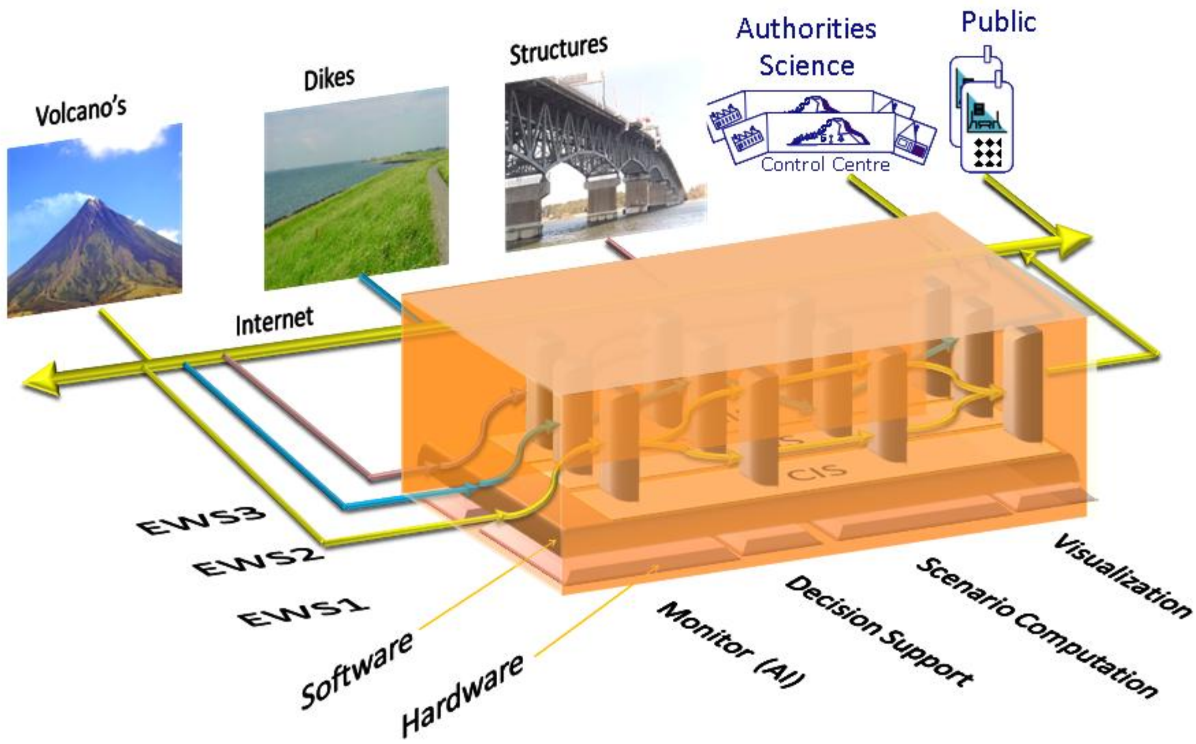

Figure 6 Architecture, from a business point of view, of the UrbanFlood internet based early warning system

The Urbanflood project will develop and test an internet based platform on which multiple EWS can run. The essence of the concept, from the stakeholders point of view, is that stakeholders have to connect sensors to the system via the internet and the UrbanFlood EWS does the monitoring and generation of information for the stakeholders (e.g.

[12] en.wikipedia.org/wiki/RM-ODP

authorities and the general public). To support the stakeholders a variety of visualizations can be generated. Urbanflood will especially develop visualization on multitouch tables which are aimed at supporting groups of experts (such as emergency response teams) to cooperate, jointly interact with data and coordinate more effectives responses to manage the flood risk.

In Figure 6 it can be seen that:

23. Sensor systems use the internet to communicate data.
24. The internet is the main medium through which the EWS interacts with the authorities and the public.
25. Multiple EWSs can run in parallel, allowing multiple objects to be monitored, or, as important, old and new versions of the EWS to coexist.
26. The EWS has a modular architecture that enables plug-ins as the CIS (common information space) and ones for artificial intelligence, decision support, scenario computations and visualization.

Many detailed features are omitted from the concept shown in Figure 6. Most importantly, it does show the fact that the technology is able to support multiple EWS at the same time. This addresses the economies of scale and scope issues mentioned in previous chapters. In Figure 4, where stakeholders of the EWS are shown in relation to each other, one should note that the UrbanFlood EWS uses the internet to access hardware of cloud computing service providers and that the modular characteristics of the EWS will need to allow the running of modules as plug-in (“apps”). These plug-ins can not be reengineered and hence protect investments made by their creators or owners.

5.2 The Common Information Space

A crucial functionality/component of the UrbanFlood EWS is use of the CIS (Common Information Space) which facilitates interactions between the components of the EWS. These interactions are mostly through the exchange and storage of information and software services (e.g. visualization of data). State of the art integration technologies (jargon: enterprise service bus technologies) support, out of the box, commonly used interfaces to applications and facilitate an efficient development of new ones.

Figure 7 Initiatives on earth monitoring, mostly from space, have inspired the concept of the "Single Common Information Space (CIS) for the environment. The CIS is a key component in Europe's Inspire directive and in the concept of the Global Earth Observation System of Systems (GEOSS) developed by The Group on Earth Observation (GEO) that have created the above picture. The CIS is an approach to interchange environmental data and software services built around them. The CIS of UrbanFlood will support relevant GEOSS and Inspire standards.

The concept of a CIS is also central in initiatives like GEOSS[13] and Inspire[14] where the CIS is associated with a portal for data[15] and (software) services[13] related to earth observation, as well with as standardization efforts coordinated by public bodies. It is efficient for the implementation of the EWS that the integration technology, the CIS, can be reapplied frequently. In UrbanFlood,

27. A single CIS technology should be used multiple times to implement all EWS functions and services, including the allocation of hardware resources, and the

[13] www.earthobservations.org

[14] inspire.jrc.ec.europa.eu

[15] www.un-spider.org

support of CIS services in the same manner as adopted by GEOSS and INSPIRE, as well as the management of EWSs[16].

Indeed, as there are multiple EWS operating in parallel in the UrbanFlood concept, a software facility that creates and manages these EWSs is needed. The CIS integration technology can do that too, provided that

28. A complete EWS should be managed in a similar manner to a single plug-in (!), allowing the CIS technology also to manage complete EWSs.

The technical design of the CIS technology is specified in deliverables 5.2, 5.3 and 5.5

5.3 CIS Functions

The UrbanFlood project will create an internet based EWS service platform that can be used to link sensors via the internet to predictive models and emergency warning systems. The data collected from the sensors will be verified, and then interpreted to assess the condition and likelihood of failure. This potentially involves multiple models that calculate the probability of certain failure modes and subsequent inundations in near real time. Through the internet, additional computer resources required by the framework are made available on demand.

This requires that

29. The CIS should manage the communication channels between the sensors and the EWS, e.g. to facilitate the process of adding new sensors.

Furthermore, the CIS operates on data coming from the sensors, e.g. to a format or formats that suit subsequent processing best. To supply application programs in the EWS with data, the CIS needs to create the necessary workflows.

Other parties, such as authorities, the public and other stakeholders, should be accommodated by the CIS to connect and interact with the information provided by the EWS. This requires that

30. Metadata should be available through the CIS / EWS services to ensure a proper interpretation of the data

by these other parties and to

31. Enable other parties to locate the necessary entry points to the EWS to request the data.

The data can be visualized for these authorities using

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[16]A well suited and general design pattern for a CIS implementation is that of an enterprise service bus (ESB) en.wikipedia.org/wiki/Enterprise_service_bus

32. The data will be be visualised for these authorities using the decision support tool included in the EWS. The decision support tool is an inter-active tool running on a Multi-Touch table[17].

5.4 A platform for Early Warning systems

The UrbanFlood proposal mentioned the ability that multiple environments can be monitored and hence, that multiple EWSs are hosted in parallel. This means that the UrbanFlood project will develop technology that is a hosting platform for early warning systems. This approach means that much of the technology created in UrbanFlood has to have a general applicability for monitoring and mitigating the effects of climate change. However, additional benefits from the ability of hosting multiple EWSs are that:

33. Various versions of the EWS should be able to run in parallel allowing a smooth software upgrade strategy.

34. Multiple EWS should be able to monitor the same data, facilitating second opinions in the decision taking processes.

35. An EWS must be created through an installer program (not by populating computer systems manually with software). This kick starts, technically and financially, the development of an EWS for the monitoring of another dike system or even a completely different environmental issue.

36. An dedicated EWS must be created to (self) monitoring the UrbanFlood EWS, that is potentially running on several places on the internet, to create a robust EWS platform.

37. The CIS technology should facilitate the integration of other EWSs running on the same platform. This benefits, for instance, the modularity of complex EWSs as well as collaborations between several authorities each having a (part of) an EWS.

These advanced features require that the CIS of UrbanFlood acknowledges these requirements in the design phase. Many of the requirements impacts only naming conventions, which can be solved by introducing namespace concepts. Other features merely elaborate on the information and service facilities of the CIS. Crucially, the advanced capabilities require the cloud services (plug in management) concept described in the next section.

5.5 Internet based Cloud Computing Services

It has been described that all software runs as plug-ins, using virtualization technology like VMware[18] to create virtual machines, in the EWS framework. For many purposes virtual

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[17] en.wikipedia.org/wiki/Surface_computer

[18] www.vmware.com, or for a general description en.wikipedia.org/wiki/Hypervisor

machines and real computers can be interchanged. On a single real computer, multiple virtual machines can be hosted (a cloud). Virtual machines can be started, stopped, copied (!), saved, paused and moved to another hardware machine.

38. Most, if not all software should run in a virtual computer / machine.

39. Virtual computers are organized with the UrbanFlood EWS framework software in a cloud.

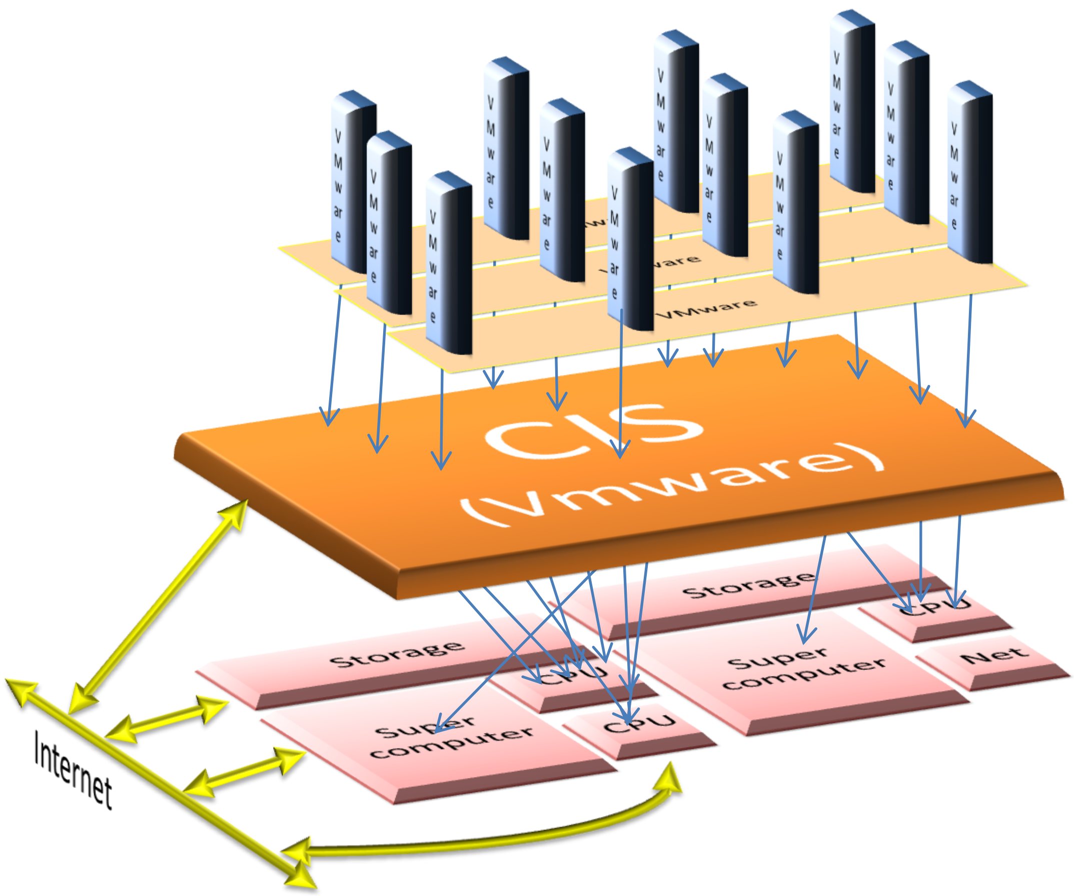

Figure 8. Architecture, from a stakeholders point of view, of the UrbanFlood cloud computing capabilities. This relies heavily on plug-ins – software that runs on a dedicated virtual machine, like the commercial VMWARE software for that. Open source alternatives are currently under study by the UrbanFlood team. Plug-ins can be stopped, saved to disk and copied (cloned) – the foundations of an EWS framework that runs multiple EWS on shared resources over the internet.

40. The CIS should manage the hardware resources needed by other plug-ins, resources are also obtained through the internet, distributing the EWS platform over multiple locations.

This virtualization technology (and the multiple use and instantiations of the CIS technology) are the basis of the UrbanFlood advanced EWS capabilities. The virtual machine technology shields the managing entity of a plug in from many details, allowing for the development of simple management technology. Figure 8 shows the use of the plug-in technology.

41. CIS management technology only addresses rather abstract key performance parameters such as CPU time, storage capacity, memory in use and communication bandwidth. The management technology is otherwise unaware of what the components are doing. This should be the basis of the general purpose EWS hosting platform.

5.6 Not a proven technology

Although the aforementioned benefits of the Urbanflood EWS are appealing, they have not yet proven themselves in practice. Indeed, sensor based dike monitoring is at a very early stage of development. However, the results obtained by the IJkdijk foundation (see Footnote 4) are very promising. Urbanflood will add to this experience by monitoring dikes situated in prominent places. Practical experience with development and application of the EWS will ultimately propel or halt development in dike monitoring systems. This document addresses a number of these key concerns and addresses them in the specifications of the EWS.

Reliability and trust of a hosted EWS

For owners of dikes, a sensor based EWS is likely to be a new development. However, bad experiences that every professional has had with different aspects of ICT combined with stories about systems being hacked, automatically raise questions about the reliability of such an EWS.

42. The EWS should deploy state of the art mechanisms for robust and secure operations.

43. The system should monitor itself, the internet and sensor connections, and resource usage to warn and take real time counter measures for any technical failures and to acquire statistics about the availability of all components.

Urbanflood relies heavily on plug-in technology that permits even multiple EWS systems to be running at multiple locations, analyzing the same sensor data streams.

44. Performance parameters of the EWS should be available for the EWS stakeholders.

The CIS for UrbanFlood should be designed to service computer applications from various organizations. The CIS should be based on (open source) enterprise service bus technology. Hence:

45. Common design patters in securing and hardening enterprise service bus implementations can be and should be deployed.

Use of third party sensor data

One application of the system might be that the EWS potentially can use sensors or sensor data owned by other organizations. An EWS might even monitor social media as an input for it's decision making process (e.g. Twitter: "water is rising at my home"). Although sharing resources and data has many advantages, resources and data can be manipulated to influence the operation in a certain way. Many specific actions can be designed to increase the confidence in information. However, as a general measure,

46. The origin of data and services should be traceable and logged.

Intellectual property rights

The EWS host, development of plug-ins and various applications represent years of R&D effort and investment by their owners. Hence it is important that plug-ins and the software that runs on the associated virtual machines is not used illegally and cannot be reverse engineered.

47. The plug-in and cloud services technology developed, should guard the IPR (and other commercial) issues of their owners.

Benefit of science and education

A special application area for the EWS is in science and education. A monitored object, such as a dike, can be very interesting as part of a scientific study or as an example for students (e.g. a project in high school education - is the water pressure in a dike at full moon the highest?)

48. The EWS, and especially the CIS, will contain a webserver and webservices technology that can support scientific and educational applications.

6 Conclusions

This document describes the architecture of an EWS that is developed in the EU funded, FP7 work program 6.4, UrbanFlood project and that allows UrbanFlood to meet the generic target outcome of that work programme.

This document shows that there is a clear economic justification for the use of an EWS in the case of flooding. Hence, obstacles for its introduction are the availability of the proper EWS technology and trust of stakeholders in this technology. It is the goal of UrbanFlood to create this technology and contribute to the creation of this trust developing and piloting an internet based EWS platform that operates several EWS in parallel.

This document presents an architecture of that EWS platform, from a business (stakeholders) point of view. About 50 EWS design criteria are identified that allow optimal, offering economies of scale and scope, deployment of an EWS and to create the proper business context for it. Furthermore, the EWS can reduce the cost of daily management of a dike system.

Characteristic of the EWS requirements is the ability to share the use and cost of the EWS amongst stakeholders, the ability to run multiple EWS in simultaneously, and to obtain peak computing resources from the internet. As the EWS runs as a service over the internet it provides climate change mitigation services to a European or even worldwide market.

Annex 1 List of specifications

No	Specification	Page
1	By using modern sensor and internet technologies, the UrbanFlood EWS must allows the estimation of dike reliability and hence flood risk to be much more accurate and timely.	6
2	UrbanFlood exploits the internet and internet based services to create a powerful yet cost effective EWS.	6
3	The sensors and the Urbanflood EWS must be able to detect a selection of major failure mechanisms of dikes. The EWS must be extensible to detect others.	6
4	The EWS should provide a number of functional modes such as routine asset management, event simulation and event management capabilities to assist stakeholders in routine working, event planning and event management.	6
5	An EWS should provide the capacity for automated, round the clock, electronic enhancement of dike inspection processes. (In a most basic form this information will indicate dikes requiring maintenance.)	7
6	The design of an EWS must be such that for every stakeholder the added value has the same relationship to the investment in the EWS.	9
7	The UrbanFlood EWS should offer stakeholders straightforward economies of scale and scope.	10
8	The EWS should be developed such that it can be offered as a service, and specialized service providers may exploit it as an online service.	11
9	The EWS platform should be operated as a shared service.	12
10	Multiple EWS share the same resources.	12
11	Resources to support EWS operations at peak times should be obtained, via the internet, from cloud computing service providers.	12
12	The EWS should maximize its market by providing an internet based service.	12
13	An EWS should be constructed in such way that several suppliers can deliver, in competition, parts of an EWS.	12
147	The EWS should provide information on the actual condition of the dikes,	13
15	The EWS should provide information on the risk related to breaching, inundation scenarios and should support the development of evacuation plans.	13
16	An EWS platform should be open source.	13
17	Specialized manufacturers should be able to produce specific modules (plug ins) of the EWS, whist the EWS platform protects the investments made by the manufacturers and buyers of the EWS.	14
18	The platform should take care that plug-ins, that are not open source, should be replaceable with other plug-ins that have more or less the same functionality.	14
19	An EWS should be able to translate sensor data to information that can be used in the maintenance of dikes	16
20	Sensor data, and information that is derived from it, must be protected in order to prevent manipulation.	16
21	Data of EWS should be available for the scientific community in order to improve the knowledge of dikes and that of the performance of EWS itself.	17
22	An EWS must have the built-in property to accommodate changing technologies and requirements.	17

23	Sensor systems use the internet to communicate data.	**20**
24	The internet is the main medium through which the EWS interacts with the authorities and the public.	**20**
25	Multiple EWSs can run in parallel, allowing multiple objects to be monitored, or, as important, old and new versions of the EWS to coexist.	**20**
26	The EWS has a modular architecture that enables plug-ins as the CIS (common information space) and ones for artificial intelligence, decision support, scenario computations and visualization.	**20**
27	A single CIS technology should be used multiple times to implement all EWS functions and services, including the allocation of hardware resources, and the support of CIS services in the same manner as adopted by GEOSS and INSPIRE, as well as the management of EWSs.	**21**
28	A complete EWS should be managed in a similar manner to a single plug-in (!), allowing the CIS technology also to manage complete EWSs.	**22**
29	The CIS should manage the communication channels between the sensors and the EWS, e.g. to facilitate the process of adding new sensors.	**22**
30	Metadata should be available through the CIS / EWS services to ensure a proper interpretation of the data	**22**
31	Enable other parties to locate the necessary entry points to the EWS to request the data.	**22**
32	The data will be be visualised for these authorities using the decision support tool included in the EWS. The decision support tool is an inter-active tool running on a Multi-Touch table.	**23**
33	Various versions of the EWS should be able to run in parallel allowing a smooth software upgrade strategy.	**23**
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42	The EWS should deploy state of the art mechanisms for robust and secure operations.	**25**
43	The system should monitor itself, the internet and sensor connections, and resource usage to warn and take real time counter measures for any technical failures and to acquire statistics about the availability of all components.	**25**

44	Performance parameters of the EWS should be available for the EWS stakeholders.	**25**
45	Common design patters in securing and hardening enterprise service bus implementations can be and should be deployed.	**25**
46	The origin of data and services should be traceable and logged.	**26**
47	The plug-in and cloud services technology developed, should guard the IPR (and other commercial) issues of their owners.	**26**
48	The EWS, and especially the CIS, will contain a webserver and webservices technology that can support scientific and educational applications.	**26**