CASE STUDIES

Flood assessment and warning system

Aaron Ciaghi

PHOTO: Boane Bridge on the River, Mozambique. Pietro Molini.

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CASE STUDIES **Flood assessment and warning system**

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DL B 10735-2015
ISBN 978-84-606-7546-4

Citation: Ciaghi, A. (2015) ' Flood assessment and warning system', in *Case studies for developing globally responsible engineers*,
GDEE (eds.), Global Dimension in Engineering Education, Barcelona. Available from: http://gdee.eu/index.php/resources.html

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FLOOD ASSESSMENT AND WARNING SYSTEM

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1. Introduction

"Countries cannot escape from the accidents of geography that put them in harm's way and increase their exposure to climate risks. What they can do is reduce these risks through policies and institutions that minimise impacts and maximize resilience."

(The World Bank, 2005)

According to the World Meteorological Organization (WMO), 50% of water-related natural disasters in the decade 1990-2001 have been caused by floods. The International Disasters Database[1] shows that the same is true for natural disasters in developing African countries, with Eastern Africa being the most hit sub-region. This case study focuses on Mozambique, where floods and droughts are the natural disasters that most strongly impact the local economy. According to the World Bank, this is one of the main limiting factors for human development in the region together with HIV/AIDS.

The ICT4G research unit of Fondazione Bruno Kessler organized a Summer School of Ruby On Rails in 2011-2013 to teach agile web development to students of Mozambican Universities and personnel of NGOs and Government Agencies. During the last edition (held in August 2013), we developed a flood assessment and warning system based on requirements from the Department of Emergency of the Government of Mozambique. The system we developed is composed of two main components:

- One to allow a team to provide a qualitative assessment of different risks using a variation of the Delphi method.
- One to allow a team to monitor and send information about the level of rivers, using a mobile application.

Although the system has not been deployed on the field, it is based on actual requirements on actual contextual information collected by international organizations and governmental agencies. This case study is based on this project and it can be used to present the challenges that must be faced when designing and developing an ICT tool to be deployed in areas such as rural Mozambique.

1.1. Disciplines covered

This case study falls into the broad topic of ICT for Development (ICT4D), covering concepts of software engineering and risk assessment in the context of rural Mozambique. Therefore, this case study is more suitable for computer science and engineering students who are keen on exploring how their main discipline can be applied in human development contexts.

[1] http://www.emdat.be/database

The case study can be solved at different levels of detail that correspond to the ideal development process of an ICT4D solution:

1. Understanding the context and the risk assessment process for floods and other water related natural disasters.
2. Understanding the design constraints due to the geographical, social and technological environments in which the solution will be deployed.
3. Developing the software solution addressing the identified constraints.

The work proposed in this case study should be carried out in teams of 3-4 people, ideally with a software design/development background.

1.2. Learning outcomes

- Gain a basic understanding of risk assessment.
- Understand the constraints and requirements of ICT projects in a development context vs. a "traditional" developed context.
- Understand the common design considerations that should be incorporated in an ICT4D project.

1.3. Activities

The two activities proposed in the case study are for groups of 3-4 students and are structured as follows:

- The activity in class will allow students to get acquainted with the risk assessment process using the Delphi-like methodology that will be implemented in the project. This will allow them to subsequently elicit the requirements for the ICT solution. The students will be presented with the methodology and the general requirements of the system to be implemented and will be asked to transform the requirements into *User Stories*, considering all the peculiarities of the deployment region.
- The homework activity will use the outputs of the activity in class as starting point, allowing the teams to design and develop a prototype for an ICT risk assessment and warning system. The teams can choose their preferred technology for the implementation and can design and develop the solution at different levels of detail.

2. Description of the context

In the context of the Summer School of ICTs, where we teach Ruby On Rails to students of the Mozambican Universities, we develop applications whose requirements come from various NGOs and Government Agencies. During the last edition (held in August 2013), we developed a flood assessment and warning system based on requirements coming from the Department of Emergency of the Government of Mozambique. The system we developed is composed of two main components. The first component allows a team to provide a qualitative assessment of different risks using a variation of the Delphi method. The second component allows a team to monitor and send information about the level of rivers, using a mobile application.

Although the system has not been deployed in the field, it is based on actual requirements. The first component has also been implemented by the students during the one-month training they had.

2.1. Human Development in Mozambique

Mozambique is one of the poorest countries in the world, listed 170th out of 173 in the UN Human Development Index, with 69% of the population living below the poverty line of USD 0.40 per day.

When the country became independent from Portugal in 1975, the Portuguese rapidly left a highly undeveloped country with very low levels of education and training and an economy and transport system skewed to the rest of southern Africa’s economic needs. The creation of the rebel Renamo (Resistência Nacional Moçambicana) movement by the Rhodesian government in 1976, which was subsequently backed by South Africa, led to a 17 year Civil War and an extended period of attack and destabilisation by South Africa in defence of its apartheid system. The war resulted in at least one million deaths and devastated many parts of the country and its infrastructure. Over one third of the population was displaced at some point, and 1.7 million lived as refugees in neighbouring countries. 60% of primary schools and 40% of primary health posts were destroyed.

A peace agreement in 1992 and elections in 1994 ended the conflict, with the UN supervising the return of refugees and internally displaced people.

Mozambique remains a developing democracy with substantial tensions between the Renamo areas of the north and center and the Frelimo areas of the south, including the capital Maputo. Second general elections were held in 1999 and Renamo, disappointed by the result, challenged the validity of the elections and threatened to set up its own government. These political developments were overtaken by the 2000 floods, but the volatile relationship between the two political parties in the Parliament remains an impediment to Mozambique's transition to a more stable political environment.

Economically, the Frelimo government, under heavy pressure from donors, started to transition from a centrally-planned economy with a socialist approach to a market economy back in 1987. Since the war ended, the country has maintained a high growth rate, averaging 8 percent, partly due to the catching up process once land was accessible, and once substantial recovery projects and mega projects began.

Mozambique has received high levels of international donor support and has a substantial dependency on foreign assistance, with more than 50 percent of its public spending and about two thirds of public investment coming from external sources (Batley, 2005). Economic growth has tended to be concentrated in and around Maputo, and to a lesser extent in Beira, in the center. Maputo produces 40 percent of the GDP and accounts for 10 percent of the population. The impact of economic growth has been uneven with parts of the population of urban areas benefiting disproportionately, particularly in Maputo.

Mozambique continues to be held back by its poor infrastructure. It still remains uneconomical or impractical to move food surpluses from one part of the country to another. The Mozambican population is predominately young and rural, with only 23 percent of the population living in urban areas (provincial capitals) and almost half of the entire urban population living in Maputo city. Mozambique has one of the lowest urbanisation rates in the world.

2.2. Natural Disasters in Mozambique

This section presents a few important facts from extracts from the Working Paper n. 12 about Disaster Risk Management by The World Bank (Wiles, Selvester, Fidalgo, 2005). These facts should help the students in understanding the situation in Mozambique and the impact of the most disastrous floods that hit the country in 2000 and 2001.

According to The World Bank, natural disasters, along with the social and economic impact of HIV/AIDS, are one of the main risks to the achievement of Mozambique's poverty reduction strategy. From 1965 to 1998, there were twelve major floods, nine major droughts, and four major cyclone disasters. Droughts have had the most devastating impacts due to their occurrence during the Mozambican War of Independence and the Mozambican Civil War. Four major droughts and famine between 1980 and 1992 caused an estimated 100,000 deaths.

In 2000 and 2001, Mozambique was hit by floods created by a succession of tropical storms, starting with depression Connie between 4-7 February. Cyclones Eline and Gloria followed later in the month. Heavy and persistent rain across southern Africa resulted for the first recorded time in the simultaneous flooding of the Limpopo, Incomati, Umbeluzi, Save, Buze and Pungoe rivers. At least 700 people died, 650,000 were displaced and 4.5 million were affected, totalling about a quarter of Mozambique's population.

The flooding devastated the agriculture sector, partly because of the prolonged nature of the inundation in some areas. 140,000 hectares of crops were destroyed or seriously damaged and irrigation systems were also destroyed. An estimated 350,000 livestock were lost or seriously injured and 6,000 fisher people lost 50 percent of their boats and gear.

A massive national and international relief operation avoided greater loss of life with 16,500 people rescued by aircraft and over 29,000 by boats. The displaced were accommodated in 100 temporary centers, the largest being Chiaquelane with a peak population of 80,000 people. Public health measures avoided measles and cholera epidemics. A feature of the international aid coordination was that it was set up within the National Institute of Disaster Management (INGC) which was led by the Minister for Foreign Affairs and Cooperation. In this way, Mozambique preserved an element of national sovereignty and control.

In 2001, the floods mainly affected Zambezia, northern Sofala, then the Tete and Manica provinces in Central Mozambique during February and March. The floods were caused both by prolonged and intensive rains at the end of 2000 and in early 2001 in central Mozambique, and by neighbouring countries' increasing flows from the Kariba and Cabora Bassa dams. In March, coastal Nampula was hit by cyclone Dera. About 500,000 people were affected, of which 223,000 were displaced. Loss of life was minimal because of the slower onset of the disaster, as compared with the "wall of water" impact of the 2000 floods further south.

Agencies were better prepared to respond to the 2001 floods because the systems and contacts established in 2000 were in place. The government, the UN system, and the major agencies, such as the Mozambique Red Cross, had all undertaken lessons learning exercises and developed contingency plans, which resulted in significant improvements in responses. Preparedness measures had been taken, including the pre-placement of food, boats, and other relief materials. Contact with neighbouring countries also resulted in some coordination of discharges from the Kariba and Cabora Bassa dams.

The experience of the 2000 flood gave rise to intensive dialogue within Mozambique and between Mozambique and its aid donors. Detailed flood risk analysis was carried out across the country's river basins, identifying 40 districts with a population of 5.7 million that were highly vulnerable to flooding. Community-based disaster risk management strategies and disaster simulation exercises were conducted in a number of high-risk basins. Meanwhile, the meteorological network was strengthened: in flood-prone Sofala province, for example, the number of stations was increased from 6 to 14. In addition, Mozambique has developed a tropical cyclone early warning system.

Mozambique's policymakers also recognised the importance of the mass media in disaster preparedness. Radio is particularly important. The local language network of Radio Mozambique now provides regular updates on climate risks, communicating information from the National Institute of Meteorology.

During 2007, early warning systems and the media enabled government and local communities to identify the most at-risk areas in advance. Mass evacuations were carried out in the most threatened low-lying districts. Elsewhere, emergency food supplies and medical equipment were put in place before the floods arrived.

2.3. Risk Management Process

A periodic data collection (e.g. hydrological data, water levels at key points) can be used to conduct risk assessments to prevent damages to the population and to warn them in time. Collecting this type of data in developing countries can be very costly due to lack of equipment, unreliable infrastructure, lack of skills and inability to store historical data. Furthermore, this data should be interpreted periodically in order to provide a quick disaster response and - more importantly - prevent or limit the damages caused by natural disasters. Once this data is obtained, the standard Risk Management process (Figure 1, adapted from

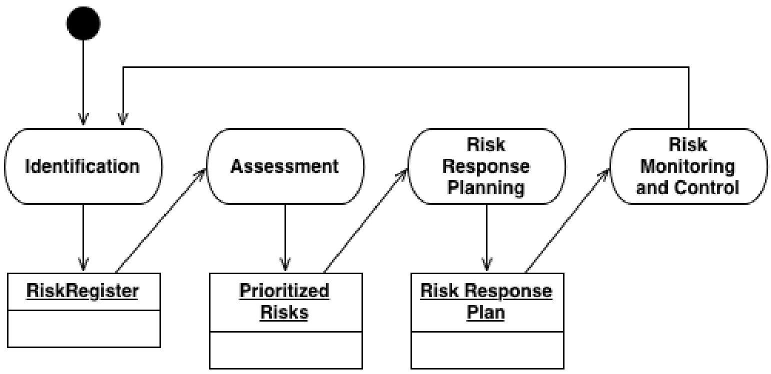

Figure 1 *Risk Management process*

PMI, 2013) can be performed by an individual or a group of experts.
The process is structured as follows:

1. **Identification:** this is an ongoing process as new risks may arise and existing risks may change over time. This process should identify and characterise the threats to a certain area by analysing the available data (see, for example, Brito, Famba, Munguambe, Ibraimo, & Julaia, 2009). Risks are elicited, for instance, with meetings, by looking at the history of a region, and by analogy with plans defined in similar regions (or checklists). The output of this process is a risk register that includes information such as risk probability, impact and counter-measures.

2. **Assessment:** not all risks are equally important and not all of them deserve the same attention. Therefore, this process assigns each risk a probability and an impact, commonly using five-scale values (qualitative assessment) such as the ones below:
    - Probability: Very Low, Low, Normal, High, Very High
    - Impact: Negligible, Minor, Major, Severe, Catastrophic
    - Impact on people:
        - None
        - Few minor injuries
        - Multiple minor injuries or a major injury
        - Multiple major injuries or a death
        - Multiple deaths and major injuries
        -
3. **Response Planning:** also called *Mitigation Planning*, this process aims at developing options and actions to enhance the opportunities to reduce threats (PMI, 2013). For each risk previously identified and evaluated (possibly both qualitatively and quantitatively), an appropriate response is chosen among the following:
    - Avoid
    - Transfer
    - Mitigate
    - Accept

4. **Monitoring and Control:** this process monitors risks according to the response plan(s), identifies new risks and monitors residual risks.

The Project Management Body of Knowledge (PMI, 2013) is an excellent resource to expand the students' knowledge on the subject as the PMBOK includes a Risk Management knowledge area. However, in this case study we are more interested in the first two steps of the process.

2.4. The Delphi Method

The project and the activities presented in this case study use the Delphi method for risk identification and assessment.

The Delphi method is a structured communication technique, originally developed as a systematic, interactive forecasting method which relies on a panel of experts (Dalkey,& Helmer, 1963). The process is the following:

1. The experts answer questionnaires in two or more rounds.
2. After each round, a facilitator provides an anonymous summary of the experts' forecasts from the previous round as well as the reasons they provided for their judgments.

3. Experts are encouraged to revise their earlier answers in light of the replies of other members of their panel.

The range of the answers is expected to decrease and the group should converge towards the "correct" answer. The process is stopped after a pre-defined stop criterion (e.g. number of rounds, achievement of consensus, stability of results) and the mean or median scores of the final rounds determine the results (Rowe, & Wright, 1999).

3. CLASS ACTIVITY

In this class activity, the students should be divided in teams of 3-4 people. After a presentation of the risk management process, the students are given the task of coming up with a set of *user stories* for an ICT tool to be used in Mozambique to conduct risk assessment using a Delphi-based approach. The following subsections present the four steps in which the activity is structured.

3.1. PRESENTATION OF THE REQUIREMENTS (20 MINUTES)

In this phase, the instructor presents the scope of the tool to be developed and discusses it with the students. Below is a possible scope definition that can be adapted to the level of the class.

- **Context:** we are building an application to meet the Emergency Department needs to assess different types of risks in Mozambique, in particular in rural areas.
- **Goal:** we want to develop an application to manage a risk register and to collect data from rural and remote areas. A risk register is a list of risks (characterised by different information) and to which an expert assigns priority and impact. The information we want to collect are simple reports by citizens or by volunteers around the country such as “the water level of the Limpopo river is unusually high at Macarretane”.
- **Why:**
    - The application will help the Emergency Department simplify the management of the risk register, possibly enabling forms of online collaboration.
    - Having updated data is crucial for being able to assess risks. However, rural areas are often cut off from the more urbanised areas of the country due to a very limited infrastructure. We can use local knowledge (experience and tradition) to get early warnings and aid experts in their risk assessment.

- In the long term, integration with other systems will simplify monitoring and alerting.

We thus want to develop three components for our system:

- **Risk Reporting:** a component that allows citizens to report potential risks.
- **Risk Identification:** a component that lists the risks reported by citizens and identified by experts from the available data.
- **Risk Assessment:** a component that allows the experts to classify and prioritise risks using the Delphi-method described in Section 2.4.

Other functions could be added as a bonus (for instance, attaching a risk response plan to a risk, attaching monitoring data to a risk).

3.2. Overview of the Constraints and Sustainability Issues (30 minutes)

Following the scope definition, it is important to discuss with the class the characteristics of the deployment environment. This is especially relevant for the Risk Reporting component as it involves the population in urban, peri-urban and rural areas. Having updated information is important for experts to be able to assess risks. However, the information available is often not up to date and monitoring stations are either not functioning or data is transmitted with so much delay that it becomes useless.

In this activity we are particularly interested in ICTs in Mozambique. Figure 2 shows how only limited broadband is available in the country while mobile telephony is widely available. This presents interesting opportunities to use less sophisticated tools such as SMSes to allow volunteers to communicate from remote areas. A more sophisticated approach could require the system to be designed so that data is stored on a device that can either be sent physically to the experts or that stores data until connectivity is available.

The students should be made aware of the fact that mobile connectivity is currently the main form of communication in Africa. In Mozambique, 56% of the population has access to mobile phones as opposed to only 0.3% of the population with access to a fixed telephone line. Internet is available only to 7.9% of the population[2].

[2] http://www.budde.com.au/Research/Mozambique-Telecoms-Mobile-and-Broadband-Market-Insights-Statistics-and-Forecasts.html

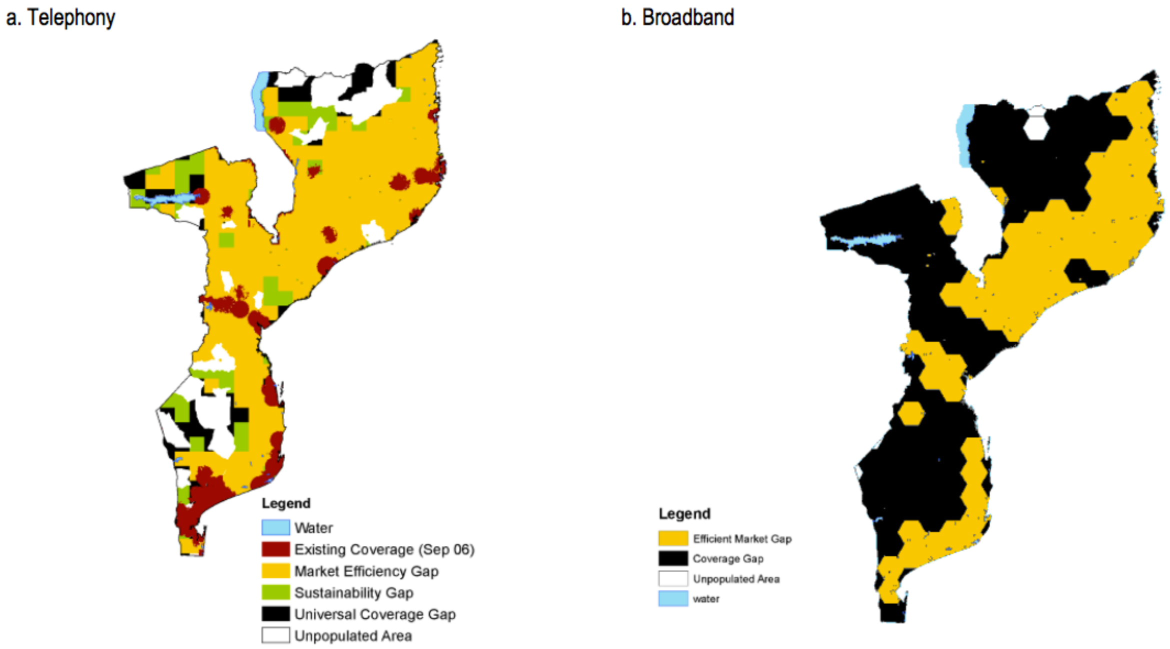

Figure 2 *Telephony and Broadband penetration in Mozambique*

On top of the infrastructural issues to be considered when elaborating the scope statement and the user stories, the students should also try to figure out how and which of the following sustainability constraints apply to this project (Inveneo, 2010):

- **Technology Constraints**
  - **Electricity:** Rural and other underserved locations rarely have a reliable electrical power infrastructure that can support a standard ICT implementation. Traditional computing systems are therefore cost-prohibitive – upwards of 200 watts per computer – when solar installations average $12 per watt. This project can be implemented without requiring the installation of hardware in rural areas. For example, if volunteers report risks via SMS, the only constraint related to electricity is the availability of power plugs to charge their phones.
  - **Computer Viruses:** Computer viruses are particularly problematic for underserved communities – the lack of connectivity and access to regular virus software updates often renders anti-virus protection useless over time. Once again, the use of SMS for reporting from rural communities mitigates this risk.
  - **Lack of Connectivity:** Local Internet Service Providers (ISPs) generally do not offer connectivity in the remote areas where we work and mobile phone data networks often have limited reach and can be prohibitively expensive. Figure 2 summaries the ICT penetration in Mozambique. While the use of SMS would allow us to mitigate the risk due to the wider

coverage of mobile telephony, it is important that the students consider the fact that even SMSes could take some time to reach the system due to bad reception or uncharged phones. A possible solution to this can be purely by using software or logistic. The system could allow volunteer reporters to store the reports on flash drives or their phone's internal memory, which would be automatically uploaded to the system as soon as connectivity is available. The logistic solution could require setting up data collection points in telecenters or other community centres that have more stable connectivity and electricity. Depending on the individual target areas, schools could be good candidates as they may have a computer and a working Internet connection.

- **Human Capacity Constraints**
  - **Inexperienced Users:** Because they haven't had access to ICT, inexperienced users often make simple mistakes that can render computers unusable. It is therefore important that the students include in their plan a survey of the ICT capabilities of the intended users (experts and volunteers) in order to set up the necessary training.
  - **Distant Tech Support:** All the previous challenges with ICT implementations in underserved communities are compounded by the lack of local capacity to provide technology support and maintenance. Without knowledgeable tech support, any mistake or user error can destroy a system, depriving the community of ICT's benefits. Yet communities often do not have the means to keep qualified technicians in their midst. Considering this, the product backlog could include features that simplify remote administration as well as fail-safe mechanisms.

3.3. User Stories Elicitation (40 minutes)

Based on the discussions of the previous two parts of the activity, the students are asked to come up with a set of user stories to implement a minimum viable product (MVP). The user stories should be in the form "As a <role> I want to <action> [in order to <goal to achieve>]". A possible solution is shown in Table 1.

3.4. Discussion and Prioritisation (30 minutes)

Once the user stories have been identified, the instructor should ask the students to present them in order to come up with a common version of the product backlog (i.e., a prioritised list of user stories). When a common product backlog is elaborated, the instructor can choose their preferred estimation method to allow the students to discuss and prioritise the user stories. For the estimation, story points can be used as they can provide a relative measure for each story without having to estimate man-hours or monetary costs.

3.5. Solution and evaluation criteria

The class activity should be evaluated based on the discussion during the four parts of the activity. Another parameter for evaluation is the level of detail of the motivations for the user stories produced by the students. An example backlog is provided in Table 1.

STORY	PRIORITY	COST
As a user I want to enter, edit, and delete risks. A risk is characterized by a description, a location, a type, a date, and a time.	H	13
As a user I want to view all the risks of a given type.	H	3
As a user I want to enter and view related data using selection lists (and not numbers)	H	1
As a user I want to search for risks by type, description, time, or location.	M	13
As a user I want to enter different intervals (time or date) for any given risk	M	1
As a user I want to view the locations on a map.	L	8
As a user I want to paginate the list of risks.	L	3
As a user I want to make sure only authorized people can edit risks.	M	20
As a user I want to attach a document to a risk.	L	3
As a user I want to define the types of risks.	H	5
As a user I want to define the locations using a geographical name.	L	8
As a user I want to define the locations clicking on a map and defining a radius.	L	13
As a volunteer I want to report an event related to a risk	H	20

STORY	PRIORITY	COST
As a volunteer I want to send reports via SMS so that I don't need to search for 3G signal	M	40
As an expert I want to assign a priority and a probability to a risk	H	5
As an expert I want to see the evaluations of other experts at the end of each Delphi round	H	8

Table 1 *Possible set of user stories. The Priority column shows a possible prioritisation (L=low, M=medium, H=high).*

4. Homework activity

The homework activity follows directly the activity in class and allows the students to take it to a first implementation stage.

Starting from the product backlog developed in class, the students are asked to:

1. Refine the estimation of the difficulty of each user story based on the experience of the team. This varies depending on the team members' skills. However, the challenges posed by the deployment environment should be taken into account when estimating.
2. According to the prioritisation and the estimated difficulty, the team should select the user stories for the first sprint[3]. They should consider a sprint duration of about 15 man-hours. The criteria for selecting the user stories should be the following:
    1.1. Priority.
    1.2. Difficulty (Cost).
    1.3. Organization of the work (infrastructure first).
3. The team should implement the user stories of the first sprint and submit their MVP for review. A summary of the design decisions made by the team should be submitted together with the prototype. They can be in the form of UML diagrams or of a short report.

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[3] A sprint is a time-boxed development phase to implement a set of user stories selected from the product backlog according to their priority and value. It should produce a working prototype or an increment on the product.

The submission to the instructors should include:

- The specification for the prototype, indicating the design choices made and how they address the infrastructural and cultural characteristics of the deployment environment.
- The backlog for the first sprint and a plan of the following sprint with motivations.
- A link to a public repository with the implemented prototype and a link to a working demo.

4.1. SOLUTION AND EVALUATION CRITERIA

There is no given solution for this homework activity. However, a possible working implementation can be found at http://dev.ict4g.org/crato and the code for an example solution implemented in Ruby on Rails is available at https://github.com/ict4g/ssror13_material/tree/master/exercises/rima. Below are some evaluation criteria to use for inspiration that can be used to evaluate the projects from two perspectives:

- Project management perspective
  - Adherence to the original specification.
  - Adherence to the user stories identified during the class activity.
  - Accuracy of the estimations.
- ICT4D perspective
  - How the design of the solution takes into consideration the infrastructural challenges and opportunities of developing countries. Some quantitative and qualitative metrics that can be used to evaluate this include:
    - Resources required by the technology and the implementation of the intended final system.
    - Technologies supported by the system (e.g. low-end smartphones, feature phones, SMS, etc.)
    - Solution adopted for storing and sharing information.
  - Whether or not and how was local knowledge, traditions and languages taken into account when designing the solution. For example:
    - If volunteers can send risk reports, do they have to send quantitative data? What about warning signs that are recognised by village elders and farmers?
    - Are there any plans to localise the interface of the system? Or has it already been localised?

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This project is funded by