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EVALUATION OF AN OPEN-SOURCE COLLABORATIVE WEBGIS PROTOTYPE IN RISK MANAGEMENT WITH STUDENTS

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ABSTRACT

Over the past decades, advancements in web services and web-based geospatial technologies have led to increasing delivery, access and analysis of rich spatial information over the web. With the use of open access data and open-source technology, it has become possible to make better, transparent and informed decisions for policy and decision makers. Under the framework of the European Marie Curie CHANGES project, a prototype web-based collaborative decision support platform was developed for the evaluation and selection of risk management strategies, mainly targeting flood and landslide hazards. The design of the conceptual framework was based on the initial feedback and observations obtained from field visits and stakeholder meetings of the case study areas of the project. A three-tier client-server architecture backed up by Boundless (OpenGeo) was applied with its client side development environment for rapid prototyping.

The developed prototype was tested with university students to obtain feedback on the conceptual and technical aspects of the platform as well as to analyze how the application of interactive tools in the exercise could assist students in studying and understanding risk management. During the exercise, different roles (authorities, technicians, community) were assigned to each group of students for identification and selection of risk mitigation measures in the study area: Cucco village located in MalborghettoValbruna commune of North-Eastern Italy. Data were collected by means of written feedback forms on specific aspects of the platform and the exercise. A subsequent analysis of the feedback reveals that students with previous experience in GIS (Geographical Information Systems) responded positively and showed interests in performing exercises with such kinds of interactive tools for learning, compared to the ones with fewer or no GIS experience. These results also show that the prototype is useful and supportive as a decision support tool in risk management while user-friendliness, interactivity and practical aspects of the platform could be further improved.

1. INTRODUCTION

There have been an increasing numberof disasters reported by natural hazards (EM-DAT, 2012). The frequency, magnitude and impactsof such hazards, especially in mountainous regions, are increased due to the changing patterns in climate and development (Sterlacchini et al., 2014).In the past years, structural control measures played an important role in the mitigation of disasters and protection of people. Few or no consideration was given to the long-term sustainability or social, cultural and environmental perspectives of the chosen risk reduction strategy(APFM, 2006).Only during the past decade, the need for an integrated risk management framework has been recognized, accounting for both temporary and permanent preventive measures in order to reduce the impact of natural hazards (Fuchs et al., 2012). Such kind ofintegrated approach calls for coordinated efforts in the selection of efficient and effective measuresin order to achieve the best combination of strategies and practicesregardless of the size of disasters (Hansson et al., 2008).It is important that diverse views and preferences of various stakeholders are considered in the decision-making process towards a common goal (Jankowski and Nyerges, 2001).

Natural hazards and associated risks are spatial in nature.Geographic information systems (GIS) arepowerful and valuable tools for spatial data analysis, manipulation and visualization in disaster risk management. Nowadays, with an increasing and emerging use of the web and geospatial technology, it has become possible not only to share, exchange and disseminate but also to analyze spatial information over the web.A web-GIS architecture thus allows users with different values from different organizations, located in different places at the same or different time, to seamlessly collaborate via a web environment (Dragićević and Balram, 2004). Moreover, the growing use of open access data and open-source technology makes it possible to enable a better, transparent and informed decision-making process for policy and decision makers.Many researches have initiated for decision support in the fields of planning, environmental and natural hazards management (Geertman and Stillwell, 2004;Salewicz and Nakayama, 2004; Sugumaran et al., 2004; Mysiak et al., 2005; Pasche et al., 2007; Zhang et al., 2011).Despite the variety of applications, there arefew systemswhichattempt to engage various stakeholders especially in planning of combined risk management strategies based on available risk information, through the integration of collaborative web-GIS based platformwith decision support tools.

Under the framework of CHANGES project, an online collaborative web-GIS platform was developed for risk management of hydro-meteorological hazards, in particular floods, debris flows and landslides. The aim of this decision support platform is to assist and integrate stakeholders' inputs into the formulation and selection of different risk management measures.To collect the preliminary feedback, the prototype platform was presented to the local and regional stakeholders of the case study sites(Romania, Italy and Poland) during the dissemination meetings of the project.As a further step, in this study, the prototype was tested with students from University of Lausanne (Switzerland) not only to obtain in-depths feedback on the different aspects of the platform (such as visualization, accessibility, usefulness, ease of use and so on) but also to analyze the potential of such interactive tools for students' learning process related to natural hazards and risk management.In thispaper, sections are organized as follows: section 2 introduces the collaborative web-GIS framework of the developed prototype.Section 3 presents the structure of the evaluation exercise carried out with students,along with the study area used for the exercise. The feedback results of the tested prototype arepresented and discussed in Section 4, and finally, we conclude the paper (section 5) with presented aspects and potential perspectives of the developed platform.

2. A COLLABORATIVE WEBGIS PROTOTYPE

The preliminary conceptual inputs of the platform were derived from initial field visits and stakeholder meetings at the three European case study sites of the project: Buzău County of Romania,the Friuli-Venezia-Giulia region of Italy and the MalopolskaVoivodeship of Poland. During the recent years, natural hazards such as floods, landslides and debris flows have occurredand affected mountainous communities in these study areas. Moreover, these areas suffered from the lack of funds, urging for a more efficient use of limited resources and better interactions between responsible authorities managing the risk (Prenger-Berninghoff et al., 2014).Although different platforms appeared to exist in the study areas, there is no collaborative platform in the selection of risk management alternatives, which brings together therelevant stakeholderswith different expertise in risk management (Aye et al., 2014). This collaborative framework, hence, specifically combines a web-GIS interface with a multi-criteria evaluation (MCE) tool to support stakeholders in decision-making process, allowing to identify and compare different alternatives in a participative manner, and this could ensure the proper and efficient use of limited funds and resources in risk management.

Figure 1 illustrates the main features of the platform, consisting of 1) Main navigation panel on the left with access to three main modules (i.e. *data management*, *risk management* and *user management*); 2) Map view panel in the center (with layer navigation and legend panel on the left) with tools for zooming, searching locations, styling, drawing and editing features, etc.; and 3) Data view panel in the south to show feature information of the respective (vector) map layers. The *data management* module includes the tools for uploading and visualizing of raster and vector maps as well as for creation of vulnerability curves. The main features of the *risk management* module are qualitative and quantitative risk analysis tools as well as tools for creation and selection of different risk reduction scenarios.The *user management* module is used for creating, assigning and managing user accounts and roles used in the collaborative process.

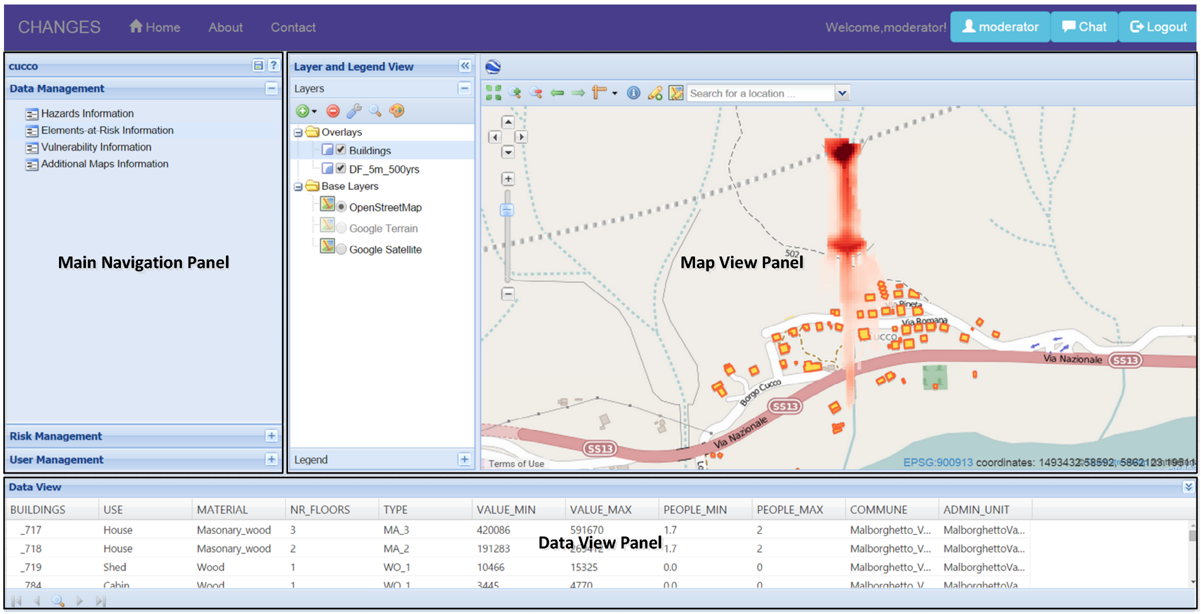


Figure 1. Main features of the prototype platform (for a user with admin rights).

The prototype is fully functional and developed based on theBoundless framework, i.e.an open-source geospatial software with modular components, and its client side software development kit (SDK). This was chosen due to a modular, customizable and extensible framework for the development of high-level web applications with built-in plugins and widgets for integration of existing map tools and functionality.A number of open source software solutions are employed: GeoServer for web map server;GeoWebCache for tile cache; PostGISdatabase for spatial data storage; GeoExt, ExtJSand OpenLayersfor user interface development and PHP server scripts.

This prototype was presented to the stakeholders from the three study areas and preliminary feedback was collected to obtain their opinions and suggestions. From the 49 collected forms, it was concluded that the platform is useful, innovative and supportive while user friendliness and practical aspects could be improved. Results obtained from this first round of feedback can be foundin the relatedpublications (Aye et al., 2014; Aye et al., 2015).

3. EVALUATION OF THE PROTOTYPE(WITH STUDENTS)

3.1 Structure of the evaluation exercise

To collect the feedback on conceptual and technical aspects of the collaborative platform, the prototype was further tested with university students. The evaluation of prototype with students is also believed to allow them in learning aboutrisk management with a “real world” problem of decision making. This kind of activity can be regarded as “active learning” in which students are involved “in doing things and thinking about the things they are doing” as defined in Bonwell and Eison (1991, p.2).Well-designed activities can contribute to the understanding of concepts to be learned (Wiggins and McTighe, 1998).

Thisevaluation exercise was carried out, during a morning session of a course on risk communication,with8 Master students(majoring in Geology, Risk analysis and monitoring,Environmental risks, Social environment) at the University of Lausanne. The exercise is composed of three main stages: 1) Identification of areas at risk; 2) Formulation of alternative scenarios; and 3) Selection of alternative scenarios. These steps followan integrated risk management approach with involvement of various stakeholder groups.The students (in groups) played the roles of different stakeholders depending on the stages of the exercise(i.e. stage 2 and 3). The structure of the exercise is illustrated in Figure 2.Some of the necessary information (e.g. creation of user accounts, uploading of maps, etc.) wasprepared by the moderator (teacher), considering the limited time allocated to the exercise. The moderator is an administrative user with the capacity to moderate the whole process, and could be one of the expert stakeholders in a real life setting.

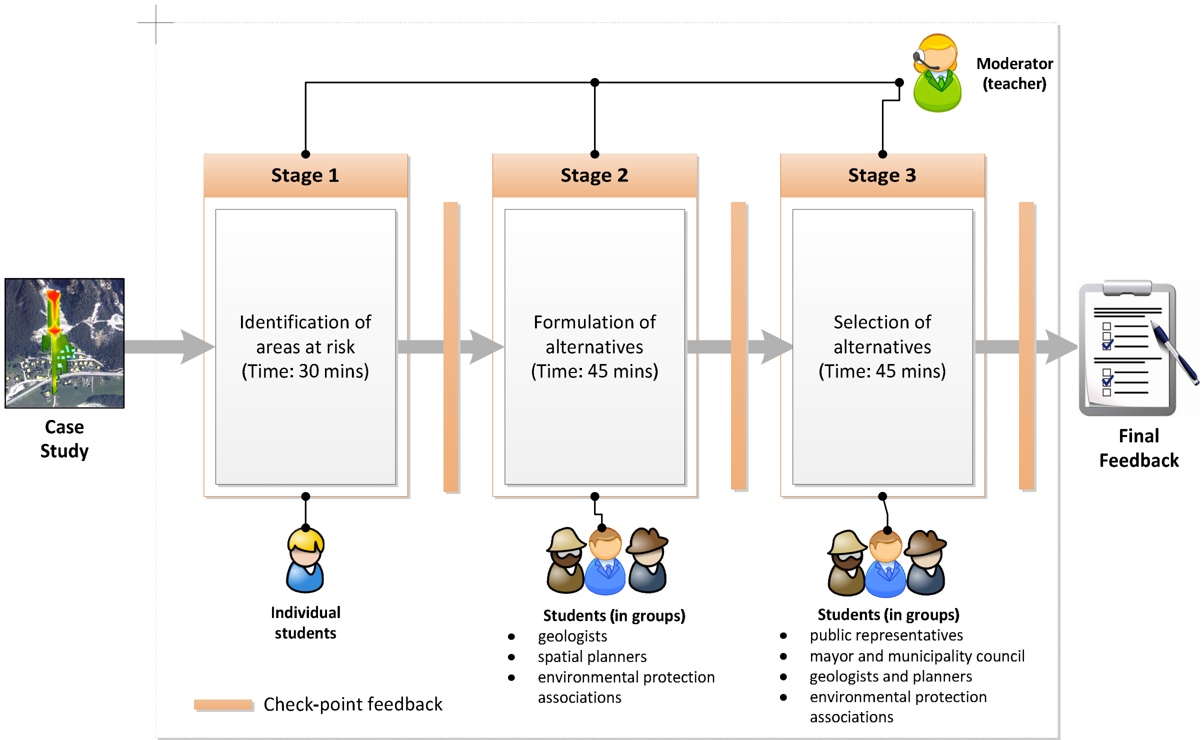


Figure 2. Structure of the evaluation exercise of the prototype.

As a guidance of the exercise, the following documents were handed out to the students at each stage of the exercise:

- *log-in* access information,
- a *scenario*sheet including the step-by-step instructions to follow by the students,
- a *role description* sheetincluding the description of the stakeholder roles for group works, and
- a*check-point feedback* form including the evaluation of certain aspects of the prototype, to be filled out by students at the end of each stage. It was composed of 1) an open question for the analysis of the presented problem; 2)five to ten rating questions (with a scale of 1 to 5) for specific evaluationson the interface and functionality; and 3) two open questions for improvements and suggestions on the presented stage of the prototype.

At the end of the exercise, the students were asked to fill two *final feedback* forms:*user evaluation* and *exercise feedback*. The *user evaluation feedback* evaluates the overall prototype such as innovativeness, interactivity, usefulness, user-friendliness, satisfaction and support as a decision support tool, rather than detailed aspects like in thecheck-point feedback. The *exercise feedback* evaluates the exercise itself in order to have the understanding and opinions of students on the presented aspects such as usefulness forlearning and understanding,helpfulness in understanding of how real world situation works, stimulation of interests in risk management topic andin doing further exercises which involve interactive tools.

3.2 Study area of the exercise

The Cucco village, Malborghetto-Valbruna municipality located in North-Eastern Italy, was used as the study area for the exercise. This area has been affected by debris flows in August 2003 and some houses were damaged. After this event, new mitigation measures were placed by the Civil Protection. This debris flow event is estimated to have a return period of 500 years according to the rainfall data analysis and potential future scenario was modelledto identify remaining risk and assess the effects of existing mitigation measures in the area (Hussin et al., 2014).

3.3 Three stages of the exercise

In the *first* stage (see Figure 2), individual students were asked to identify the areas at risk in Cucco village.For this purpose, debris flow hazard and building footprints mapswere uploaded beforehand into the platform by the moderator. The students conducted their analysis by simply overlaying these two layers and visualizing the areas being touched by debris flow in the web-GIS interface of the platform.

After identifying the areas at risk, the next step is to determine the possible measures to protect those areas at risk. Therefore, in the *second* stage, students worked in three groups assigned with a stakeholder role that are representative of a real-life situation: geologists, spatial planners and environmental protection associations. The task of each group is to design its own alternative scenario, which is a combination of possible risk reduction measures (both structural and/or non-structural measures).Potential structural measures include creation of new mitigation measures, structural adjustments of the existing measures or houses. Non-structural measures concernednon-physical actions such as relocation of houses, natural regeneration in the area or establishment of an early warning system. Each group of students proposed its own alternative scenario by creating (sketching) measures in the platform.In the check-point feedback form of this stage, the students were asked to explain why their scenarios should be considered as the most appropriate compared to other groups, along with other specific assessments of the functionality provided.

The alternative scenarios proposed by different groupswere evaluated and ranked in the *third* stage of the exercise in order to select one single alternative scenario.The decision-making process that is needed to achieve this selection benefits from using MCE methods. These methods consider the inclusion of additional important criteria such as social and environmental impacts than the traditional cost-benefit analysis (Munda, 2004) in evaluating the performance of alternatives. In the prototype platform, Compromise Programming (CP) method (Zeleny, 1973; Simonovic, 2010) is used to calculate the ranking of alternatives. This method identifies alternatives which are the closest to the ideal solution by means of distance values. The ideal solution is the one for which performance values of all considered criteria are maximized.The alternative with the minimum distance value to the ideal situation is considered as the "best compromise solution".For the simplification, within this exercise, criteria are pre-defined by the moderator (in real life, an expert) to evaluate the performance of the alternativesderived from the second stage. The alternative scenarios and their correspondingperformance values against criteria are evaluated by the moderatorin advance due to the time constraints of the exercise.Four groups of students are re-assigned in this stage to work in groups: public representatives, mayor and municipality council, geologists and planners, and environmental protection associations.The task of each group is to rank the alternatives by assigning weights to the defined criteria. In other words, depending on the role of each group, the students are asked to classify the importance of the criteria (with a scale of 1: the least important to 5: the most important criteria). Within the platform, each group can assign weights and visualize their ranking outcomes of alternatives in comparison with the ones of the other groups. A negotiation process(using the chat function) is started with the other groups to try to achieve a final ranking of the alternatives on which every group agree. In the follow-up check-point feedback form, students commented on the results of their given weights and ranking outcomes as well as on the certain aspects of the interface such as visualization of charts for criteria weights and alternative rankings.

4. RESULTS AND DISCUSSION

4.1 Check-point feedback

The check-point feedback evaluates certain parts of the prototype in three sections as explained in Section 3. To demonstrate the*open analysis question*, the results obtained from the second stage of the exercise are presented. As an example, the measures designed by the geologist group is illustrated in Figure 3. This group of students proposed the combination of measures which included the improvement of the retention basin, the barrier nets and the protection forests in the area. In their opinions, structural measures are effective and durable despite bearing the high cost in the implementation of such measures. Similarly, the planner group also proposed structural measures such as the structural adjustments ofhouses and implementation of individual measures such as small walls and metal plates for the protection of houses. However, as opposed to other groups, the group of environmental protection associations proposed non-structural measures such as awareness raising, early warning system and relocation of houses which are believed to be better than structural measures as the later might give theillusionto the people that such measures fully protect them).These feedback results show that students performed wellin role-playing and proposed differentmitigationmeasuresaccording to their assignedroles of stakeholders. Importantly, this participatory exercise with engagement of expert stakeholders also demonstrated why anefficient, combinedand coordinated risk management strategy is important inrisk management.

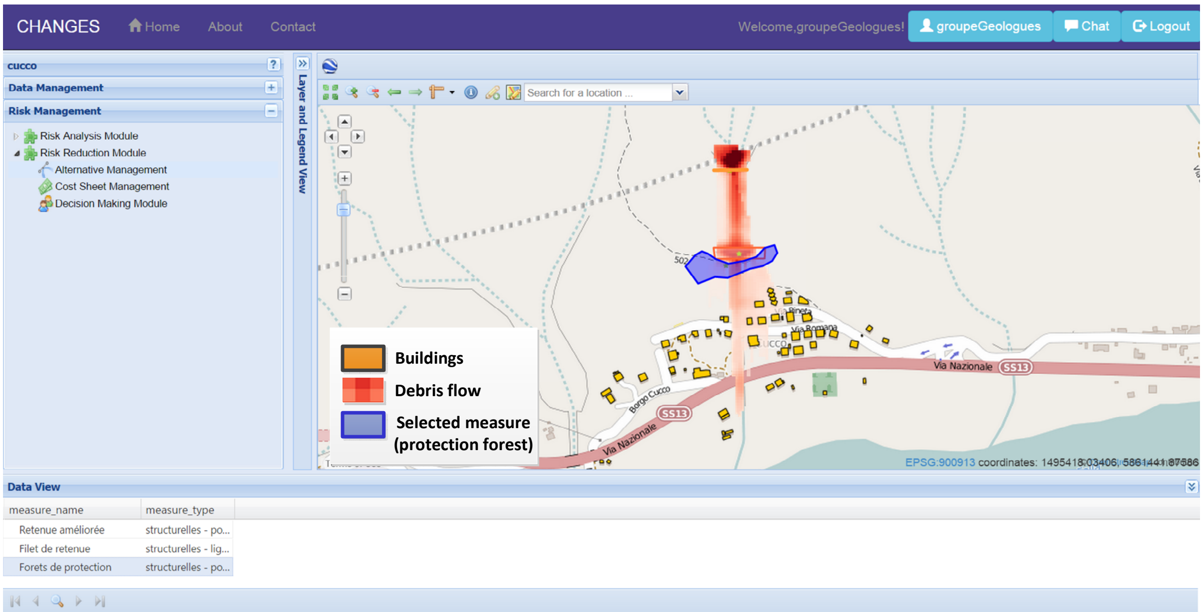


Figure 3. An alternative scenario as designed by a group of students (geologists).

The *rating questions*were related to various aspects of the interfaces, tools and functionality such as user-friendliness, satisfaction, usefulness, supporting ability, relevance and understanding of contents and so on. A total of 21 rating questions were collected for three stages of the exercise. Table 1 presents some extracted check-point feedback with respective average scores given by the participating students. The rating score ranges from a scale of 1 (Not at all) to 5 (Absolutely). As can be seen in the table, the user friendliness of sketching interface could be improved (average score = 3.5). This is maybe due to the confusing layer style option. This can be improved by restricting the sketching tool to allow only either point, line or polygon geometry within the same layer. However, students mentioned thatsketching tools (i.e. “create” and “editing” feature) are useful for designing measures (average score = 4). The chart options were also found helpful to visualize criteria weights and compare alternatives with others (average scores> 4) in the third selection stage of the exercise. Overall, the transparency of decision-making process achieved an average of score of 3.9, in which students with experiences in GIS (75%) scored 4.7 and the rest (25%) scored only 1.5. This explained why high transparency score is not achieved as expected.

Table 1. Selected check-point feedback(with average scores) given by students.

Selected questions	Average scores
How easy was it to find the maps you needed to visualize?	3.9
How easy was it to sketch measures in the map interface?	3.5
How useful is the “create” and “editing” feature tools?	4

How helpful would it be if a toolbox of mitigation measures was available?	4.5
How understandable is the weighting scale?	4.3
How helpful is the pie-chart visualization (criteria weights)?	4.4
How helpful is the comparison of ranking outcomes with other groups?	4.3
How transparent is the decision-making process?	3.9

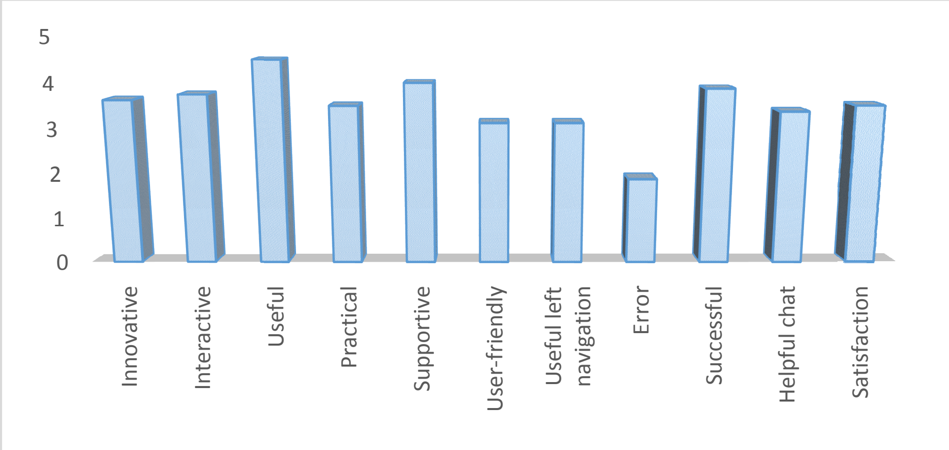
Regarding the *open improvement and suggestion questions*, feedback of students provided an important input for the improvement of the prototype platform such as:

- the visibility of layer and legend view tabshould be expanded and visible;
- the geographical coordinates on the map should be available;
- the visibility of the hazard zone in the image should be made more understandable;
- the compatibility of additional browsers for 3D Google Earth visualizationtool should be improved;
- the readability of the interface should be improved;
- the visibility and friendliness of tools for the creation of alternative scenarios should be enhanced;
- the weighting scale of criteria should be indicated;
- the (stacked) bar chart visualization for ranking outcomes should be clearer;
- the explanation of the terminology usage in the interface should be provided andof the chat option should be made better accessible.

4.2 Final feedback: prototype

In the first section of the *evaluation feedback* form, students were asked to explain, in a few words, their understanding of the tested prototype. Students mentioned that it is a good decision tool for formulation and selection of scenarios with all the concerned actors in the presented risk zone. Moreover, it was stated that the tool is not only useful to communicate hazards and related impacts but also to enhance the collaboration betweenthe different experts in risk management. It was also mentioned that the tool allows to include different privileged criteria for the parties in decision making for the selectionof alternatives.According to feedback responses, the purpose of the platformwas well-understood and thus one of the important evaluation aspects of the exercise and platform was fulfilled.

The average scores for overall aspects of the prototype are shown in Figure 4.As can be seen in the figure, the students found the platform useful (average score = 4.5), and supportive as a decision support tool (average score = 4). Meanwhile, user friendliness of the interface and the usefulness of themain left navigation panel could especially be improved (average scores of 3.1 for both). The feedback results also show that the prototype platform is successful in performing its intended task (average score = 3.9).The overall user satisfaction achieved an average score of 3.5 (i.e. more than enough in the scale of 1-5), which is acceptable considering theunavailability of tutorial documentation and training sessionsfor students before the exercise.



Q1.	Is the prototype innovative?	**Q7.**	How useful is the left navigation panel to find information needed?
Q2.	Is the prototype interactive?	**Q8.**	How often the prototype have errors and need to refresh?
Q3.	Is the prototype useful?	**Q9.**	How successful is the prototype in performing its intended task?
Q4.	Is the prototype practical?	**Q10.**	How helpful is the chat functionality between users?
Q5.	Is the prototype supportive as a decision support tool?	**Q11.**	Are you satisfied with the prototype, in overall?
Q6.	Is the prototype easy to use?		

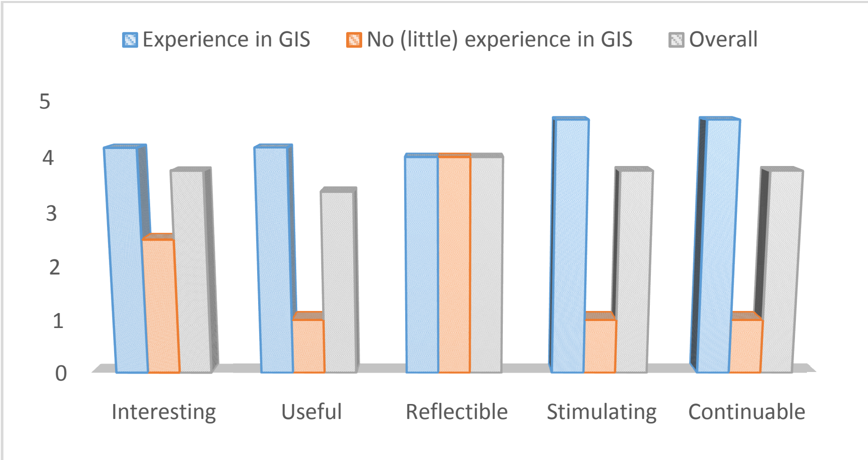
Figure 4. Feedback on the platform (overall) based on the rating scale of 1 to 5.

For the overall aspects to improve, students stated that the tool needs to be more interactive, accessible, user-friendly and intuitive. During the short discussion, they also mentioned that the availability of a step-by-step video explanation, manual or training documentation of the tools and modules would be helpful in using the platform.Moreover, some mentionedthat the applicability of the platform in real world by the authority could be limited as risk management is quite “tricky”, and we agree that potential ways of how to encourage and engage stakeholders in the process should be explored. However, it should also be noted that the purpose of a decision support platform is to assist the stakeholders in making better-informed decisions by providing necessary information and tools. Therefore, the legal responsibility of stakeholders and the primary decision makerremains depending on the institutional context of the study area where this platform is applied.

4.3 Final feedback: exercise

The first section of the *exercise feedback* formasked students of what they learned from this exercise. Note that all participating students had previous experience in role-playing. Students mentioned that it is a multi-disciplinary tool for decision making and the exercise was very useful as they were able to see the effects of the same problem from different points of views.They have also learned how an optimal decision can be reached considering different aspects at the same time in comparison with other stakeholders.

Figure 5 shows the average ratings of the five questions asked in the second section of the exercise. According to the responses, the students with experience in GIS (75%) found the exercise quite interesting, useful and helpful; while almost excellent in stimulating their interests in risk management topic and doing other exercises with such interactive tools. On the other hand, the students with few or little experience in GIS (25%) found that the exercise is quite helpful in understanding of how real situation works while results were quite low for the other questioned aspects.This result is not surprising as these students did not haveexperience working with similar software, and thus, the feeling of being uncomfortable doing the exercise and using the platform for the first time is believed to be normal. This aspect could be improved by giving training to students before the actual exercise.



Q1. Is this exercise interesting?
Q2. Is this exercise useful for your learning and understanding?
Q3. Is this exercise helpful in understanding of how real situation works?
Q4. Does this exercise simulate your interests in risk management topic more?
Q5. Would you like to do other exercises with interactive tools?

Figure 5. Feedback on the exercise based on the rating scale of 1 to 5.

Regarding aspects of the exercise to be improved, students commented that more time for the exercise is needed in order to present and discuss the results with others (to reach a best consensus solution at the end). It has also been mentioned that the exercise gave them a good ideaof the difficulties that can be facedin risk management based on participative decision making. Students with no or few experience in GIS stated that use of the platform could be more simple and adaptable for those who never worked in a mapping environmentbefore (or alternatively, training can be given to those). Nevertheless, less-experienced students found the exercise interesting to understand scenarios of risk management because this topic is not addressed in their major, i.e. social environment.

For the allocated time frame of the exercise, at least one half-day should be allocated so that sufficient time is given not only for the good explanation of the theoretical framework of the platform but also for the follow-ups discussion with students at every stage of the exercise. This could especially enhance the usefulness aspect of the exercise in learning and understanding of the presented topic. During the exercise, it was observed that students were less confused andadapted to the exerciseas the time went on. The students especially enjoyed the third stage of the exercise in assigning preference weights on criteria according to their playing roles and in comparing the outcomes with other groups for the selection of alternative scenarios.This is, maybe, due to the simplicity and less complicated steps needed to perform in this stage of the platform. Or maybe because this is the most interesting part of the exercise asinteractions take place between groups (unlike in other stages: individually or within groups). Discussion within some groups also got little heatedas they debateoverwhich measures to propose in the second stage of the exercise. However, all groups managed to finish the tasks within the specific time frame. Interestingly, one student, in particular, expressed that "collaboration is hard" when being asked to explain what they learn from this exercise. In addition, some students raised questions and showed their interests in the approach used for the decision-making process.

5. CONCLUSION

In this paper, we presented how the evaluation of a collaborative decision support platform was carried out with Master students from University of Lausanne majoring in environmental topics. Thisevaluated prototype was developed based on the open-source framework, and combined web-GIS interface with a MCE tool for decision support in selection of risk management strategies for natural hazards like floods and landslides. The role of students in this exercise was to evaluate the prototype as well as to learn the process of risk management through the evaluation process, which allows them to analyze the presented problem, propose and select a solution by working together with other students. Students in groups (towards a common goal)brought their own experiences and background knowledge as they come from different specialized majors. As discussed before, conflicting interests and values between different groups were observed, for example, structural measures were more favored by geologist group while nature group favored non-structural ones. To achieve the most appropriate solution, all potential alternatives should be considered and compared against each other in terms of economic, social and environmental criteria. This allowed to reflect the real inter-disciplinary situation in which the involvement of various experts, decision makers and the community is crucial to achieve a sustainable and combined risk management strategy,especially for the case study areas where limited funds are available and weak link of interaction activities exist between risk management stakeholders.

In overall, the analysis of feedback results especially shows that the prototype is quite supportive and useful as a decision support instrument with good performance in carrying out its intended task. However, aspects such as user-friendliness, interactivity and practical aspects of the platform could be further improved.As students suggested, provision of manual documentation and or video demonstration would be helpful in using the platform. Importantly, students benefit learningfromthe prototype evaluation. During the exercise feedback,75% (i.e. 6 out of 8 participated students) responded positively and showed great interests in active learning with such interactive tools, compared to the rest which had no or few GIS experience. However, this can be improved by giving training to those who are not familiar with GIS applications, if such innovative hands-on exercises were to be developedforrelevant courses at the university. Nevertheless, all students agreed that this exercise reflected the real situation and helped them in improved understanding of the decision-making process in risk management. This feedback provided an important inputnot only for further improvements on presented aspects of the prototypebut alsofor potential application of the platform for activelearning with the students. Some of the improvements are already considered in the next version of the prototype and it is also planned to adapt the platform for environmental risk related exercises with Bachelor students at the university.

6. ACKNOWLEDGEMENTS

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