MurGame:
Protect your village from debris flows!

Information for players, Version MurGame 2.0

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Change control

Version	Date	Name / Job	Remarks
1.0	16.11.2021	Developer team	Supplement for online version of MurGame 2.0

Comments on the document

Created with	Microsoft Office Word, Version 2010
File name	\\geo7\data\3000_projekte\4171 murgame weiterentwicklung\05 bearbeitung\01_dokumentation\release2 unterlagen\murgame2 informationen für spielende 20210809_v2.docx
File size	9219 kBytes

Content

1 Introduction

Past natural hazard events tend to leave a significant imprint in people's memories. Debris flows, like in Bondo (GR, 2017) and Brienz (BE, 2005) have been heavily covered in the (Swiss) media, illustrating how destructive such events can get. Protection measures play an important role in dealing with natural hazards. Debris flows are considered to be very complex and multidimensional processes. Imagining and foreseeing the course and progression of a debris flow as well as estimating the potential damage and the influence of protection measures is a difficult task. Serious games offer a possibility to simulate these kinds of situations.

With the MurGame, we have developed an application for natural hazard prevention. In the three-dimensional, interactive game, a village is created step by step by selecting different objects, such as residential buildings or schools. Debris flow simulations show, which buildings would be destroyed and what damage would occur in the event of a debris flow. Different protection measures may be implemented to protect the village. Their effectiveness can be monitored during the simulation of another debris flow. After the event, it is necessary to evaluate which measures offer the desired protection, what they may cost and how the needs of the population are met.

The MurGame can be played online at www.murgame.ch.This document provides an overview of the MurGame and explains the most important features and keywords. Further detailed background information is available for those interested. Additional developments are possible, and therefore user feedback is welcomed by the developers and promoters of the MurGame.

Figure 1: Impressions MurGame 2.0 - Protect your village from debris flows! A village is built on the alluvial fan which is then severely damaged by a debris flow. After the event, several protection measures may be implemented to reduce the damage of future debris flows. A report shows the development of costs and damage over several game rounds. It then finally becomes a matter of optimising the protection measures.

2 Overview of the MurGame

2.1 Game goals

The MurGame teaches various aspects of integral risk management through the example of the debris flow hazard process. If a debris flow occurs, human lives, buildings and infrastructure facilities are threatened. The aim of the interactive game is to reduce the possible damage caused by debris flows by means of various constructional and organisational measures and spatial planning, while obtaining the best possible cost-benefit assessment. In order to achieve this goal, the MurGamer has to fulfil a minimal number of tasks, which include the expansion of the village as well as the implementation of effective protection measures. A focus should be given to the economic efficiency of the measures. Therefore, it is crucial to achieve an optimal balance between the prevented damage and the construction costs. Besides the cost-benefit considerations the success of protection measures will also be dependent on the acceptance of the measures by the village population. All these aspects must be coordinated in order to best protect the village that has been built.

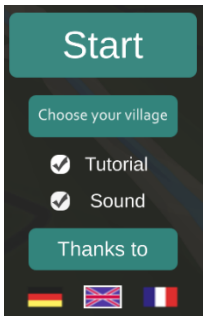
2.2 Target group

The game reaches out for different target groups, primarily for those with limited background knowledge in natural hazard management. The MurGame offers information for those who seek an alternative approach to introduce the topic of integral risk management. It may also be integrated on websites. Another suitable implementation would be to include the game during conventions or events (e.g., trade fair), with an information booth including supervision. The game may also be used as a presentation tool during lectures. In the context of training and further education, supplementary topics can be focused on (cf. game ideas in chapter 7 and supplementary materials under "Documents" on the main webpage www.murgame.ch).

2.3 General settings

In the main menu, the following settings can be selected and further information can be retrieved:

- Start of game:
  - Start without the tutorial: uncheck the tutorial box
  - Start with the tutorial: check the tutorial box
- Choose your village: While staying within the same browser session, previously built villages can be reused and modified.
- Sound: check or uncheck the sound box.
- Thanks: Information about the sponsors, the development team and the e-mail address for questions and feedback about the MurGame.



- Choose your language: Switch between German, English and French via the respective country flags.
- Full screen display: Switch to full screen via the full screen icon at the bottom right. Press the ESC key to exit full screen mode.

- Pause the game: After starting the game, it is possible to return to the main menu via the exit button at the bottom left.

- Turn off sound: While playing the game, the sound can be switched on and off via the speaker icon at the bottom left.

2.4 Playing time

The playing time is approx. 10 - 15 minutes but can be extended or shortened if necessary.

2.5 First steps

The first step of the game includes the construction of a fictional village. The tutorial helps with going through the first tasks step by step. Feel free to skip the tutorial, if you already know how to play the game. The game can be paused at any time by pressing the "Exit" button at the bottom left, which will take you back to the main menu. The course of the game follows the scheme according to figure 2.

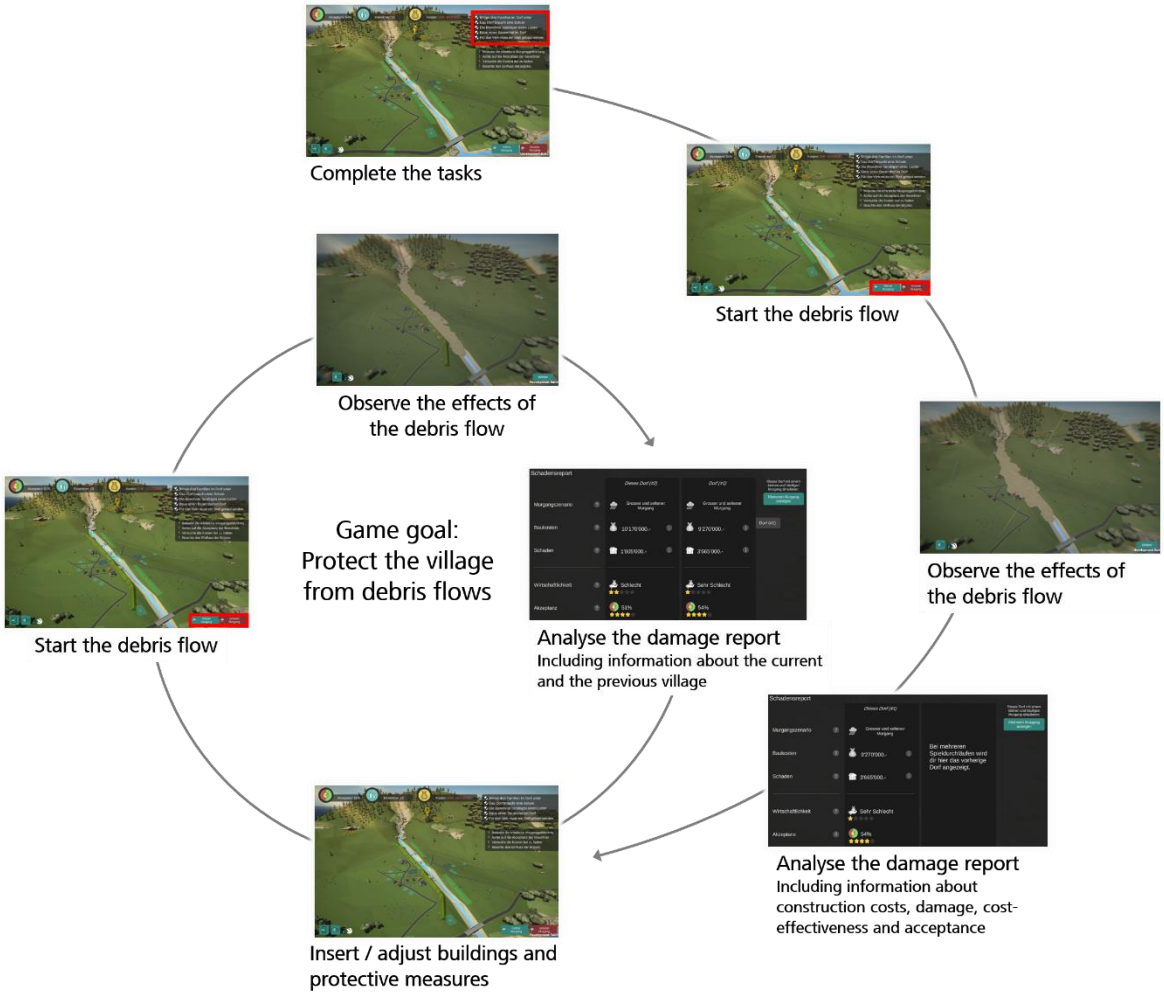


Figure 2: Schematic course of a gaming session in MurGame 2.0. The aim of the game is to provide protection for the village by optimizing effectiveness and costs of protection measures.

To start with the game, it is required to fulfil a minimal number of tasks. Buildings (like houses, barns etc.), bridges or campsites can be selected and placed on plots highlighted in blue. As the number of housing increases, so does the number of inhabitants. Additional facilities (e.g., a school), are needed to fulfil the requirements of the growing population. Building costs are continuously added up and the acceptance among the population with these facilities changes depending on the built objects. The simulation of a small debris flow can be started, as soon as the minimal tasks are fulfilled and the village is set up. After a debris flow event, the damage report provides information on construction costs, damage caused and acceptance by the population in respect to the village infrastructure.

The next step includes the construction of protection measures in and around the village. Existing buildings may be relocated or demolished. Plots for the construction of protection measures are highlighted in green. Changes to an existing object may be made by clicking on that object.

As soon as the player is happy with the setup of the village, a second debris flow can be simulated. The updated damage report allows the player to assess the effects of the protection measures, their construction costs, the damage caused or prevented and the acceptance of the measures by the population. In addition, the economic efficiency of the protection measures is calculated. The data is calculated for each village setting, including measures and size of the debris flow. The different village designs can be compared with each other.

In order to fulfil the game objective in the best possible way, an optimal relationship between economic efficiency, acceptance within the population, construction costs and the damage must be achieved. However, as in reality, it will never be possible to achieve a complete protection against natural hazards. Therefore, the player must find the best possible balance between the degree of protection, the costs of implementing the protection measures and the residual risk.

2.6 Tips and Tricks

- Change perspective: Change the perspective while zooming in and out. Some elements are not visible in the standard view. Maybe your villagers would like to welcome guests to their campsite, or you are planning to protect it by means of a debris flow barrier? Pay attention to the forest, as it plays an important role when planning protection against natural hazards.
- Buildings of different sizes: Large buildings such as a school, a farm or a church require a lot of space and therefore a large plot. For smaller buildings (e.g., a house, shop or stable) a small plot is sufficient. The plot sizes are differentiated by colours: light blue for small plots, dark blue for large plots. Select a small or large plot depending on the size of the building you want to build and then add your desired object.
- Construct, relocate and demolish buildings: Click on a free plot to construct a building/object. By selecting an existing object, you can demolish the object for free or relocate it to another free plot.
- Bridge: yes or no? This is a central question! Do we connect the parts of the village on both sides of the stream or not? It would definitely be a practical building and the acceptance among the population would be accordingly high. However, it also represents a point of weakness in case of a debris flow. As events of recent years have shown, debris flows and floods tend to break out of their channel at narrow passages, like bridges. Is it possible to prevent this, just by building a larger bridge?
- Range of protection measures: The green plots indicate locations for protection measures as well as organisational measures (e.g., barrier, information bulletin, siren) and structural measures. Structural measures can influence the spread of a debris flow on the alluvial fan: Retention (bedload retention basin, debris flow net) or guidance structures (e.g., check dam, concrete wall) are available. Spatial planning measures such as relocation or object protection measures are applied directly by clicking on the building.
- Small or large debris flow: The aim here is to find out, whether the protection measures are built to withstand debris flows of different magnitude. And if not, where their limits are. In some scenarios, there is a sufficient protection against the small debris flow, but we have to live with the danger of not being entirely protected against a large debris flow. Scenarios like this, directly lead to a discussion about risk! As a suggestion: start with a small debris flow first…
- Debris flow retention at the apex of the alluvial fan: The bedload collector or the debris flow net can hold back a small debris flow and offer good protection. However, the retention volume is limited, and a large debris flow can still cause major damage to the village and its infrastructure. In addition, some villagers are not particularly fond of these

retention structures. The question is how much protection do we want, what damage are we willing to accept and how do we deal with the acceptance of the measures within the population.

- **Damage report**: This report provides an overview of the most important key figures (construction costs, damage caused, cost-effectiveness of the measures and acceptance by the population). For the construction costs, a distinction is made between buildings and protection measures. The damage is shown according to the size of the debris flow and divided into personal injury, property damage and damage to structural facilities. The economic efficiency of the measures and the acceptance by the population are determined for a small and a large debris flow. Incidentally, the large debris flow (or small debris flow) does not have to be modelled separately. Instead, the other event can be displayed directly in the damage report on the right-hand side.
- **Choose your village**: Village settings, that have already been set up and for which a damage report has been calculated, can be reloaded and changed at a later time within the same browser session. This can be done via the main menu via the menu of the damage report. Maybe you already had a good solution and only want to optimise a few things?
- **The crucial question at the end**: How big should the village grow and how much are we able and willing to invest in protection measures? These decisions have a direct impact on the key figures in the damage report. We must weigh which damage we want to avoid at all costs and which hazards or risks we accept. Do you draw more importance to the cost-effectiveness of the measures or the acceptance by the population?

3 Keywords

In the following section, a few important keywords of the MurGame are being explained:

- **Hazard** is a condition, circumstance or process from which harm to people, the environment and property may result (definition according to [2]).
- **Debris flow**: Mudslide consisting of a mixture of water, debris and possibly tree trunks. Debris flows develop in the steep upper reaches of a stream and can reach very high flow velocities. They come to a standstill in shallow areas and deposit the transported material there - which can sometimes be huge quantities (definition according to [5]).
- **Risk**: The term "risk" is a technical expression for the extent and probability of a possible damage (definition according to [5] and cf. explanations in Chapter 6.3.5).
- **Integral risk management** describes a systematic management concept for dealing with risks. Risks must be identified and assessed according to the same criteria and reduced with an optimal combination of spatial planning, as wells as structural, biological and organisational measures. Integral risk management strives for the equivalence of prevention, intervention and recovery and includes communication with all actors and stakeholders (definition according to [2]).
- **Damage**: Negative consequences of a natural event. The damage potential describes the damage that could occur to persons, to material assets and to the landscape (definition according to [5]). The damage report of the MurGame lists the damage to persons, buildings and interrupted traffic routes. These values are based on damage from realistic events.
- **Protection measures**: We can protect ourselves against natural hazards with spatial planning, as well as structural, biological and organisational measures.
    - **Structural measures**: In the MurGame, we can protect the village from debris flows with structural measures such as retaining structures or guiding measures such as dams or walls or the enlargement of the bridge. These measures can protect a larger area than on-site protection measures that are aimed at protecting one object. On-site protection measures refer to measures on or directly at

the object and aim to reduce or minimise damage to persons and property on that specific object. Debris flow protection measures reach their limits, as debris flows cause very high impacts. Therefore, massive and often drastic and expensive measures are necessary to achieve a sufficient level of protection.

- **Organisational measures**: In the MurGame, the population can be prepared for debris flow events by means of alerts or an information bulletin. Emergency planning defines responsibilities and immediate measures in the event of an incident, and procedures should be practised in a test environment. For instance, in the case of a debris flow in the upper part of a catchment, an automatic barrier closes the main road in the lower area of the alluvial fan before the debris flow reaches the main road.
- **Spatial planning measures:** Spatial planning measures can be implemented by demolishing buildings (that are at risk), resettling inhabitants or by not building structure on certain plots.
- **Biological measures:** Protection forests are an important element of hazard prevention. If a debris flow is triggered, they only provide limited protection due to the enormous forces involved. However, a protection forest can significantly influence the development of debris flows through its soil-stabilising and water-storing effects.

- **Acceptance:** The inhabitants evaluate the various objects in their village very differently (and subjectively). The acceptance of the individual buildings and protection measures by the village population cannot be changed in the MurGame and the player must come to terms with this. As in reality, the needs of the population should also be considered in the MurGame - however, achieving one hundred percent acceptance remains wishful thinking in the game as well.
- **Economic efficiency:** Economic efficiency describes the relationship between the benefits and costs of protection measures. The benefit of protection measures lies in their protective capacity. The economic efficiency given in the MurGame for a village #XY with protection measures refers to the damage to the same village without measures compared to the costs of the measures. If the protective performance is equal to or greater than the investment for the measures, it is called a cost-effective measure.

4 Further developments

For MurGame version 1.0, the focus was on its use at the Swissbau 2020 trade fair at the booth of the "Protection against natural hazards" information platform. Accordingly, the content was designed for this application. During the further development of the MurGame, ideas for additional content, uses/applications and optimisations were continuously collected.

The updated version MurGame 2.0 includes the following points:

- Integral risk management: The range of measures has been expanded and includes spatial planning, construction and organisational measures.
- Debris flow modelling: The debris flow sizes were adjusted, the loading times were optimised and the visualisation was improved.
- Game development: Processes in the game have been optimised and new elements such as acceptance and population counters have been added.
- Risk dialogue: Balancing the cost-effectiveness of the measures and acceptance by the population increases the challenge.
- Language: The MurGame is available in three languages: German, French and English.

Inputs for further ideas as well as concrete requests for further development are welcome and can be sent to murgame@geo7.ch.

5 Project team & executing agency

The MurGame was developed by:

geo7 Geowissenschaftliches Büro

Koboldgames

SLF

Thanks to the sponsors who made the project possible:

PS Präventionsstiftung der Kantonalen Gebäudeversicherungen
FP Fondation de prévention des établissements cantonaux d'assurance

die Mobiliar

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Bundesamt für Umwelt BAFU
Office fédéral de l'environnement OFEV
Uffizi federal d'ambient UFAM

6 Background information

Only relevant information is directly provided within the MurGame. Players, who are interested will find more background information on the main points of the game below. Further documents are listed in chapter 8.

6.1 Setting

The MurGame is set in a fictional environment. A typical torrent flows from a steep catchment area to a larger river on the valley floor. On the alluvial fan of the torrent, there is a settlement with a main access road running along the river in the valley floor. The elevation model used for the MurGame is taken from a real torrent catchment and was prepared for use in the game.

6.2 Debris flow modelling

The MurGame uses the simulation model RAMMS::DEBRIS FLOW to represent the debris flow and the damage calculation based on it. This is a numerical model developed at the Institute for Snow and Avalanche Research (SLF) of the Swiss Federal Institute for Forest, Snow and Landscape Research (WSL).

RAMMS::DEBRIS FLOW is based on the Voellmy model using two friction parameters. To calculate the flow depths and velocities of debris flows, the depth-averaged shallow water equation of the 2nd order is solved based on a 3D elevation model.

In the MurGame, two realistic debris flow scenarios are used for the torrent catchment described above. Large objects (church, school, farm) as well as robust structural measures (dams, concrete walls, retention structures) and bridges influence the flow path of a debris flow. These elements are taken into account in the simulations and lead to a protective effect behind dams, for example. Small objects (residential buildings, shops, stables, garages) and ineffective measures such as sandbags do not significantly influence the course of a debris flow. Therefore, they are not taken into account in the simulations.

Debris flows for every possible combination of objects and measures have been pre-simulated and are available at stock. Depending on the village design, the corresponding simulation is loaded, visualised and used for the damage calculation. A total of approx. 1,200 simulations were pre-simulated for the MurGame.

6.3 Loss calculation

6.3.1 Basics

Basically, damage occurs when a hazard process hits an object. The extent of the damage depends on the type and value of the object as well as the natural hazard process and the intensity of the process. In the MurGame, the principles of integral risk management are mapped. The damage is calculated according to the approaches commonly used in practice [1], [2], [4].

In a first step, the debris flow intensity is determined in the corresponding village setting per existing object and road section as a function of the respective flow depth at the object or road from the corresponding RAMMS::DEBRIS FLOW simulation. Based on this flow depth, the parameters for the damage calculation are derived.

The damage calculation in the MurGame takes into account personal injury and property damage for objects and roads according to EconoMe [1] as well as supply damage due to the interruption of traffic routes according to the approach of the Canton of Zurich [4].

6.3.2 Parameters

For the loss calculation of personal injury and property damage, the values for the respective objects according to EconoMe 5.0 [1] were used for the parameter sensitivity and lethality. For the basic values of the buildings, reference values of the project partners from the insurance industry (Vereinigung Kantonaler Gebäudeversicherungen VKG, Mobiliar) were used. The movable property was added to the tangible value by a surcharge of 20 %. The costs of measures could be derived from empirical values for construction projects. Further parameters for buildings (number of occupancies and presence probability factors) and road traffic (speeds, values for average daily traffic and number of average journeys) were adapted to the setting in the MurGame. A distinction was made between municipal and cantonal roads, and parameters and classes were derived for the supply interruption according to [4].

The monetarisation of the personal injuries was carried out with marginal costs of CHF 6.6 million according to EconoMe 5.0 [1]. In the damage calculation, a spatial probability of occurrence of 100 % is used, as the debris flow simulations represent discrete process areas.

6.3.3 Damage

The personal injury and property damage (probable extent of damage) are determined according to the methodology by EconoMe 4.0 [3] and the parameters described in Chapter 6.3.2 for persons in the affected buildings and on the roads. If there are no fatalities in the damage report, but personal injury is nevertheless reported, this is an indication that injured persons are to be expected.

The calculation of the supply damage is based on the methodology of the risk analysis of the Canton of Zurich [4] and the parameters mentioned in chapter 6.3.2. This approach is based on a qualitative determination of the risk for the interruption of traffic routes (municipal, cantonal road and bridge). As soon as a debris flow buries a section of a road, a corresponding damage due to the interruption of supply is calculated. For a better comparison with the other damages, the qualitative values were monetarised (marginal costs 500'000 CHF).

6.3.4 Acceptance

The acceptance among the population in the damage report consists of the individual evaluations for the buildings, bridges, structural and organisational protection measures. For buildings, in addition to the construction costs, (subjective) popularity contributes to acceptance. For measures, the protective effect and the (subjectively assessed) visual appearance are the decisive criteria in addition to the costs.

6.3.5 Simplifications

In order to visualise the topic of integral risk management in a clear and informative way, a number of simplifications have been made and certain aspects of the risk assessment have been excluded.

Basically, the term risk is understood as the possibility that damage may occur as a result of a certain event. In the context of natural hazards, the risk is composed of the frequency or return period of several events and the possible extent of damage (persons and property). In Switzerland, the collective and the individual risk are considered for the assessment of the risk [2].

The risk concept consists of three elements: risk analysis, risk assessment and risk management. An important basis for this are the hazard and intensity maps that exist throughout Switzerland in the vicinity of settlements. The calculated risk is assessed as part of the risk evaluation and, if necessary, measures are taken. However, even after protection measures have been taken, there is still a residual risk, as absolute safety from natural hazards cannot be achieved in a hazard-prone area.

A variety of different systems can be used for the implementation of protection measures. However, aspects such as additional hazards or the shifting of hazards and legal requirements such as ecology and the economic efficiency of the measures must be considered. Furthermore, the possibilities for protection measures are often limited due to spatial, social and economic framework conditions. All these aspects cannot be included in the MurGame version. However, depending on the type of application and moderation, these points can be addressed.

The concrete calculation of the risk to settlement areas and infrastructure facilities from the threat of natural hazards is carried out in Switzerland according to the EconoMe methodology [1] and forms the basis for integral risk management and thus the handling of natural hazards.

7 Suggestions for gaming assignments

Depending on the target audience, different emphasis can be given, especially in the context of education and training events. In the following section. we present an array of possible ideas. Further information can be found in the additional materials on the main webpage of www.murgame.ch in the "Documents" section.

Gentle entry with a focus on a single aspect:
What measures can be taken to protect a specific village,

- while achieving the best possible economic efficiency?
- with as little damage as possible?
- while achieving the best possible acceptance among the population?

More complexity through combination of several aspects:
What measures can be taken to protect a specific village,

- while finding an ideal balance between damage, acceptance and economic efficiency?

Focus on a specific topic:

- Focus on economy: How can a village be protected in the best possible way if a total budget of e.g., CHF 15 million is available?
- Focus on types of measures: Is it possible to protect a village solely by implementing spatial planning and organisational measures?
- Focus on vulnerability: What is the impact of the bridge on the hazard situation (in case of a small/large debris flow) and how can this problem be best addressed with spatial planning or construction measures in terms of economy and acceptance?

8 Further information

Natural hazards and risk

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RAMMS

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