Seismic Cities
Design Document

TU Delft

SEISMIC CITIES

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Challenge the future

SEISMIC CITIES

DESIGN DOCUMENT

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INTRODUCTION

1.1. SERIOUS GAMES

Seismic Cities is a serious game. Meaning that its primary purpose is not mere entertainment but in this case the procurement of knowledge. By playing the game the player learns about earthquakes, the effect of different soil types and how particular building materials are better suited for certain situations.

1.2. EARTHQUAKES

Earthquakes happen on a daily basis all across the globe. Approximately 100.000 earthquakes can be felt on a yearly basis and around a 100 of them cause actual damage (USGS, 2016). They can either be naturally occurring or human-induced. But no matter the cause they often have grave social and economic effects. The earthquakes resulting from the natural gas processing in Groningen in the North of the Netherlands has forced the Dutch Government to downsize the amount of gas that is being extracted. In the aftermath of the nuclear disaster at Fukushima, Japan, caused by the Tōhoku earthquake in 2011, the discussion on the safety of nuclear power re-emerged. This eventually led to Germany closing down all their nuclear power plants. And then there are the earthquakes in developing nations as Turkey, Nepal, Thailand and Haiti. Here the often already poor population gets hit the hardest. Not only by the direct damage caused by the earthquake but also by the economic damage as a result from the recoil of tourism following the disaster.

Despite our understanding of why earthquakes occur it is still impossible to predict when they will happen. This lack of knowledge can be partly explained by the immense depth at which earthquakes happen. Accurately predicting earthquakes might be decades away and thus is it necessary to understand the destructive force and learn how to prepare for it.

1.3. PROBLEM DEFINITION

The Science Centre Delft is a public exhibition that displays past and present research of the TU Delft. The Bouwlab is a place in the science centre dedicated to structural engineering. The Bouwlab has recently been expanded by special equipment that encourages visitors to experiment with the properties of building materials on different soils under the conditions of a simulated earthquake. In addition the science centre desires to complement this physical experience with a game on their online platform that teaches the students more about earthquakes, soil types and building materials. The game should thus be playable in the online environment of the science centre. It should also be attractive for a broad audience as the visitors of the science center vary between 6 to 80 years.

1.4. PURPOSE OF THE GAME

After playing Seismic Cities the player should have a better understanding of:

1. The phenomenon of the epicenter;
2. The difference between naturally occurring and human induced earthquakes

3. The effect of different soil types on the destructiveness of an earthquake;
4. That materials choice and engineering decisions matter;

In addition to these learning goals should the game be fun to play with a simple but attractive design.

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Theoretic Background

To convey knowledge on the above mentioned learning goals through the gameplay it is important to understand the actual physics and mechanics that dictate the behaviour of earthquakes and buildings. This chapter summarizes the research done on earthquakes and their behaviours.

2.1. Earthquakes Mechanics

2.1.1. Natural vs Induced Earthquakes

The Earth's outermost shell i.e. the lithosphere or crust is made up from seven large plates and several smaller plates that together cover the globe. These are called tectonic plates and they move with very slow velocities (i.e. 0-100 mm per year). Their movement is caused by a complex geophysical processes influenced by the energy coming from the Earth's core, the variety of densities and gravity. The lines between these tectonic plates are called fault lines. Along these lines the plates move which causes friction. The friction leads to tension which builds up over time until a certain threshold is reached. When one of the plates gives in, the tensions is released and a natural earthquake occurs. This happens at a depth between 10 and 300 kilometers.

Human induced earthquakes are the direct result from altering the earth's crust through processes of resource extraction like natural gas processing and fracking. By extracting gas or oil it changes the strains and stresses of the rocks deep in the earth's crust which can induce earthquakes. Often these are much weaker than the naturally occurring ones but as they happen on much lower depth, around 3 to 10 kilometers, they can still have a devastating impact.

2.1.2. Epicenter and seismic waves

The spot in which the earthquake occurs deep in the soil is called the hypocenter. From here shock waves are send through the earth towards the surface. The spot on the surface closest to the hypocenter is called the epicenter. This is the place where the destructive force of the earthquake is at its most intense. As waves progress throughout the Earth's crust towards and along the surface it is the soil type that determines the waves speed and destructive force.

2.2. Soil Types

The soil is the medium through which a wave progresses and it thus has a substantial effect on the seismic waves moving through them. In general there is a subdivision of five categories of soil types each with a distinctive characteristic in which it affects seismic waves:

A.	Bedrock/hard rock	Speeds up waves if on the surface but when present below other soil type, it has a damping effect.
B.	Rock (Volcanic, soft bedrock)	Small amount of amplification.
C.	Dense soil/soft rock (sandstone)	Slows down the waves but increases intensity.
D.	Soft soil (mud/clay)	Significant amplification of shaking.
E.	Water Saturated	Liquefaction occurs the ground will start to act like a liquid, heavy object like buildings and cars start sinking.

[1]

[1] Data from the US Geological Survey(2015)

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GAME DESIGN

The conclusion that can be drawn from the research above is that when it comes to earthquakes there are many factors to take into account. With the target audience in mind this called for a drastic simplification of our research findings. We also accepted that not all learning objectives will be derived directly from the gameplay but parts should be taught by the storyline.

3.1. STRATEGY

The purpose of the game is for the player to achieve the learning objectives as described in chapter 1.4. The game is developed in such a way that it teaches the player in both a incremental and repetitive fashion. The different levels are increasing in difficulty. To complete a level the player has to combine the knowledge, provided by the story, acquired in the previous level and generated through intuition.

To obtain all learning objectives the player should finish the game. To stimulate the player to sit it through we have tried to create an attractive and engaging storyline:

"Poseidon the Greek God of the sea and shaker of the Earth has descended from the heavens to wreak havoc. His earthquakes have already destroyed large parts of civilization and people are struggling to rebuild. Athena the goddess of wisdom has chosen you as a vehicle to counteract Poseidon's fury. Athena guides the player through the levels while Poseidon gets ravished by the destruction of the buildings. As the player progresses through the game Poseidon tones down a bit while he comes to understand that he might have underestimated the mortal behind the computer screen."

The storyline is an important part of the game. This game element ensures the commitment of players and through the dialogue the player is taught what the best strategy is. The levels are designed in such a way that the player should intuitively make the wrong decisions on its first try. To prevent the player from getting demotivated Athena is always quick to give a hint on how to succeed. The duration of the game is relatively short therefore we chose this high intensity of feedback and guidance throughout the game.

3.2. LEVEL DESIGN

The levels have been designed to teach one aspect at a time. In table 3 these learning goals are presented. In appendix 2, the complete level characteristics can be found. After the identification of different categories of soil types, the earthquake prone areas were researched on their respective soil build-up in order to identify interesting level locations. For the prototype of the game, two countries have been picked to demonstrate the game. Italy as a location where 'normal' earthquakes regularly happen. The basics of earthquakes and prevention can be explained here. The second location is the Netherlands, where in Groningen the gas drilling has caused earthquakes. The characteristics of the soil are described in Table 1. Both Italy and The Netherlands consist of three sublevels each one teaching something new.

Each sublevel is built up out of eight different attributes:

1. Learning Objective
2. Terrain containing the different soil types
3. List of buildings and upgrades
4. Building zones
5. The location of the epicenter
6. Solution
7. Dialogs/tutorial

The worked out version of these seven attributes for each sublevel is included in appendix A.

3.2.1. TERRAIN

In reality there is a huge variety of soft and hard soils which are subdivided in five categories depending on their effect on seismic waves. In the game we've adapted these five categories and used a maximum of two different soil types per category depending on the geographic location of the level. In Italy, Limestone and Marl are most common. These soils correspond respectively to a category C and D. In the Netherlands, Clay and Sand are most common. These soils correspond respectively to a category D and E. When an earthquake strikes you can see the seismic waves progressing through the ground and what effect the different soil types have on the speed. As buildings are built on top of the soil the player also experiences what the soil does to the destructiveness of the earthquake.

A.	Bedrock	Used for the deep soil. Has no effect on the seismic waves.
B.	Rock Salt/Marl	Remains stiff, waves travel fast through it.
C.	Limestone	Slows down the waves but increases intensity.
C.	Sandstone	Has gas bubbles which can be extracted and can compresses when a wave moves through them.
D.	Clay	Acts elastic and has a significant amplification effect on shaking.
E.	Quicksand	Liquefaction occurs and the ground will start to act like a liquid, heavy object like buildings and cars start sinking.

3.2.2. BUILDINGS AND UPGRADES

The player is presented with a fixed amount of buildings in each level, all of which have to be placed. There are several building types and each building has its own characteristics which are determining if a building will survive or get destroyed by an Earthquake.

Wooden House Wood is relatively flexible in comparison to rigid materials like brick and concrete. So it will behave more stable on earthquake amplifying soils.

Brick House Is a rigid medium strong material. It will break by large shakes and is heavy enough to sink in water saturated soils without the addition of a foundation.

Apartment Building With a heavy concrete construction. Act the same as a brick house but is heavier and thus will sink easier.

Foundations An upgrade to a building that can prevent constructions from sinking in liquefied soils.

3.2.3. SOLUTION AND GUIDANCE

For each sublevel there is a single combination of buildings, upgrades and place holders that gets the level passed. I player can only succeed when the specific lesson of the level has been taken into account and the lessons of the previous levels have not been disregarded. When a player fail a level the dialogue between Poseidon and Athena will encourage the player to play on and give direction to how the level should be solved.

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GAMEPLAY

The game starts with a globe in which the player can see the fold lines running. Here they can read what the game is about and start the game. As soon as the player has started the game, Athena appear and introduce the player to the story of the game. Poseidon has come to earth to destroy civilization using his mighty earthquakes. Athena promises you to provide the knowledge to outsmart Poseidon. As soon as the first dialogue is finished the player is drawn through a quick tutorial explaining the different objects in the screen and how to use them. When the tutorial is finished the player starts in level 1.

4.1. CONCEPT & GOALS

The overall goal of the game is to beat Poseidon at his desire to destroy civilization. This goal can be obtained by placing the buildings in each level such that his earthquakes won't be able to damage any of them. Only when all houses remain after the earthquake, the level is passed. There is only one right solution for every level.

4.2. GAME MECHANICS

Each level has placeholders where the player can place the buildings as it likes. Only when all the buildings have been placed the player can finish the level by simulating the earthquake. From level 5 and up the player is able to not only place buildings but to strengthen them by the use of an upgrade.

4.3. PLAYER FEEDBACK

The player receives primary feedback by seeing the effect of the earthquake on the placed buildings. They either break, sink or remain. If the player succeeds the dialogue will be complimenting and confirm the that the player's actions where the right ones. When the player did not succeed the dialogue coming from Athena will hint on how to solve this level.

4.4. GAMEPLAY CHALLENGES

By changing the soil types and the amount of buildings and upgrades, the player is confronted with a new situation each level. Each building type has some unique characteristics, which keep the game interesting and gives the player more to think about. The player challenged to consider which building zone would fit the best for each type of building, which depends on the soil type and the distance to the hypocenter. We also have added more building zones than there are buildings to place, which gives room for more possible solutions.

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FINAL GAME

This chapter will provide an overview of all the decisions that were made to make the transition from the prototype to the final game. First the prototype will be briefly described, hereafter the changes that were made for the final game are discussed. Finally the chapter ends with a paragraph with recommendations on how to develop the game further.

5.1. PROTOTYPE DESCRIPTION

The first prototype consisted of two modes; the building mode and the earthquake mode. The player could first place the buildings on a level and then later destroy it in a minigame. In the building mode, the player was allowed to place the buildings anywhere in the level. The buildings were made of one "block", this provided little visual feedback. So in addition to the prototype with the two building modes a demonstration was provided where the buildings consisted of building blocks to provide more visual feedback.

5.2. CHANGES FROM PROTOTYPE

After the feedback from the beta testing (Testing Report), the decision was made to replace the prototype with two modes to a final game with one mode where the player focuses on placing buildings in each level. The idea behind the earthquake mode was to teach the player about how the earthquake is affected by different soil types. This was made explicit in the new format through visualisations.

In the beginning of the design process, there was the idea of making people choose what buildings should be placed, regarding the environment, the population that should be housed and the total budget that was available for that. This idea was left out of further development, because it did not add anything to the goals that are teached with the game.

Where the prototype aimed at one level at different locations around the world. The final game consists of three levels at a specific location around the world. This allows for incremental learning through the different levels. The prototype just threw the player into the deep without teaching the player anything, then the player should learn by trial and error. This was not desirable so the change was made to incremental learning in multiple levels at each location.

Also the decision was made to limit players in the areas where buildings could be constructed. This forces the player to place buildings in more undesirable areas. By doing this, the difficulty is increased because the player has to think through what types of buildings should be placed in which location. In the prototype the player could place all the buildings as far away as possible from the earthquake, and then easily passing the level.

Furthermore, the building blocks addition has been incorporated in the final game. The buildings that the player can place are made of buildingblocks. When a building has been destroyed, this provides more visual feedback.

Finally the main challenge was that the game should be more fun to play. The lack of engagement was discovered in the beta testing, which was mainly due to the lack of content. In addition to creating multiple levels, this has been solved by adding a storyline to the game in order to engage the player. Also the visualisations and sound effects should contribute to the degree of engagement.

5.3. RECOMMENDATIONS & WARNINGS

The first recommendation is to expand the game to other locations around the world. Then the game can be made even more challenging and the storyline can become more elaborate.

Next to a scoring system, features such as a multiplayer level editor mode, building editor and randomly generated levels can also enhance the replayability of the game. Through the level editor, friends can challenge each other with levels they made. This also changes the game from a single player to multi-player game. In the building editor, players can make buildings and put them in a sandbox environment. Then the earthquake mode from the prototype can be added to let people test the buildings they made. Randomly generated levels keep the game more dynamic and new, so the player is challenged with new levels over and over again. This will keep the game more interesting. Another recommendation to enhance the replayability of the game is to add a scoring system. The scores should end up in a leaderboard, resulting in a competitive incentive for players to replay the game and beat the scores of their peers. For this to be applicable the levels should be made random, because in our levels there is only one way to succeed.

A final recommendation is to enhance the transfer of information during further development. In this version, the information is shared through text. This can be changed to spoken text or animations for example. In this way, the player does not have to actively read something, they can just listen to what is said.

As a warning, the further development should not try to make the game more realistic. The aim of the game is to teach players about the different aspects of earthquakes. It is better to show the influence of factors in an exaggerated manner to demonstrate those effects. A very realistic game is more a simulation than a serious game, which is less fun to play (Harteveld, 2011).

A

Level Specifics

Level 1.1

Learning Objective	Learning about the epicenter and the basic game mechanics.
Terrain	One type of soil, limestone.
Buildings & Upgrades	2 brick houses.
Building Zones	3 building zones, 1 at the epicenter.
The Epicenter	Below the outer right placeholder.
Solution	Place both buildings as far from the epicenter as possible.
Dialogue	The player is told that the epicenter is the center of power.

Level 1.2

Learning Objective	Learn about amplification of seismic waves in clay.
Terrain	In addition to limestone a patch of clay is introduced.
Buildings & Upgrades	2 brick houses
Building Zones	2 close to the epicenter on limestone, 2 on clay away from the epicenter.
The Epicenter	In the middle.
Dialogue	The player is explained that the clay amplifies the earthquakes strength.

Level 1.3

Learning Objective	Learn that wood react differently then brick
Terrain	Same as in level 1.2
Buildings & Upgrades	2 brick houses, 1 wooden house
Building Zones	3 on limestone one far away, 2 on clay
The Epicenter	Same as level 1.2
Solution	The wooden house on clay, two brick houses on the spots furthest away from the epicenter.
Dialogue	The player gets a hint about the wood being more flexible.

Level 2.1

Learning Objective	Learn about liquefaction.
Terrain	Quicksand with a patch of clay.
Buildings & Upgrades	2 wooden houses.
Building Zones	2 on clay, 4 on quicksand on each side of the clay.
The Epicenter	Under the drilling towers.
Solution	Both houses should be put on the clay if not they'll sink.
Dialogue	Liquefaction is explained as the houses sink.

Level 2.2

Learning Objective	The use of foundations in soft soils.
Terrain	Same as level 2.1
Buildings & Upgrades	2 wooden houses, 2 brick houses, 2 foundations
Building Zones	Same as level 2.1
The Epicenter	Same as level 2.1
Solution	Wooden houses on clay. The brick houses away from the epicenter on foundations.
Dialogue	

Level 2.3

Learning Objective	Larger buildings are affected more easily by earthquakes.
Terrain	In addition to level 2.1 a patch of salt stone is added.
Buildings & Upgrades	1 brick house, 1 wooden house, 2 apartment buildings, 3 foundations
Building Zones	2 on clay, 3 on quicksand, 1 on salt rock.
The Epicenter	Close to the drilling towers by the salt rock patch.
Solution	Wooden on clay away from ec, 2 brick houses w/ found, 1 flat on slat rock, 1 flat on qs w/ found.
Dialogue	The game is finished.