Climate change adaptation model using Civ IV

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Section 1. City Model

1.1 City Population

The population of the city will be represented by an integer value which will
be set initially for each city and change each turn at a predefined rate.

*The population value affects:*

- Food, water and energy resources consumed by the city each turn
- Money resources produced by taxation policies
- Effectiveness of some infrastructure
- C02 emissions per turn

*The population value is affected by:*

- Current growth or reduction rate of the population
- Climatic events which may wipe out some of the population
- Migration from other cities
- Starvation or death due to insufficient food or water resources

1.2 City conditions

The current conditions inside the city will be represented by a wide range of values which can be described in the model. City conditions cannot be traded between cities, and only affect an individual city. Some basic examples may include:

- City Health
- Citizen Happiness
- Water inundation
- Extreme temperatures

The city conditions affect:

- Effectiveness rate of infrastructure
- Consumption of food and water by the population
- Growth or reduction rate of the population

The city conditions are affected by:

- Infrastructure, which may improve or worsen specific conditions
- Climatic events, which will affect the conditions depending on the cities resilience to the event provided by infrastructure

1.3 City Resources

The city resources represent physical levels of various resources within the city. When setting up the model, it will be possible to define different initial values for each resource in each city.

What are they?

Each of the resources is represented by a simple integer value. They are defined as:

- the food available to the citizens of the city
- the fresh drinking water available
- the energy available
- the money available

**How are they affected?**

- Resources are consumed by the population each turn
- Construction of infrastructure may require a one-off consumption or production of resources
- Each turn the city's infrastructure will produce and consume resource
- Trade agreements may regularly or sporadically affect resource levels
- Policies may regularly or sporadically affect resource levels

**What do they affect?**

- Limited resources (e.g. energy) will affect the effectiveness of certain infrastructure
- Particular events may occur as a result of insufficient resources (e.g. food/water) that affect the city conditions or population

**How can they be traded?**

- Each resource can be independently traded with every city
- Resources can be donated to any city

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### 1.4 City Climate

**How are cities affected by climate?**

- Each city will have its own climatic conditions which may vary gradually and will affect infrastructure effectiveness and resource usage by the population. Some examples include average rainfall and average temperature.
- Cities will experience climatic events occasionally which may have a direct impact on city resources and conditions, and indirectly on
infrastructure effectiveness. The magnitude of the event's effect will be affected by the cities resilience to it. Some examples include floods, hurricanes, heatwaves etc.

How does the city affect climate?
- the CO2 produced by each city contributes to a global CO2 level
- the global CO2 level affects each city's climate model individually, changing the climatic conditions and frequency and magnitude of events.

1.5 Infrastructure

Each piece of infrastructure represents an aspect of the city's industry. The different types of infrastructure are described when setting up the model, so they can be as general or as specific as required.

How does the infrastructure affect the resources and environment?
- When a piece of infrastructure is created or upgraded, there may be an initial consumption/production of resources
- Every turn each piece of infrastructure produces and consumes some resources
- Infrastructure can produce/consume CO2 either each turn or at creation/upgrade, affecting the global environment

What does infrastructure effectiveness mean?
- pieces of infrastructure have an effectiveness rate associated with them which affects their production/consumption of resources
- the rate is calculated each turn based on current climatic conditions, resource availability and city conditions
- the rate calculation can be defined differently for each type of infrastructure, reflecting their vulnerability to certain conditions

What does infrastructure resilience mean?
- pieces of infrastructure may be capable of reducing the vulnerability of a city to some of the effects of various climatic events.
- some infrastructure may reduce all effects of a particular event by reducing the entire magnitude of the event. E.g. a seawall may remove all effects of a tidal wave.
- other infrastructure may only reduce some effects of a particular event by handling the damage caused. E.g. a hospital may reduce the deaths caused by a heatwave but will not reduce the high temperature aspect, which may cause damage to agriculture.
- the resilience provided by a piece of infrastructure is described in the model, and can also be defined to increase/decrease each turn.
- the resilience to a climatic event provided by the piece of infrastructure is also affected by its effectiveness rate.

**How does infrastructure change?**
- the modeller will have the ability to describe any number of upgrades which can be performed on a certain piece of infrastructure, each with any prerequisites.
- the user is able to implement these upgrades at any stage during a turn, which may instantly produce or consume resources.
- a continual degradation of infrastructure may also occur, requiring the user to perform maintenance to maintain its effectiveness rate.
- when setting up the model, it is also possible to grant different cities different starting levels of upgrades, to reflect a city's advancement in a particular industry etc.
- cities are also able to trade/donate upgrades, so that one city can have a direct impact on another's infrastructure.

### 1.6 City Policies

- policies represent governmental policies which effect resources and the environment, but can't be easily defined as infrastructure. E.g. taxation, emission trading etc.
- policies are not affected by city conditions or resource availability but may directly affect them.
- the available policies are described by the modeller and then employed by the user.
- e.g. a taxation policy may increase the money resource available each turn but may also reduce city happiness each turn.

1.7 City Resilience

- Cities will have a certain resilience to specific climatic event impacts
- This is not explicit, but rather captured in the different pieces of infrastructure which each contribute to it.
- It will be possible for the user to easily identify the cities vulnerability to specific events, and the infrastructure which is helping to minimise the effects of them.

Section 2. Climate Model

There will be a single climate model per city, which can be configured for each city independently.

*What does the climate affect?*
- the model will be responsible for manipulating basic city climatic conditions, including average rainfall and average temperature
- the model will also produce climatic events, with varying levels of magnitude and frequency

*How is the climate model affected by the environment?*
- the model is directly affected by the current global carbon emission level, although the extent of its effect can be described when setting up the model
- thus it is possible for the carbon emissions of a city to directly affect the climatic conditions of another city.

*What happens when a climatic event is produced?*
- the event is produced by the climate model with an initial, raw magnitude
- each of the impacts of the event on the city are calculated initially using the raw magnitude of the event
- each piece of infrastructure in the city has a chance to reduce one or more of the
impacts
- these altered impact levels are then used to change the city conditions, resources and population

Section 3. City - City interaction

3.1 Trade

During each turn, each city is able to make a once off trade with another city, or set up a longer standing trade agreement. Trades can be one-sided, so that they are effectively donations, but both cities must agree to the trade.

*What is available for trade between cities?*
- each of a city's resources (food, water, money, energy)
- infrastructure upgrades (pre-requirements are still enforced)

3.2 Migration

It is possible for migration between cities, affecting both cities population (and indirectly resource use etc).

*What can cause migration?*
- insufficient resources such as food or water
- unsatisfactory city conditions such as citizen happiness
- climatic events such as floods, hurricanes etc.

3.3 Global C02 levels

Each city contributes to a global C02 level, so that the C02 produced by a city directly affects the climate of another city.
Section 4. User - City interaction

Each user is responsible for maintaining a single city. It will be possible to simulate a user using an intelligent agent, or to have a multi-player game.

What can a user do during each turn?
- construct new infrastructure
- upgrade existing infrastructure
- implement governmental policies
- invest money into technological research
- trade with other cities

Section 5. Game turn

A turn of the game represents the passing of some specified period of time. A user has an unlimited amount of time during a turn to manipulate the city in any way, before choosing to end the turn.

What can occur during a turn?
- Any number of user actions can be performed which may instantly consume/produce resources or affect city conditions
- A climatic event may occur which may instantly consume/produce resources or affect city conditions

What occurs at the completion of a turn?
- resources are consumed/produced by infrastructure/policies/population
- city conditions are affected by infrastructure/policies/population
- C02 levels are affected infrastructure/policies/population
- resource levels may trigger an event which affects city conditions or population
- effectiveness rates of infrastructure are recalculated