# Study on the Club of Rome's World3 Model

**Project Introduction to Computational Science 2014**
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## Introduction

This report describes the modelling and simulation project for the course Introduction to Computational Science of the college year 2014-2015 at the University of Amsterdam. The aim of the project is to perform a science project, which will be supported by a simulation study.

For the simulation study, we will investigate the Club of Rome's World3 model, which models interactions between industrial growth, population, food production and pollution.

## Background of the model and its use

In 1968, a group of people from politics, business and science came together to *"discuss the dilemma of prevailing short-term thinking in international affairs and, in particular, the concerns regarding unlimited resource consumption in an increasingly interdependent world"*. This group was named *The Club of Rome*, after the location of the meeting. The first and subsequent meetings resulted in the book '*Limits to Growth*', published in 1972. In the book it was predicted that economic growth could not continue indefinitely, mainly because of the limited availability of natural resources and emissions. Somewhere in the twenty-first century, the growth would end in a uncontrolled decline in population and human welfare.

The underlying model used in the study is the World3 model. It was the first model that used computer simulation to model the interactions of five sub models, which represent capital, natural resources, agriculture, population and pollution, on a global scale.

It has to be noted that World3 model is far from perfect and was merely a first step in modelling the global world. The authors point out the use of inadequate data, the usage of quantifications of factors for which the influence is not fully clear, such as pollution, and unknown development of technology in the future. Also, natural resources are seen as one identity, while in reality substitutions of depleted natural resources are possible. Increasing prices because of scarcity and the stabilising working of the law of supply and demand are missing in the World3 model; very different from assumptions economists often make in their models.

Despite its flaws, the World3 model is suitable enough to illustrate the validity of the Club of Rome's hypotheses. The model is an example that it is not necessary to have a perfect model to give an clear insight in problems. The model does not give a prediction, but is sketching alternative scenario's for humanity. For taking appropriate measures to prevent a scenario becoming true, the model and its validity need to be studied and improved extensively. The World3 model shows what possibly can go wrong. Vermeulen and De Jongh [1976] conclude that, while in *Limits to Growth* very severe measures are suggested for every subsector in the world model in order to avoid the catastrophic population collapse of the standard run, that by combining three changes of 10% each in the parameters ICOR, FIOAC, ALIC, the collapse of population can also be avoided. They speculate that the real world has so many variables and is so flexible that the correct small pressures on the correct parameters could cause desirable outcomes for the world's evolution.

Description of the impact of the model

No single country is responsible for the problems on its own or able to take appropriate actions. Measures on a world wide scale are necessary, which are very difficult to coordinate. The history of the ozone hole and acid rain shows that global coordination is not impossible. In this report, we will not elaborate on this subject.

The report and the model have received many critics, mainly by people who did not understand the main message. Changing the model does not change the conclusion: unlimited growth cannot continue. Economists often address that the used assumptions in the models are very different from the axiom's economists often use. Also, the tone of the report is pessimistic. The Club of Rome was wrongfully called the zero growth movement, although the conclusion of the report does not to deny this. In the report there is a dedicated chapter about the conditions to obtain sustainable growth and what growth in a global equilibrium means. Within these conditions, company's can rise and fall, local population can grow and decline. Technological developments can improve the average standard of living.

## Standard run of the model

Figure 1 shows the behaviour of the standard model, i.e. of the model when no changes to the parameters are made.

Note that the scale on the y-axis is missing. The model does not give predictions, but a direction. The numbers are very likely to be inaccurate and are thus not of great importance.

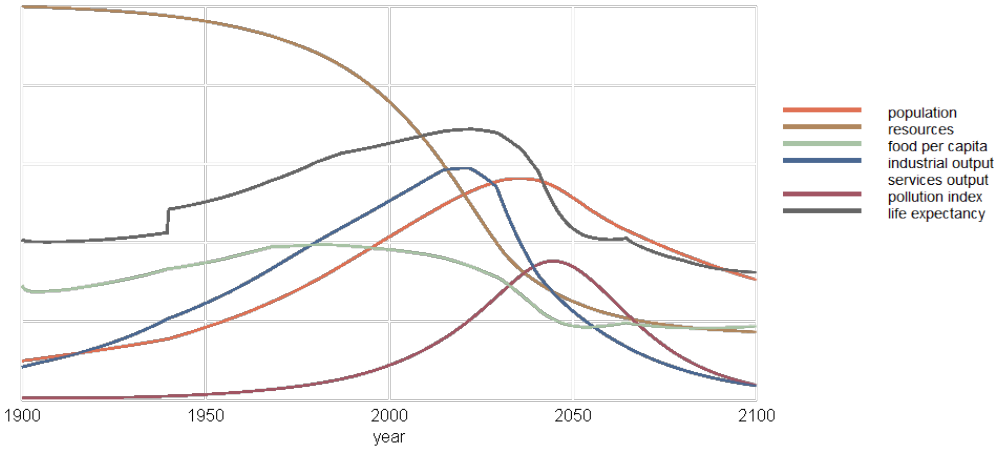


Figure 1: Behaviour of the model in the standard run

The model shown in Figure 1 shows that around 2040 society will collapse. This happens shortly after the industrial output drops. This manifestation of these catastrophes is an indication that not only the resources are depleted but also the pollution of this world is rising to a record high.

The rising pollution also has a big effect on the life expectancy of the population. Figure 1 shows a correlation around 2045, where pollution is at the largest peak and the life expectancy drops rapidly. Since the turn of a rising life expectancy to a dropping one, the population growth has stagnated, which results in a decay of the human population.

## Research questions

A full analysis of the parameters of model, the influences of the submodels and doing simplifications is enough to write a PhD thesis: see Thissen [1978]. However, we would like to study small parts of the model. Based on our interests and the discussion of the model in Thissen [1978] and Vermeulen and De Jongh [1976], we pose the following hypothesis:

- What is the influence of the size of the population on the use of natural resources?
- Can the collapse of population indeed be ICOR and FIOAC increased by 10% and ALIC decreased by 10%.
- What is the influence of the amount of available natural resources on the other submodels?
- Do the conditions in the Limits to Growth to obtain sustainable growth indeed lead to a sustainable equilibrium?

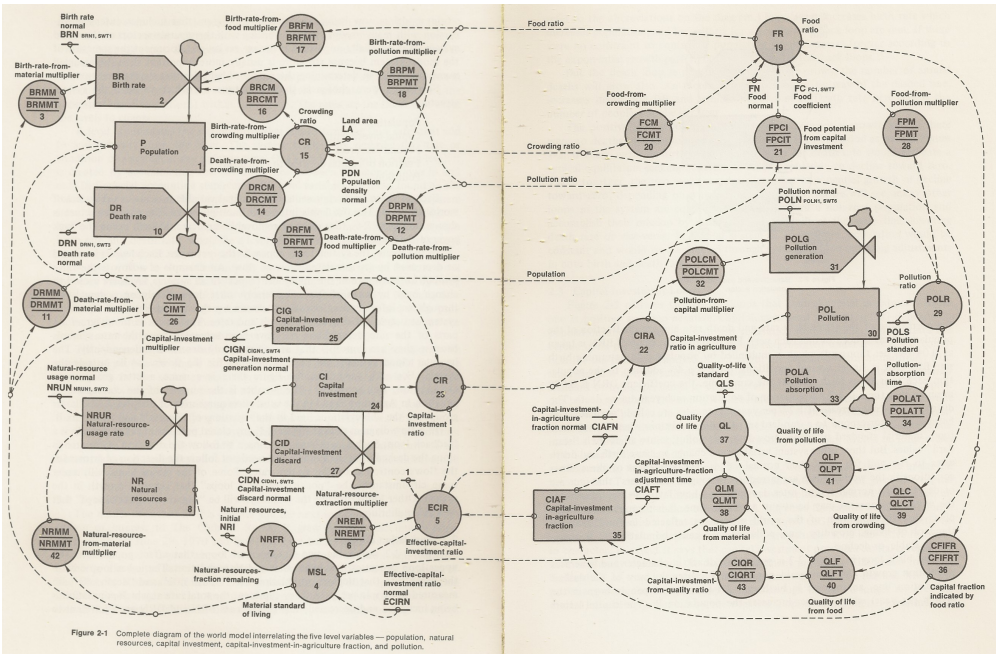


Figure 2-1 Complete diagram of the world model interrelating the five level variables — population, natural resources, capital investment, capital-investment-in-agriculture fraction, and pollution.

Figure 2: Diagram of the world model from citeforresterworld

Additionally, we will investigate behaviour of the model we find remarkable while varying parameters.

## Implementation of the model

The World3 model is an example of a model in the System dynamics formulation, which is based on feedback loops. Figure 2 An overview of the model and the interactions between the submodels. We included this to give an impression of the size of the model, not for details.

The complete model consists of more than 150 differential equations. The original model is formulated in a special language called DYNAMO.

We came very close to implement the model in the formulation as described in Thissen [1978] in Python. In Thissen's formulation, the capital and resource subsectors are merged. However, eventually we did not succeed.

First of all we implemented the simplified capital model, Thissen [1978] suggested that differences neither population, agriculture or pollution has any major effect on the capital. This simplified model therefore uses constants as an alternative.

This model shows a proper approximation of the population prediction with the original World3 model.

Because we thought this model was too easy we started to replace this simplified

capital model with the extended capital model, this model relies on the three other sub models – population, agriculture and pollution.

A particular problem is the use of a function from DYNAMO called DELAY3. This function represents a third-order linear delay, but we were not able to find an explanation we could understand.

Therefore it cannot be determined why the model does not behave the way it should.

To come up with a working model, we probably need to understand and implement the original model formulation from Forrester [1973] instead of the formulation from Thissen [1978]. DYNAMO is an old language, with a special feature. The equations of the model can be written down in any order. The compiler does reorder the equations automatically. We expect this to be a major challenge to implement this in a sequential language as Python.

### Simplified resource and capital model

We were able to implement the simplified resource and capital model from Thissen [1978].

Picture of the standard run in the simplified model and differences with the standard standard run

## Results and analysis

Illustration of the delay of collapse when natural resources are increased. One of the examples of the use of incorrect data was the amount of available natural resources. New techniques have made it, for example, possible to extract oil deeper from the earth. However, as we will see, this will only delay the point of collapse.

## The Club of Rome today

Today, the Club of Rome still exists. The views of the Club of Rome are still broadly correct: unlimited consumption and growth on a planet with limited resources cannot go on forever.

Believe in advance of technique that we can solve problems in future

## Conclusion

## References

J. Forrester. *World Dynamics, Second edition.* Wright-Allen Press, 1973.

D. Meadows. *Rapport van de Club van Rome. De grenzen aan de groei. Met commentaar van de Club van Rome.* Utrecht, Het Spectrum, 1972.

D. Meadows, J. Randers, and D. Meadows. *Limits to growth: the 30-year update*. Chelsea Green Publishing, 2004.

D. L. Meadows, W. W. Behrens, D. H. Meadows, R. F. Naill, J. Randers, and E. Zahn. *Dynamics of growth in a finite world*. Wright-Allen Press Cambridge, MA, 1974.

M. Mesarović, E. Pestel, and C. of Rome. *Mankind at the turning point: the second report to the Club of Rome*. A Signet book. Dutton, 1974. ISBN 9780525039457.

E. Pestel. *Voorbij de grenzen van de groei*. Amsterdam, Meulenhoff Informatief, Het Spectrum, 1988.

W. A. H. Thissen. *Investigations into the Club of Rome's World 3 model: lessons for understanding complicated models*. PhD thesis, Technische Hogeschool, Eindhoven, 1978.

P. Vermeulen and D. De Jongh. Parameter sensitivity of the 'limits to growth'world model. *Applied Mathematical Modelling*, 1(1):29–32, 1976.