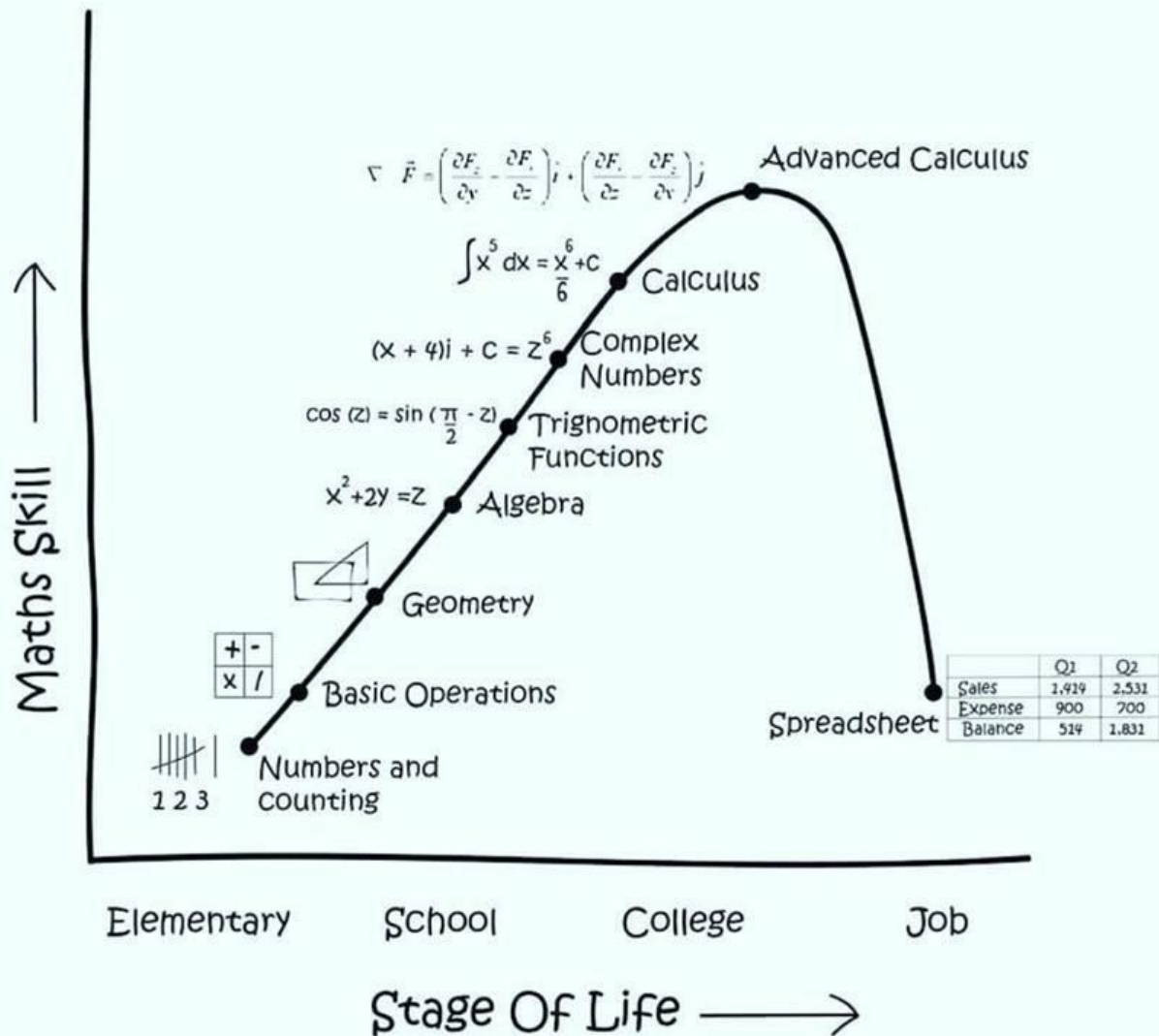




cbinsights

Statue Of Liberty, Liberty Island, New York City



Environmental modelling- an overview

Antonio Camara

April 2020

Mental models

[Useful mental models](#)

[109 mental models across disciplines](#)

[12 key mental models](#)

Imagine trying to compete as a farmer without the invention of the plough or fertilizer. Tools allow you to do new things and to get more done with fewer resources. However, just learning the tool of the day is limiting because tools go obsolete quickly. However, understanding how to use tools in general is a skillset that will stay with you forever.

If we set the wrong goal, then no amount of strategy or efficiency will help. Good strategy will only help us get to the wrong place faster.

Our world is ruled by a complex set of cause & effect interactions. People who are more advanced with cause & effect are able to get more leverage with their actions. The better you can understand what causes what, the better you can:

- Solve problems by diagnosing root causes.
- Identify what to do now in order to cause the goals you want to happen.

The 80/20 rule is one of the most simple and universally applicable

One of the most important models of cause & effect to know is a positive feedback loop. Positive feedback loops lead to power law curves. Most people think linearly and systematically undervalue the power of consistently doing small things that add up over-time (ie - investing in health, learning, and money). The best investors in the world understand and leverage the power of compound interest.

Knowing what to do is only half the battle. Many people aren't able to turn their intentions into consistent habits because of procrastination.

The most important tool we have is our mind. However, our mind has well-documented biases that lead to us making irrational thoughts. By understanding and counteracting these biases, we can increase the quality of our decisions, and therefore our destiny.

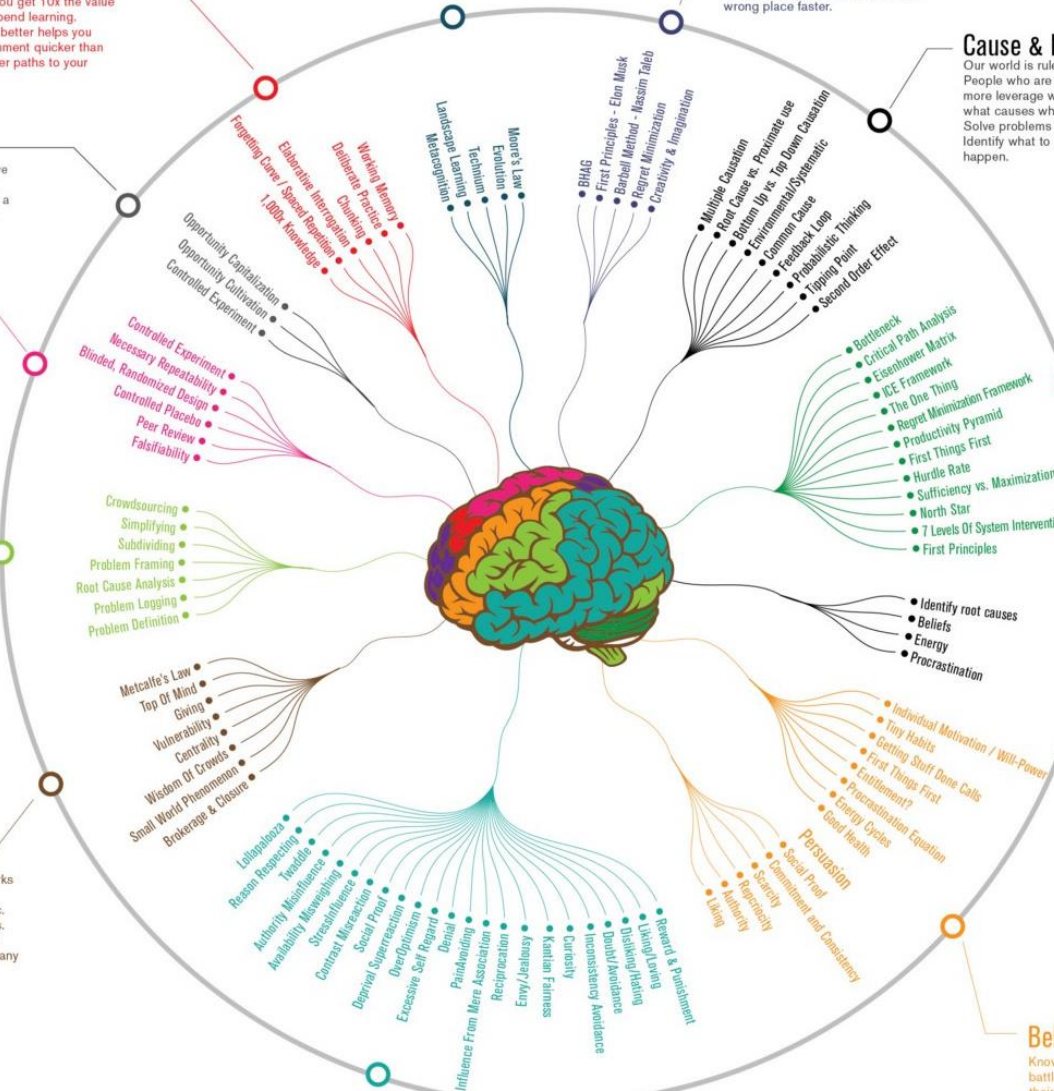
Networks appear everywhere; networks in our brain, networks of friends, networks of people in an industry, etc. All networks have underlying patterns. By understanding those patterns you can drastically get better results in many areas of your life.

Most people avoid problems or deal with them haphazardly? Great thinkers and leaders, on the other hand, look for problems, and have frameworks that help them solve problems better.

The scientific method is a set of principles and methods that have led to the greatest explosion of knowledge that humanity has ever know.

It doesn't help to just be smart or have relationships or money. These are assets. To go those assets, you need a catalyst. That catalyst is opportunity.

Learning how to learn leads to a double exponential where you get 10x the value for each hour you spend learning. Learning faster and better helps you adapt to any environment quicker than others and find better paths to your goals.

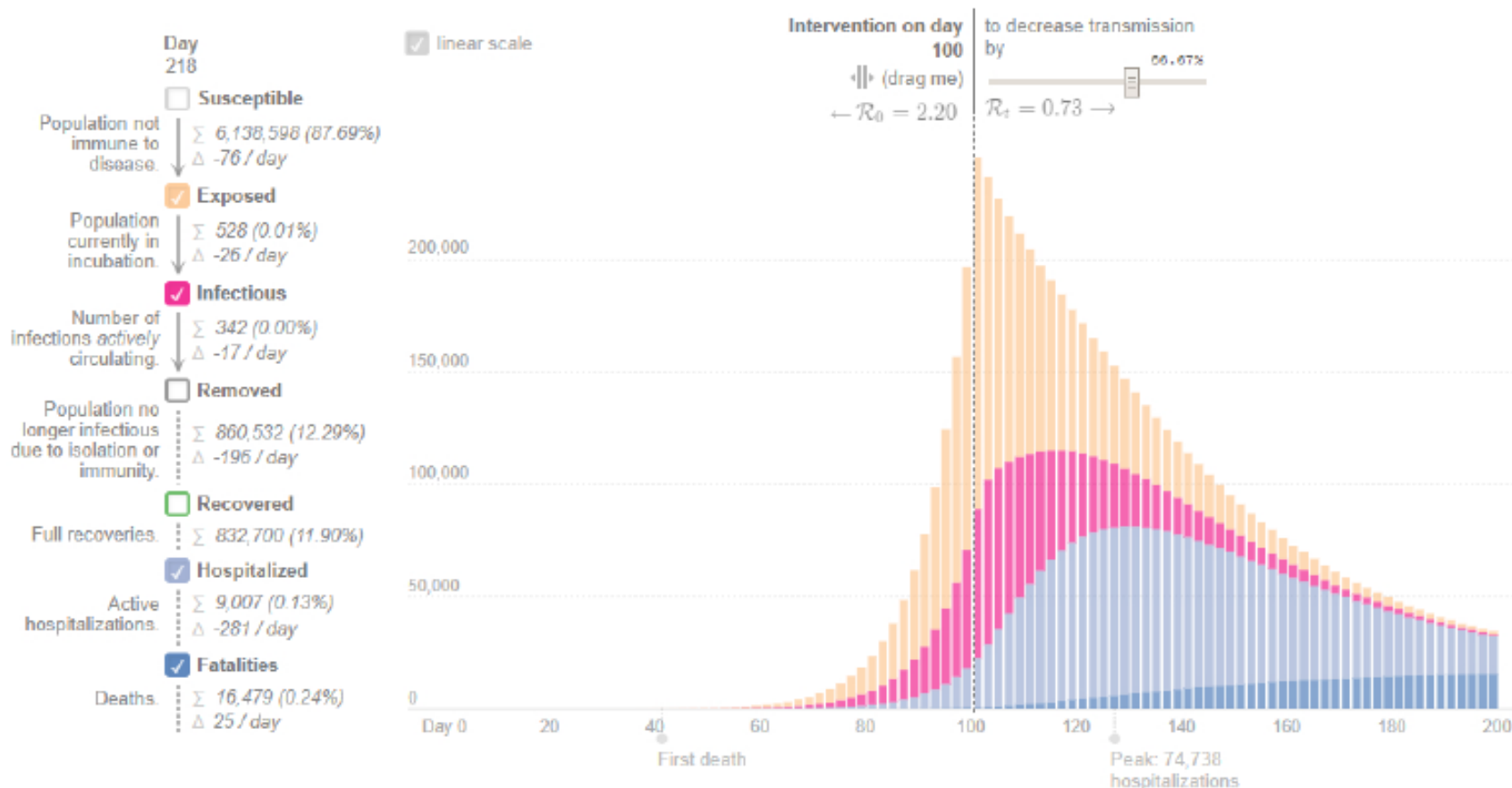


Calculators

[The epidemics calculator](#)

[Environmental calculators](#)

Epidemic Calculator



Transmission Dynamics

Population Inputs

Size of population.



Number of initial infections.



Basic Reproduction

Number $\mathcal{R}_0$

Measure of contagiousness: the number of secondary infections each infected individual produces.

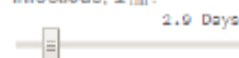


Transmission Times

Length of incubation period, T_{inc} .



Duration patient is infectious, T_{inf} .



Clinical Dynamics

Mortality Statistics

Case fatality rate.



Time from end of incubation to death.



Recovery Times

Length of hospital stay



Recovery time for mild cases



Care statistics

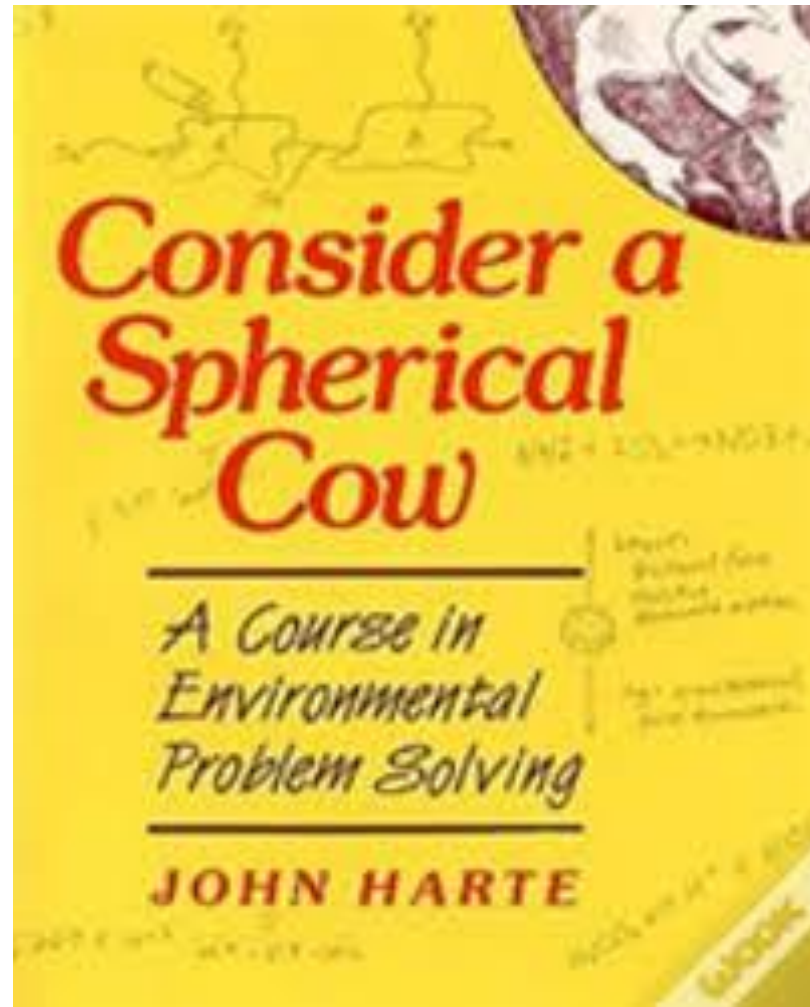
Hospitalization rate.



Time to hospitalization.



Back-of-the-envelope models



Consider a Spherical Cow

Modelling

Simulation

Differential calculus

Numerical methods: finite differences and finite elements

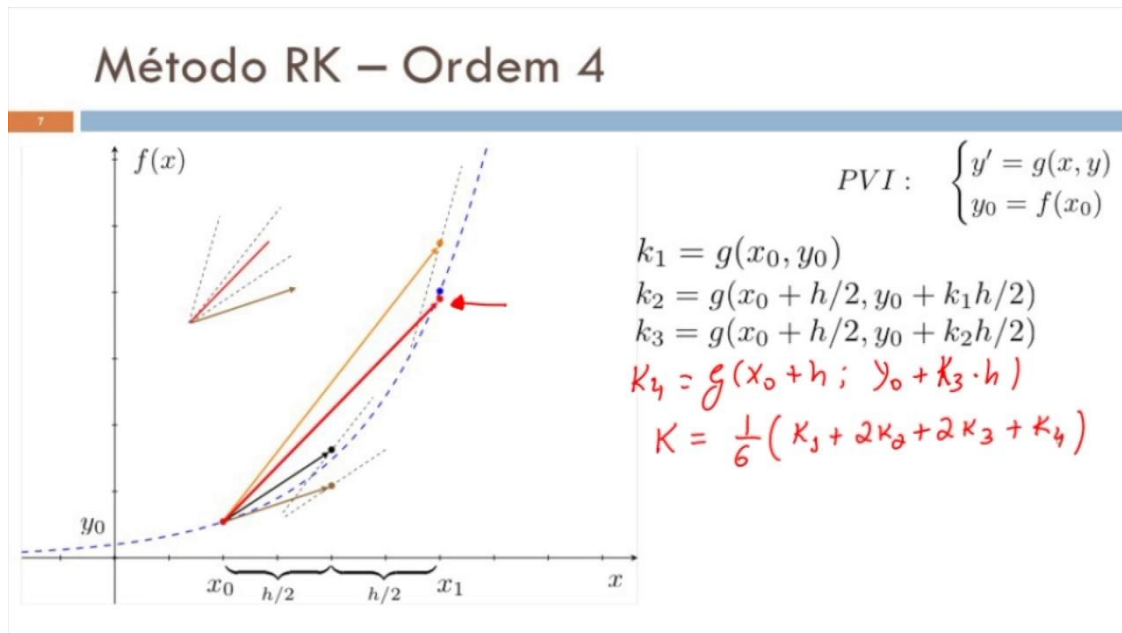
System dynamics

Discrete simulation

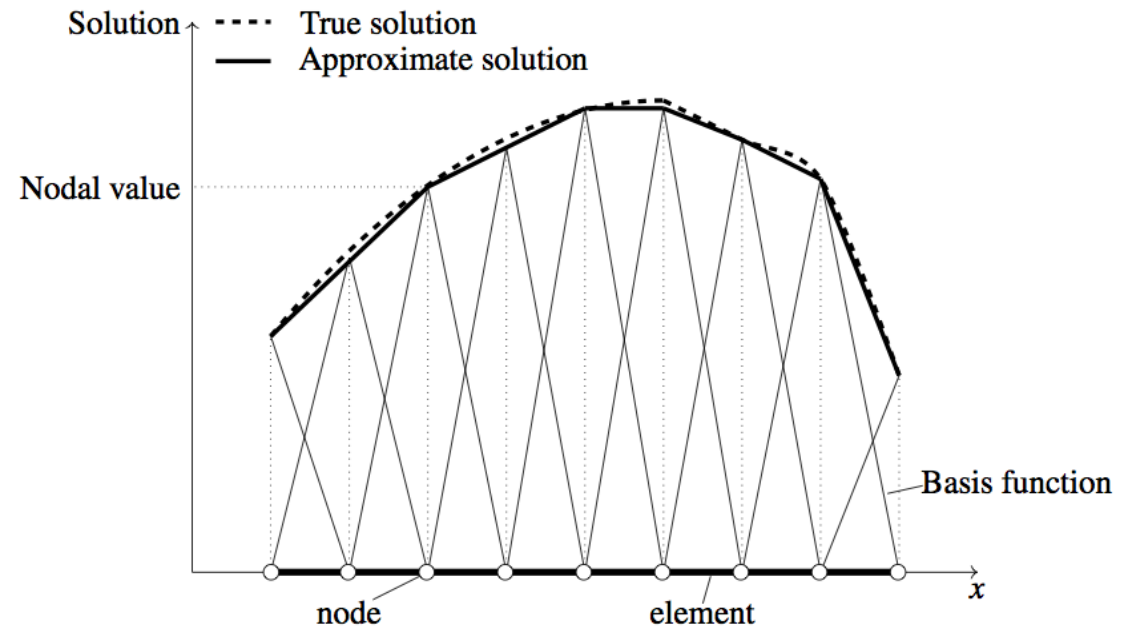
Cellular automata

Agent based models

Numerical models

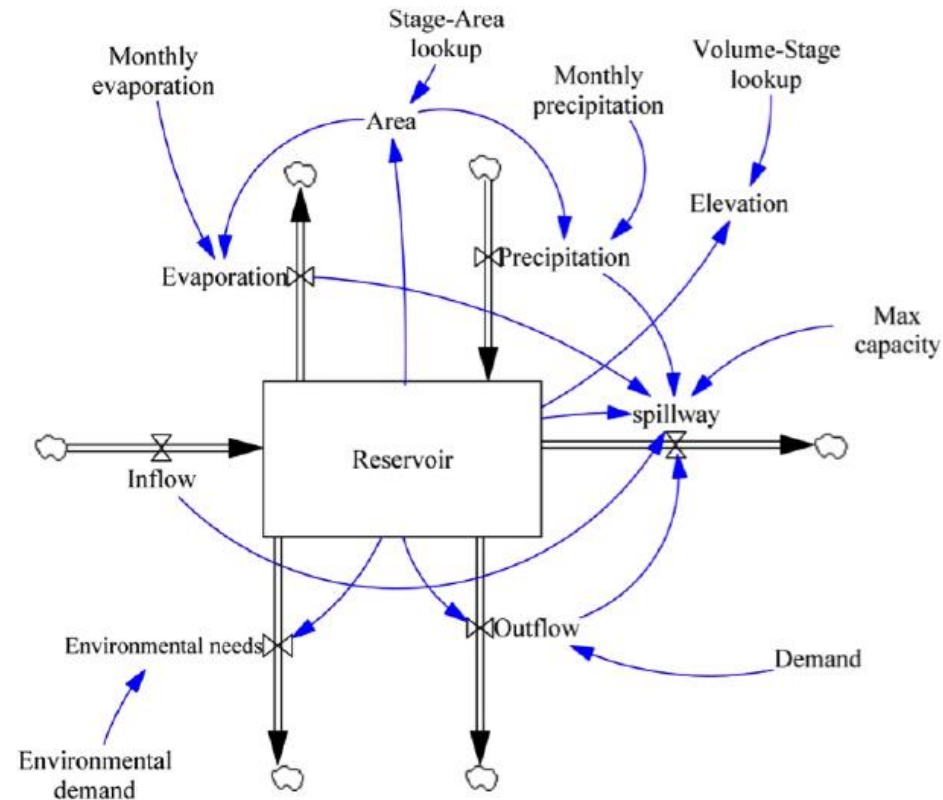


Finite differences



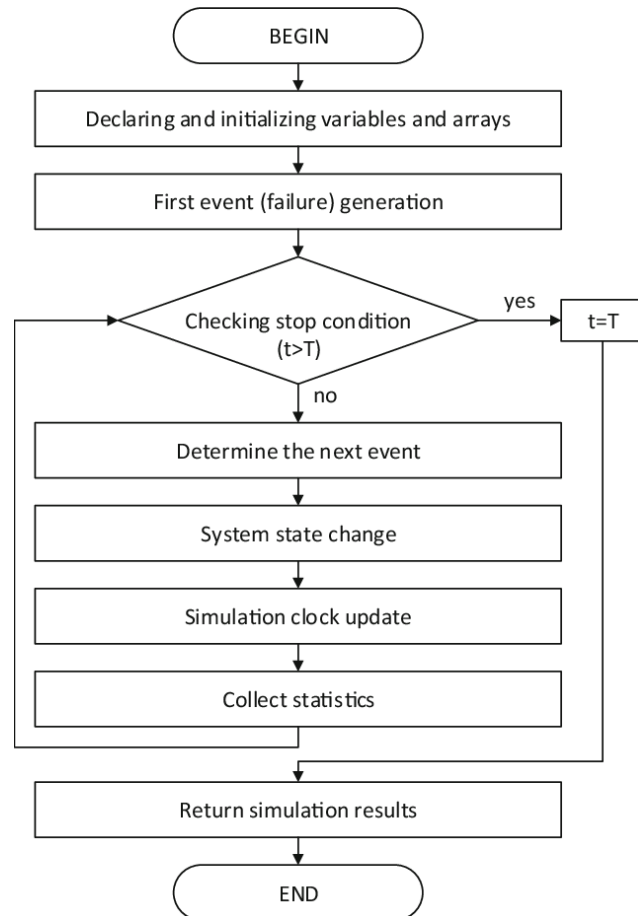
Finite elements

System dynamics models



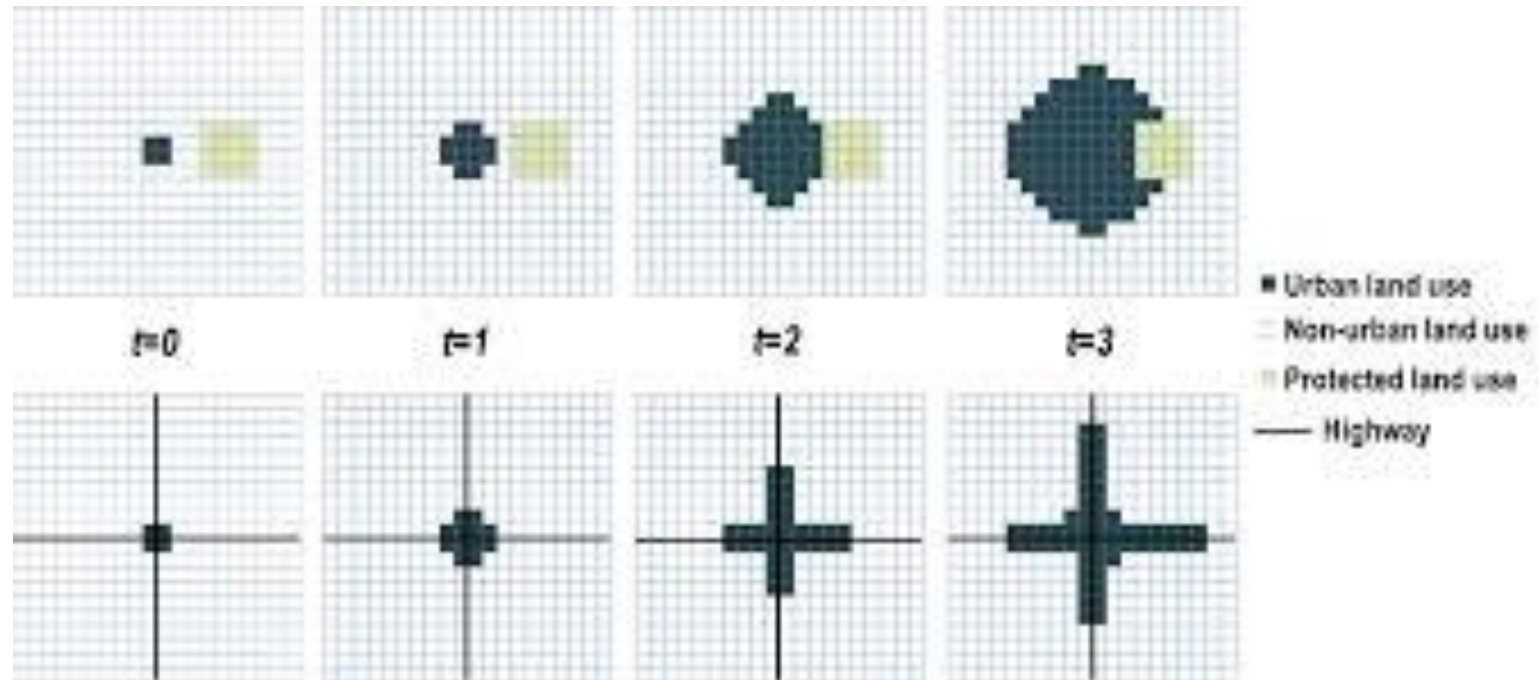
Andrew Ford, [System Dynamics Models of Environment, Energy and Climate Change](#), Springer, 2011

Discrete simulation models



Stewart Robinson, [Discrete-event Simulation: From the Pioneers to the Present, what next?](#), Journal of Operational Research, 56(6):619-629, 2005

Cellular automata



Stephen Wolfram, [A New Kind of Science: a 15 Year View](#), 2017

Agent based models



[YDreams' Lego Aquarium](#)

Klügl, Franziska & Bazzan, Ana. [Agent-Based Modeling and Simulation.](#)
AI Magazine. 33. 29-40, 2012

Modelling

Optimization

Linear programming

Integer programming

Dynamic programming

Non-linear programming

Network models

Genetic algorithms

Optimal control models

Non-linear optimization models

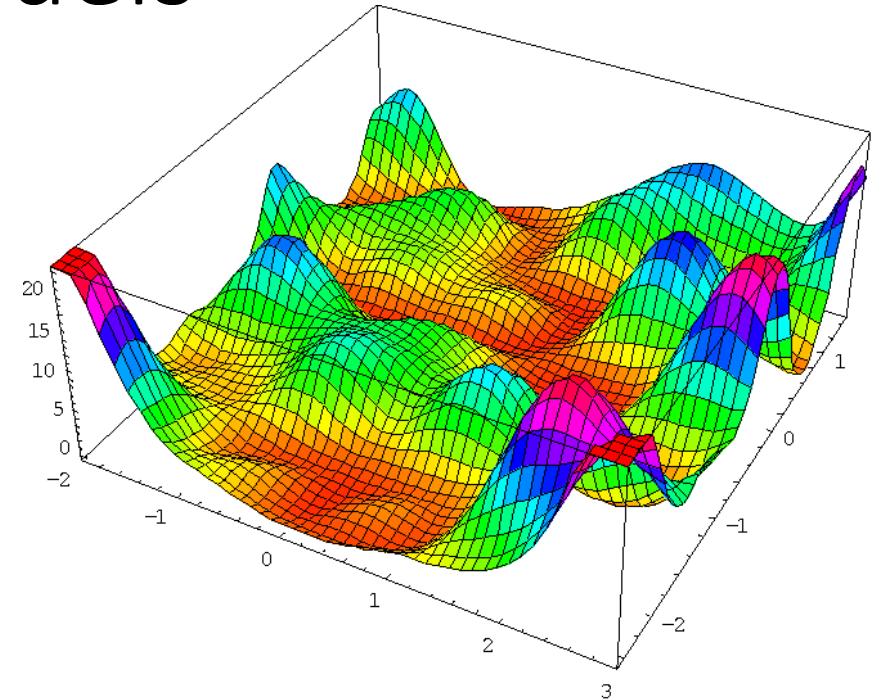
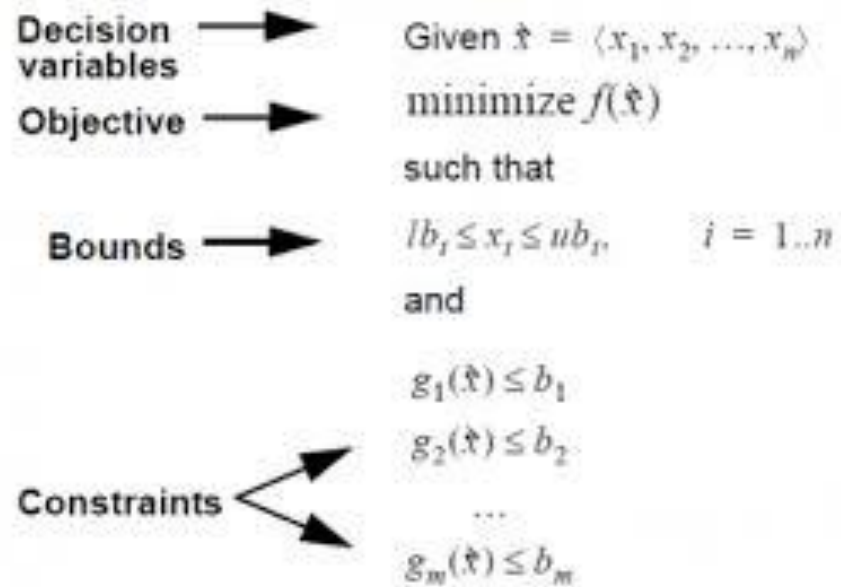
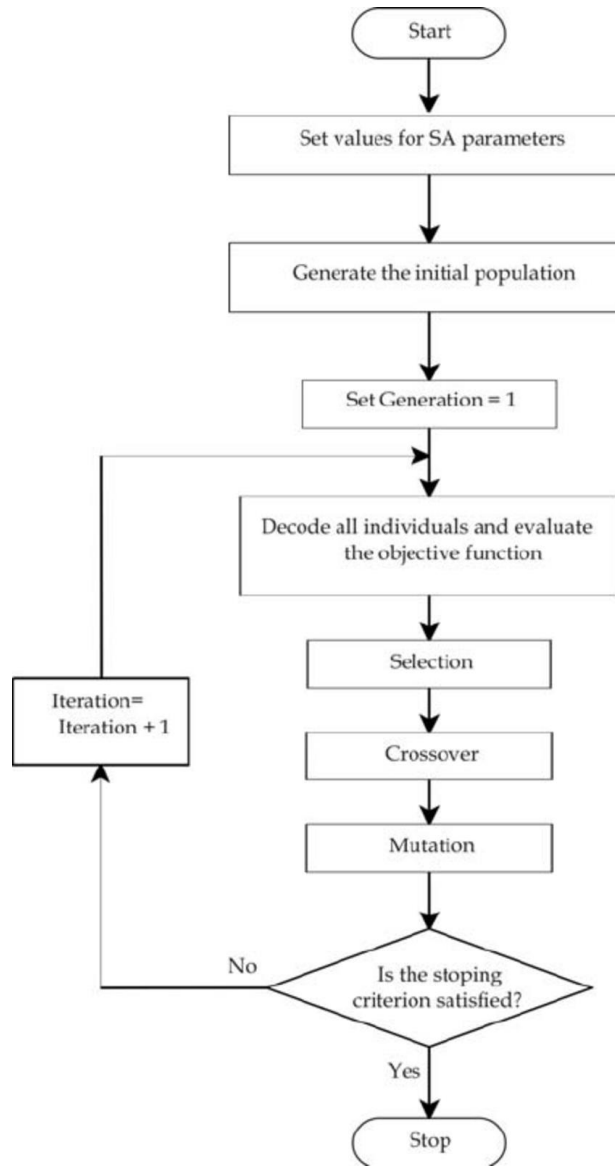


Figure 1.
An illustrative global optimization model.

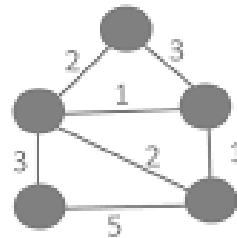
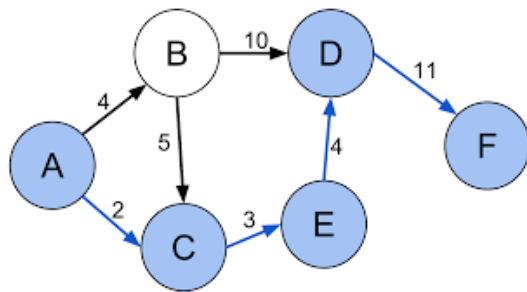
Eck, Bradley & Mevissen, Martin. [Fast Non-Linear Optimization for Design Problems on Water Networks](#). World Environmental and Water Resources Congress 2013. 696-705.

Genetic algorithms

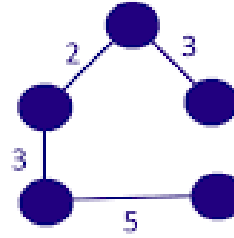


Haupt, Sue & Haupt, Randy. [Genetic Algorithms and their Applications to Environmental Sciences](#). Utah State University, 2003

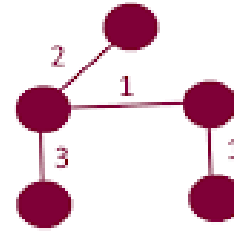
Network models



Graph



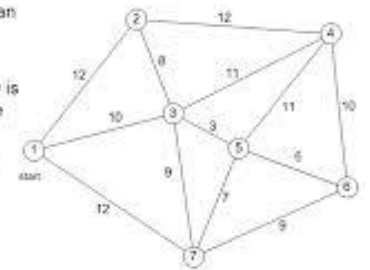
Spanning Tree
Cost = 13



Minimum Spanning
Tree, Cost = 7

The Traveling Salesman Problem

- Starting from city 1, the salesman must travel to all cities once before returning home
- The distance between each city is given, and is assumed to be the same in both directions
- Only the links shown are to be used
- Objective - Minimize the total distance to be travelled



Richard Larson and Amadeo Odoni, [Urban Operations Research](#), MIT, 1997-199

Optimal control models

Optimal Control

- Static optimization (finite dimensions)
- Calculus of variations (infinite dimensions)
- Maximum principle (Pontryagin) / minimum principle

Based on state space models

Min $V(\mathbf{x}, \mathbf{u})$

S.t. $\dot{\mathbf{x}} = \mathbf{f}(\mathbf{x}, \mathbf{u}, t)$

$\mathbf{x}(t_0)$ is given

$$V(\mathbf{x}, \mathbf{u}) = \Phi(\mathbf{x}(t_f)) + \int_{t_0}^{t_f} L(\mathbf{x}, \mathbf{u}, t) dt$$

General nonlinear control problem

Y. Shastri et al, [Optimal Control Theory for Sustainable Environmental Management](#), Environmental Science and Technology, 42, 5322-5328, 2008

Modelling

Decision models

Rational, incremental and mixed-scanning models

Payoff matrices, influence diagrams and decision trees

Dynamic decision making (Bayesian models)

Multi-criteria decision making (compensatory and non-compensatory models)

Game theoretic models

Negotiation models

Payoff matrices

Modelos de Decisão com Incerteza

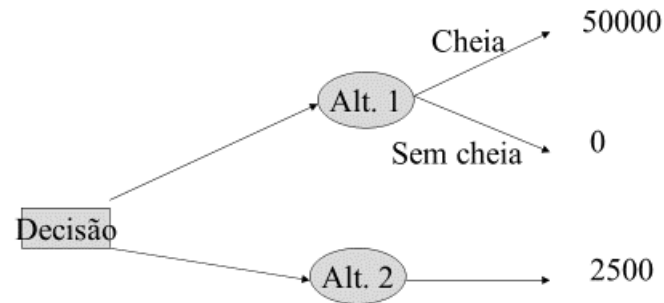
Grau de eficácia para socorro de catástrofes em três regiões

Alternativas	Trás-os-Montes	Açores	Alentejo
Av. Peq. Al.	100	40	30
Av. Med. Al.	70	80	20
Camhões	10	0	110

Decision trees

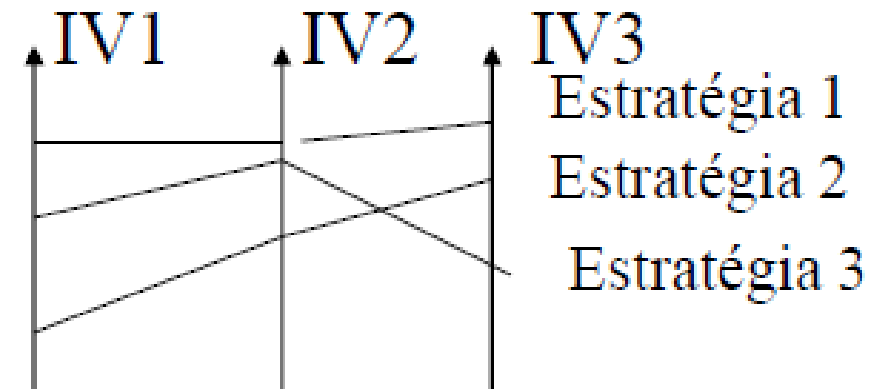
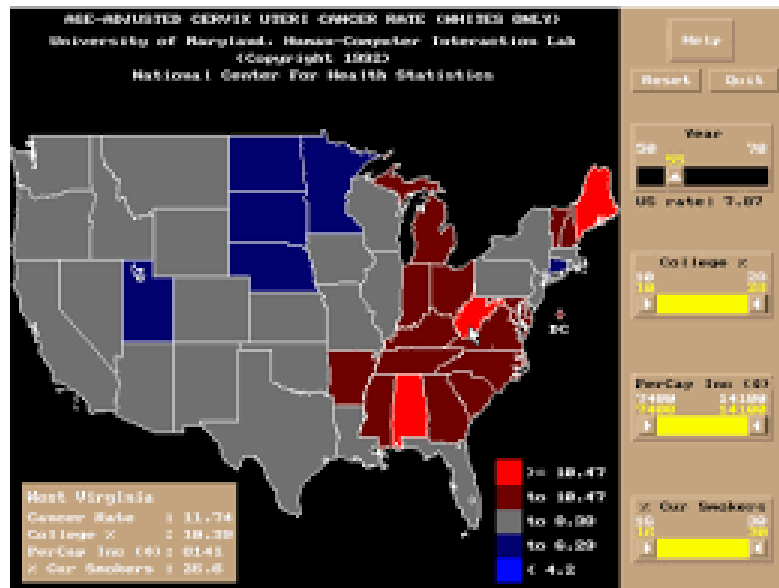
Modelos de Decisão Com Risco

Árvore de Decisão para Construtor



R. Bird, [Introduction to Decision Trees](#), 2018

Multi-criteria decision making



Pedro Mota, [Comparative Analysis of Multicriteria Decision Making Methods](#), 2013

Modelling

Statistical modelling

- Exploratory data analysis

- Sampling

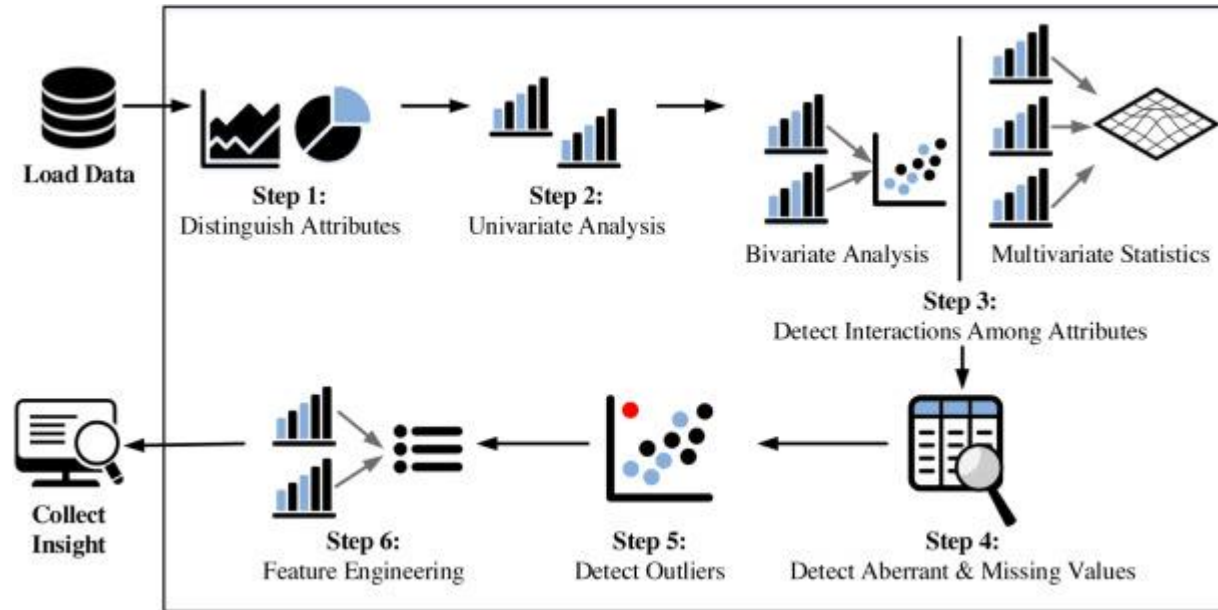
- Relationship analysis

- Time series analysis

- Spatial analysis

Statistics and machine learning will be approached in a future class

Exploratory data analysis

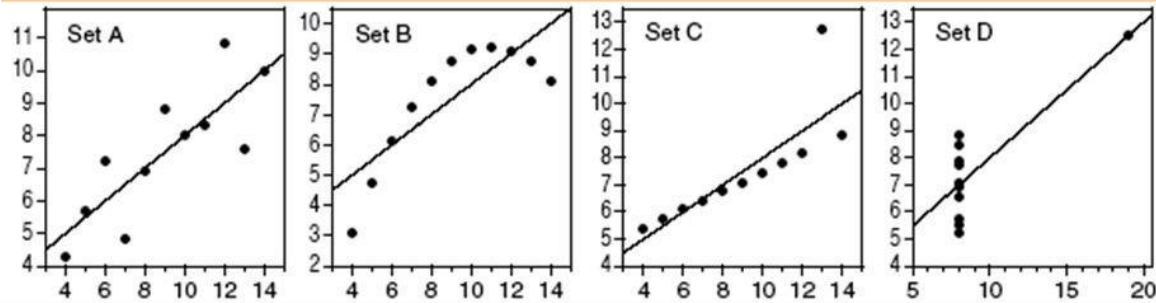


Water Quality Australia. [Monitoring data preparation and exploratory analysis](#). 2020

Relationship data analysis

+ All the same R value

However, making the scatterplots shows us that the correlation/ regression analysis is not appropriate for all data sets.



Moderate linear association; regression OK.

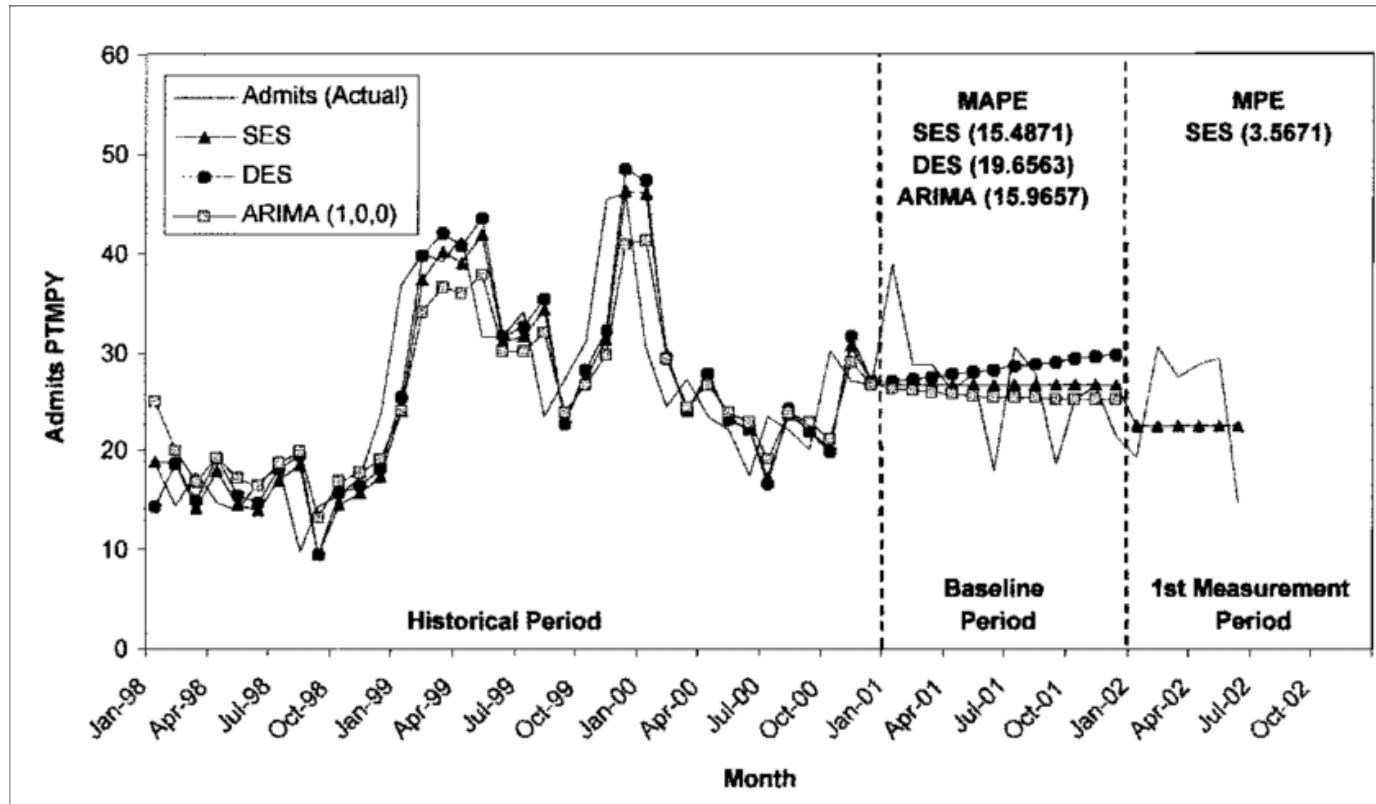
Obvious nonlinear relationship; regression inappropriate.

One point deviates from the (highly linear) pattern of the other points; it requires examination before a regression can be done

Just one very influential point and a series of other points all with the same x value; a redesign is due here...

Bruce Kendall and Chris Costello,
[Data Analysis for Environmental Science and Management](#), University of California, Santa Barbara, 2006

Time series analysis



E. E. Holmes, M. D. Scheuerell, and E. J. Ward

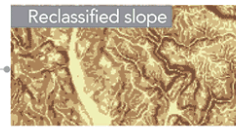
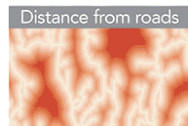
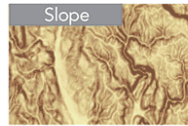
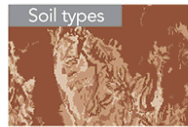
[Applied Time Series Analysis for Fisheries and Environmental Sciences](#)

University of Cape Town, 2020

Spatial analysis

Collect source layers

Data is first digitized into either polygon or raster layers. This housing suitability data is raster.

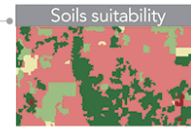
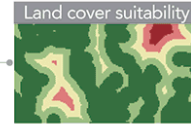


Reclassification

Source layers composed of continuous values (such as slope and distance layers) are first reclassified into meaningful ranges of values.

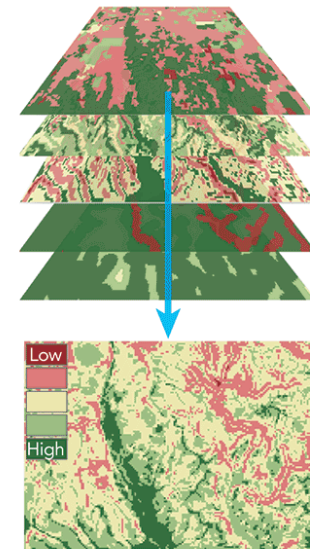
Create suitability layers

Each layer is now classified to use a common suitability scale: for example, low suitability could be assigned a value of 1 (dark red) and high suitability a value of 5 (dark green).



Calculate weighted overlay

Suitability layers are overlaid so that each cell gets an overall suitability rating. Weights of relative importance are assigned to each layer.



Gilberto Câmara, [Spatial Analysis and GIS: A Primer](#), 2020

<https://www.epa.gov/measurements-modeling/learn-about-models-epa>

Learn About Models at EPA

Environmental models are used to help guide research and policies at EPA. Modeling provides an abundance of information and can impact programmatic decision making. It allows a small or large amount of data to project details beyond boundaries of the individual values.

Within EPA, the Environmental Modeling (E-Mod) Community of Practice (CoP) helps further modeling at EPA by discussing and sharing current and innovative modeling practices. The E-Mod CoP brings together modeler developers, users and managers from across EPA to collaborate and help solve integrated environmental modeling challenges.

Below is a list of some models and modeling programs at EPA.

Additional Resources

[Registry of EPA Applications, Models and Databases \(READ\)](#)

On this page:

- [Air](#)
- [Chemical Safety](#)
- [Climate Change](#)
- [Ecosystems](#)
- [Health](#)
- [Human Health Risk Assessment](#)
- [Land and Waste Management](#)
- [Multimedia](#)
- [Water](#)

Air

[Models, Tools and Databases for Air Research](#)

[Support Center for Regulatory Atmospheric Modeling](#)

[Transportation and Air Quality Models](#)

[↑ Top of Page](#)

Chemical Safety

[Models, Web Applications and Databases for Chemical Safety Research](#)

[Pesticide Models](#)

[Predictive Models and Tools for Assessing Chemicals under the Toxic Substances Control Act](#)

- [Hazard Models and Tools](#)
- [Exposure and Fate Models and Tools](#)

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Climate Change

[Models, Tools and Databases for Climate Change Research](#)

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Ecosystems

[Methods, Models, Tools and Databases for Ecosystems Research](#)

<https://www.epa.gov/measurements-modeling/learn-about-models-epa>

Health

[Methods, Models, Tools and Databases for Health Research](#)

Human Health Risk Assessment

[Human Health Risk Assessment Research Methods, Models, Tools and Databases](#)

[Superfund Lead Exposure Models](#)

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Land and Waste Management

[EPA's Composite Model for Leachate Migration with Transformation Products \(EPACMTP\)](#)

[Industrial Waste Management Evaluation Model \(IWEM\)](#)

[Models, Tools and Databases for Land and waste Management Research](#)

[↑ Top of Page](#)

Multimedia

[Multimedia Exposure Assessment Models](#)

[↑ Top of Page](#)

Water

[Ground Water Exposure Assessment Models](#)

[Methods, Models, Tools and Databases for Water Research](#)

[Surface Water Exposure Assessment Models](#)

[Total Maximum Daily Load Exposure Assessment Models](#)

Key readings

Christensen, Villy (2012), [Ecosystem Models: Types and Characteristics](#)

Dick, Dori & hazen, Elliot, (2011) [Introduction to Ecological Modelling](#)

Haq, Gary & Schwela, Dietrich. (2008). [Air Quality Modelling](#)

Jolma, Ari & Ames, Daniel & Horning, Ned & Mitasova, Helena & Neteler, Markus & Racicot, Aaron & Sutton, Tim. (2012). [Open-Source Tools for Environmental Modeling.](#)

Loucks, Pete & Beek, Eelco. (2017). [Water Resource Systems Modeling: Its Role in Planning and Management.](#)

Marion, Glenn (2008). [An Introduction to Mathematical Modelling](#)

Pires, Ana, Martinho, Graça, Rodrigues, Susana & Gomes, Maria Isabel (2019) [Sustainable Solid Waste Collection and Management](#)

Zeidan, Bakenaz. (2015). [Mathematical Modeling of Environment Problems](#)