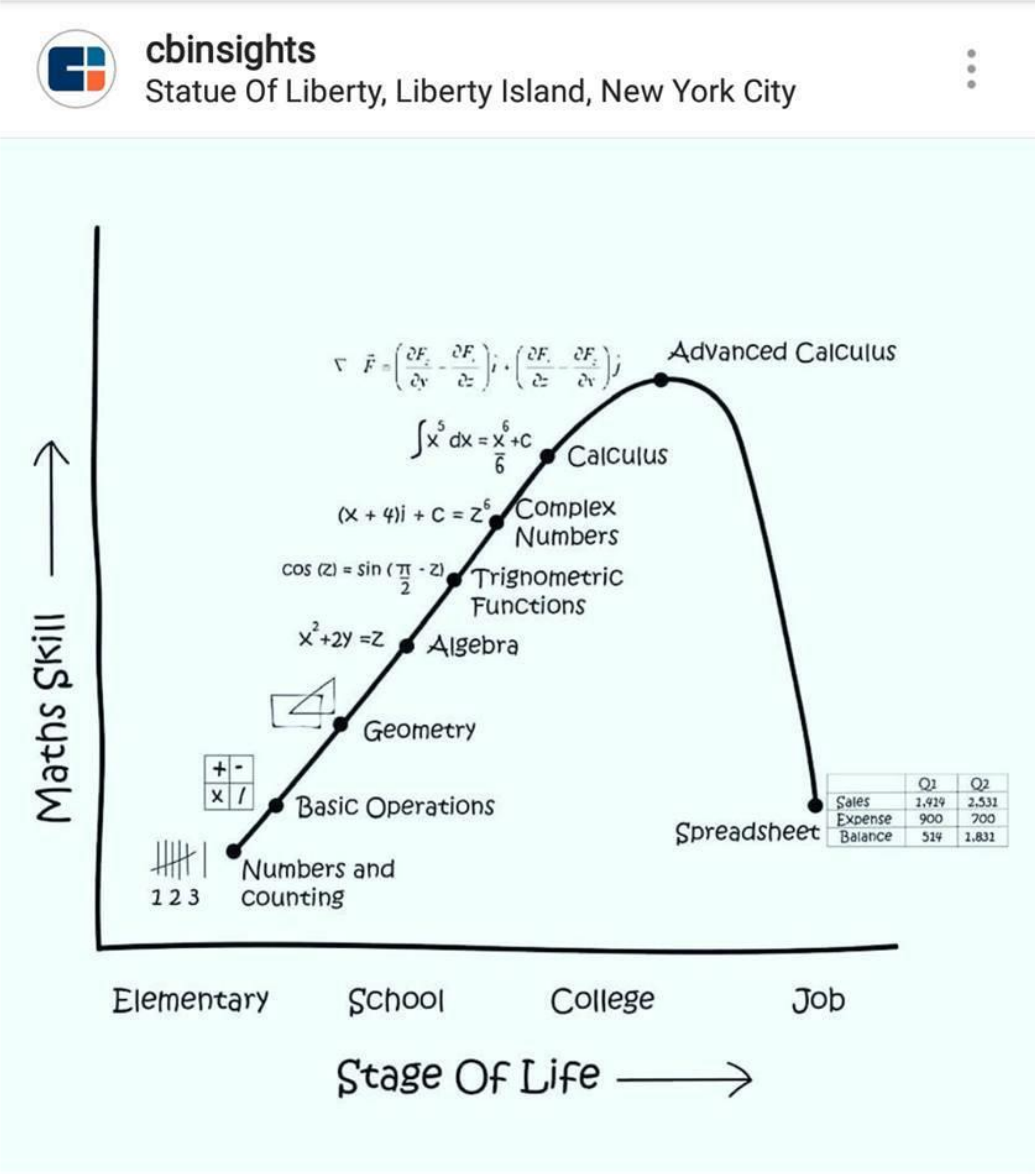


Environmental modelling- an overview

Antonio Camara

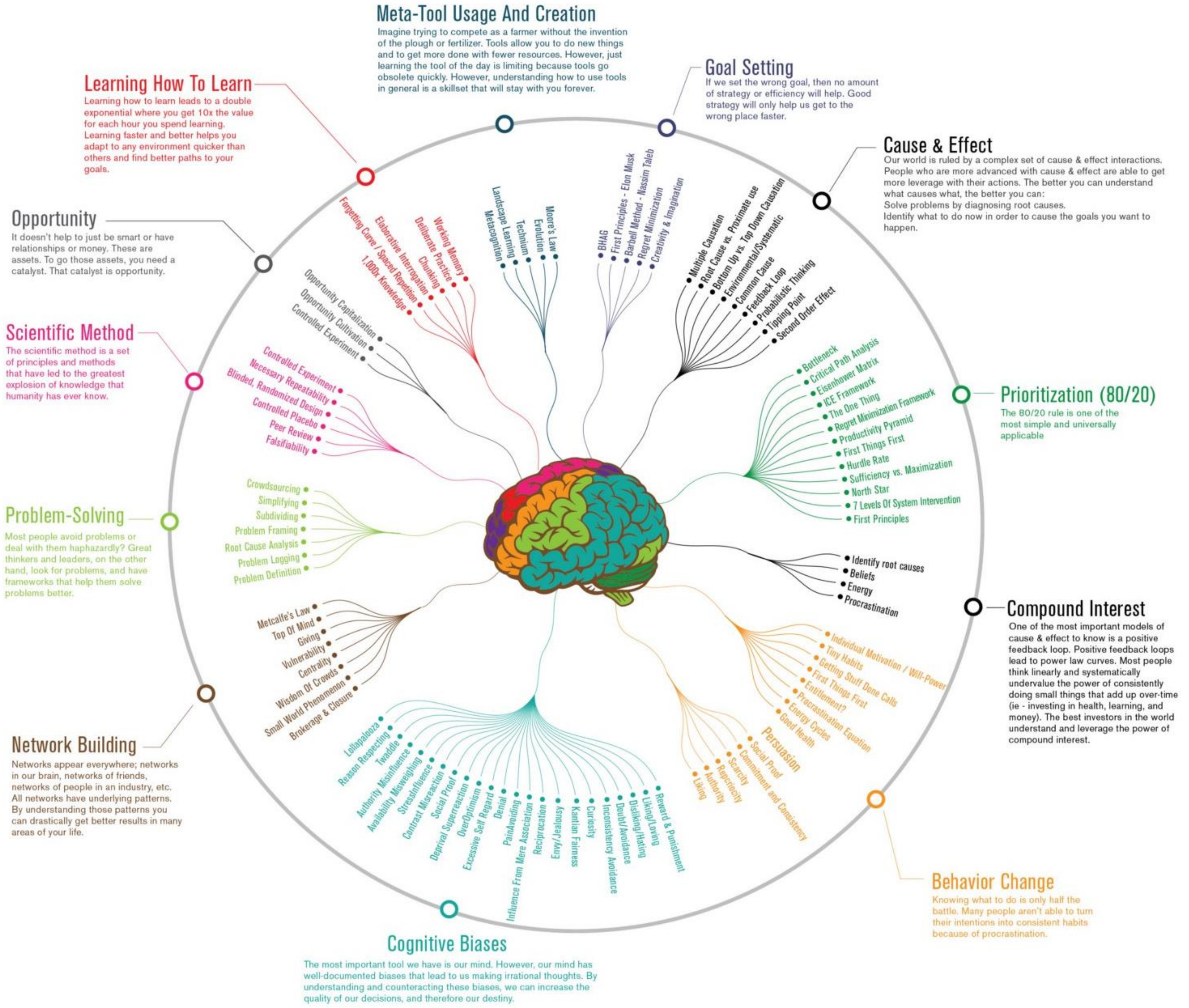
April 2020

Mental models

Useful mental models

109 mental models across disciplines

12 key mental models

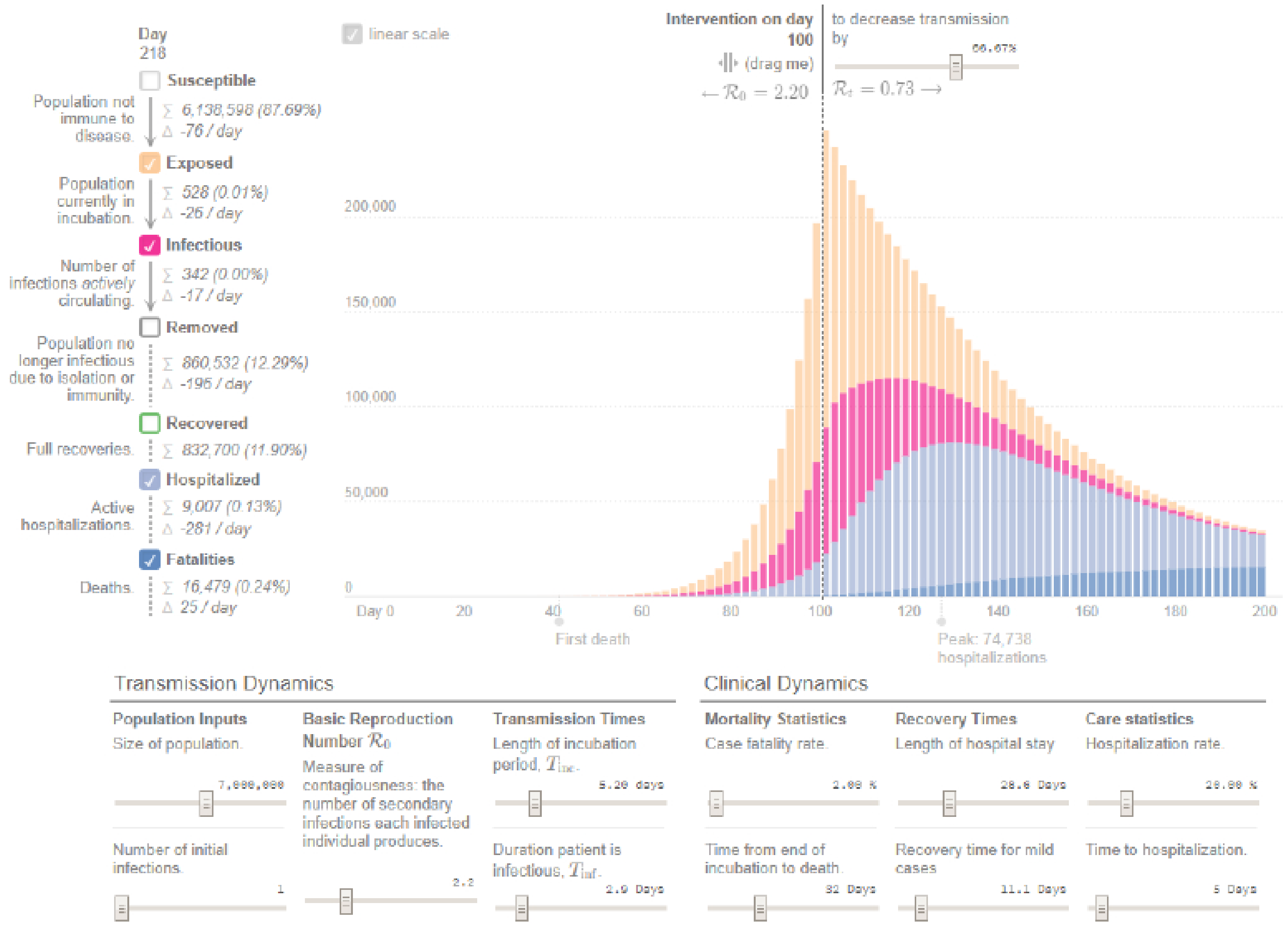

Meta-Tool Usage And Creation
Imagine trying to compete as a farmer without the invention of the plough or fertilizer. Tools allow you to do new things and to get more done with fewer resources. However, just learning the tool of the day is limiting because tools go obsolete quickly. However, understanding how to use tools in general is a skillset that will stay with you forever.
Moore's Law
Evolution
Technium
Landscape Learning
Metacognition
Goal Setting
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.
BHAG
First Principles - Elon Musk
Barbell Method - Nassim Taleb
Regret Minimization
Creativity & Imagination
Cause & Effect
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.
Multiple Causation
Root Cause vs. Proximate use
Bottom Up vs. Top Down Causation
Environmental/Systematic
Common Cause
Feedback Loop
Probabilistic Thinking
Tipping Point
Second Order Effect
Learning How To Learn
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.
Working Memory
Deliberate Practice
Chunking
Elaborative Interrogation
Forgetting Curve / Spaced Repetition
1,000x Knowledge
Opportunity
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.
Opportunity Capitalization
Opportunity Cultivation
Controlled Experiment
Scientific Method
The scientific method is a set of principles and methods that have led to the greatest explosion of knowledge that humanity has ever know.
Controlled Experiment
Necessary Repeatability
Blinded, Randomized Design
Controlled Placebo
Peer Review
Falsifiability
Prioritization (80/20)
The 80/20 rule is one of the most simple and universally applicable
Bottleneck
Critical Path Analysis
Eisenhower Matrix
ICE Framework
The One Thing
Regret Minimization Framework
Productivity Pyramid
First Things First
Hurdle Rate
Sufficiency vs. Maximization
North Star
7 Levels Of System Intervention
First Principles
Problem-Solving
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.
Crowdsourcing
Simplifying
Subdividing
Problem Framing
Root Cause Analysis
Problem Logging
Problem Definition
Identify root causes
Beliefs
Energy
Procrastination
Compound Interest
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.
Network Building
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.
Metcalfe's Law
Top Of Mind
Giving
Vulnerability
Centrality
Wisdom Of Crowds
Small World Phenomenon
Brokerage & Closure
Individual Motivation / Will-Power
Tiny Habits
Getting Stuff Done Calls
First Things First
Entitlement?
Procrastination Equation
Energy Cycles
Good Health
Persuasion
Social Proof
Commitment and Consistency
Scarcity
Reciprocity
Authority
Liking
Lollapalooza
Reason Respecting
Twaddle
Authority Misinfluence
Availability Misweighing
Stress Influence
Contrast Misreaction
Social Proof
Deprival Superreaction
OverOptimism
Excessive Self Regard
Denial
PainAvoiding
Influence From Mere Association
Reciprocation
Envy/Jealousy
Kantian Fairness
Curiosity
Inconsistency Avoidance
Doubt/Avoidance
Disliking/Hating
Liking/Loving
Reward & Punishment
Behavior Change
Knowing what to do is only half the battle. Many people aren't able to turn their intentions into consistent habits because of procrastination.
Cognitive Biases
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.

Calculators

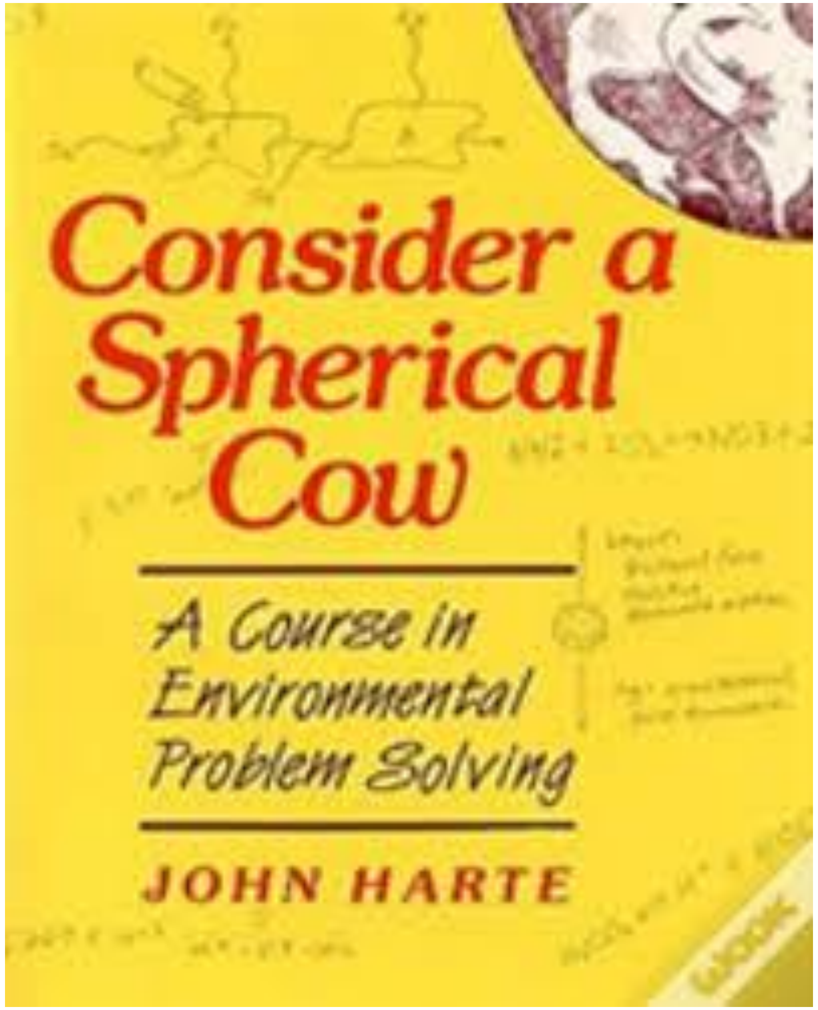
The epidemics calculator

Environmental calculators

Epidemic Calculator



Back-of-the-envelope models



Consider a Spherical Cow

Modelling

Simulation

Differential calculus

Numerical methods: finite differences and finite elements

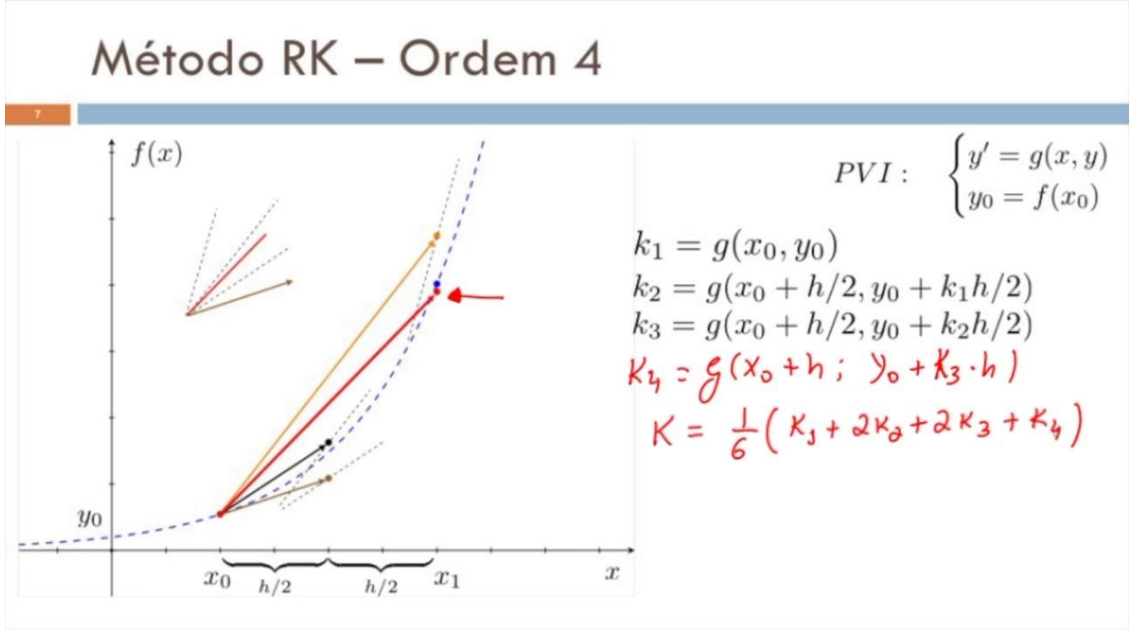
System dynamics

Discrete simulation

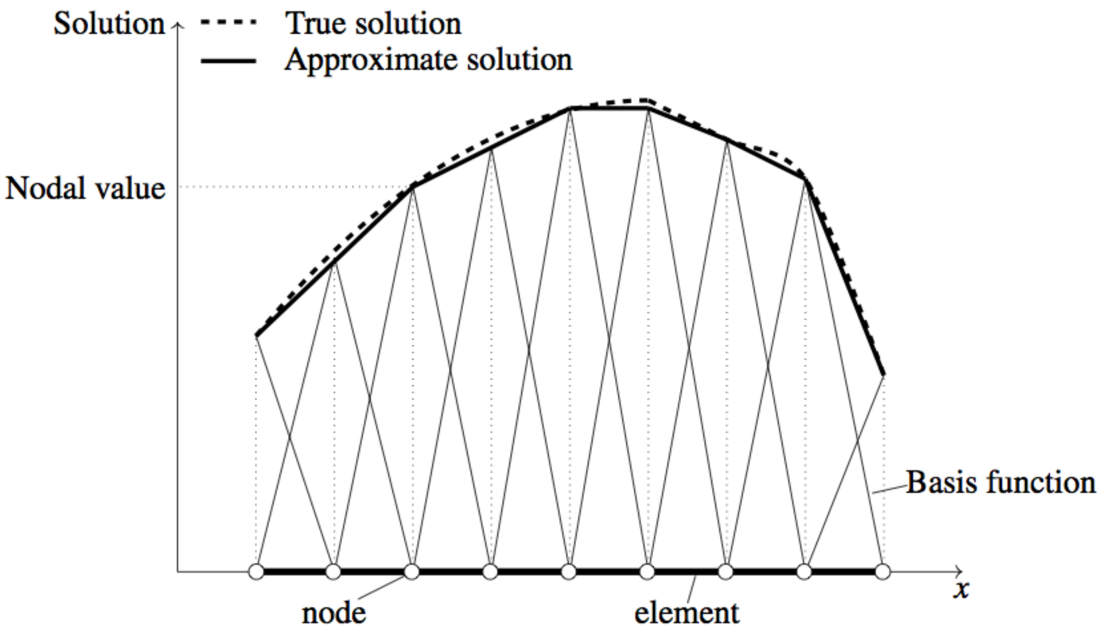
Cellular automata

Agent based models

Numerical models



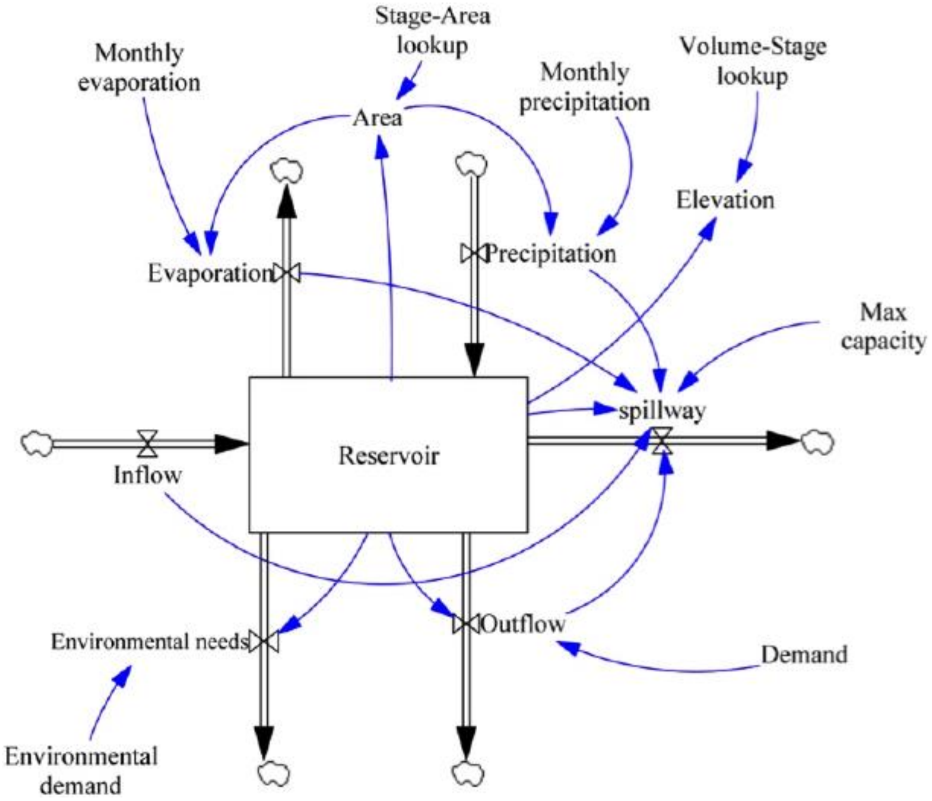
Finite differences



Finite elements

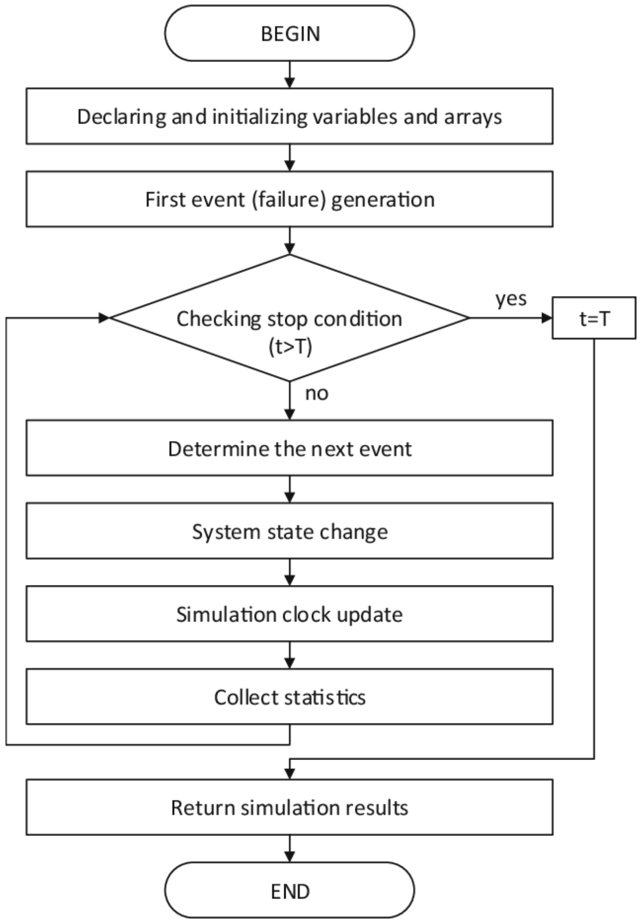
Daniel Lynch, Numerical Partial Differential Equations for Environmental Scientists and Engineers, Spring, 2005

System dynamics models



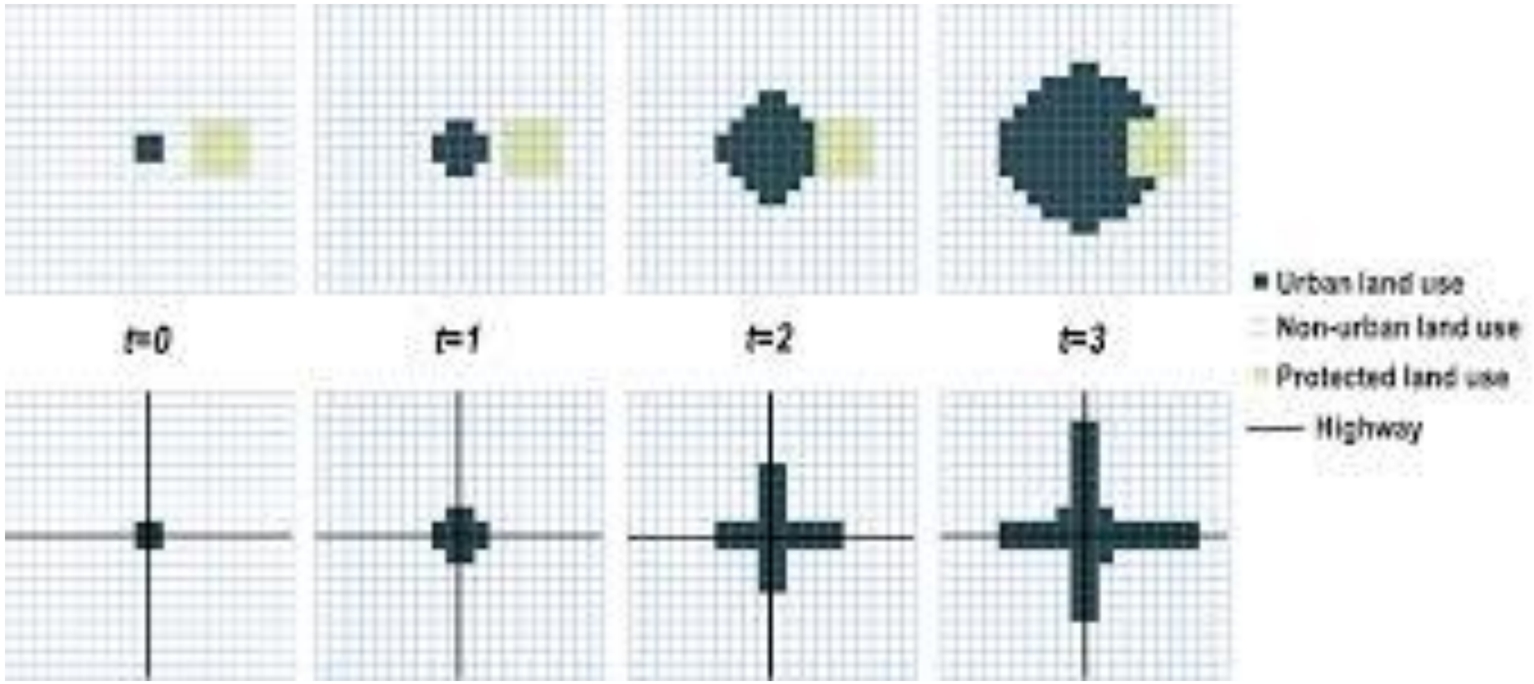
Andrew Ford, [System Dynamics Models of Environment, Energy and Climate Change](), Springer, 2011

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]

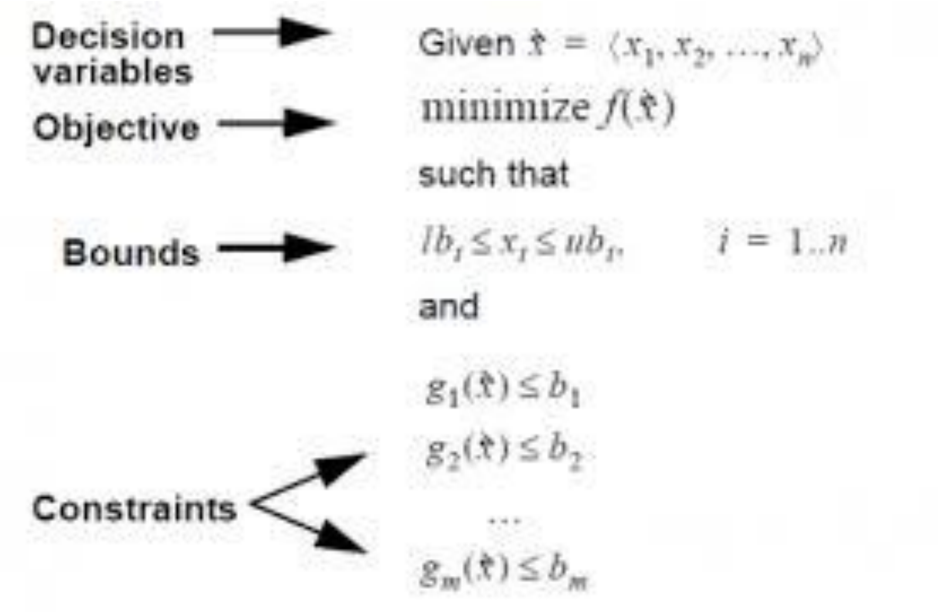
Klügl, Franziska & Bazzan, Ana. Agent-Based Modeling and Simulation. AI Magazine. 33. 29-40, 2012

Modelling

Optimization

- Linear programming
- Integer programming
- Dynamic programming
- Non-linear programming
- Network models
- Genetic algorithms
- Optimal control models

Non-linear optimization models



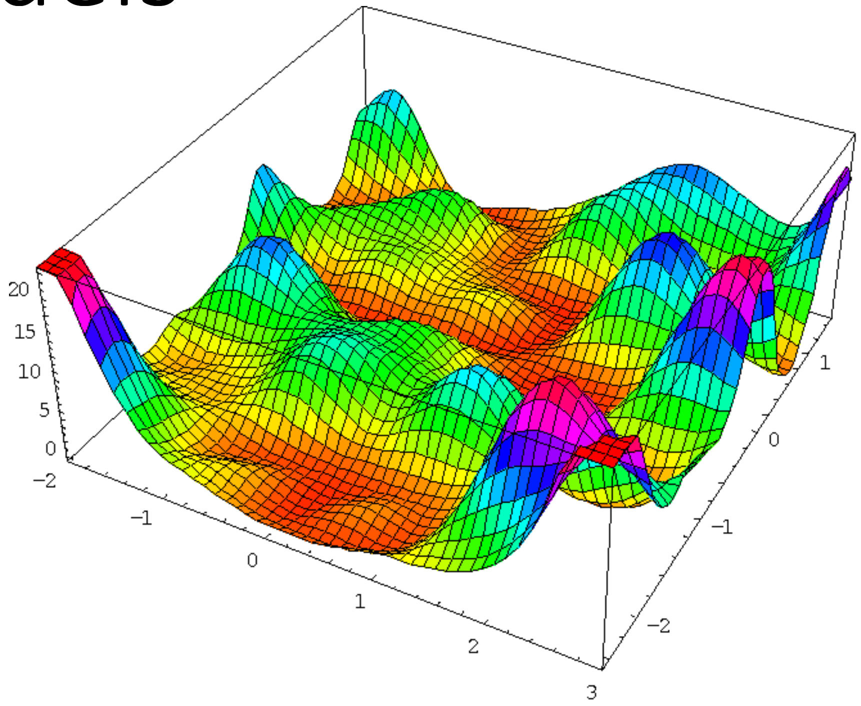
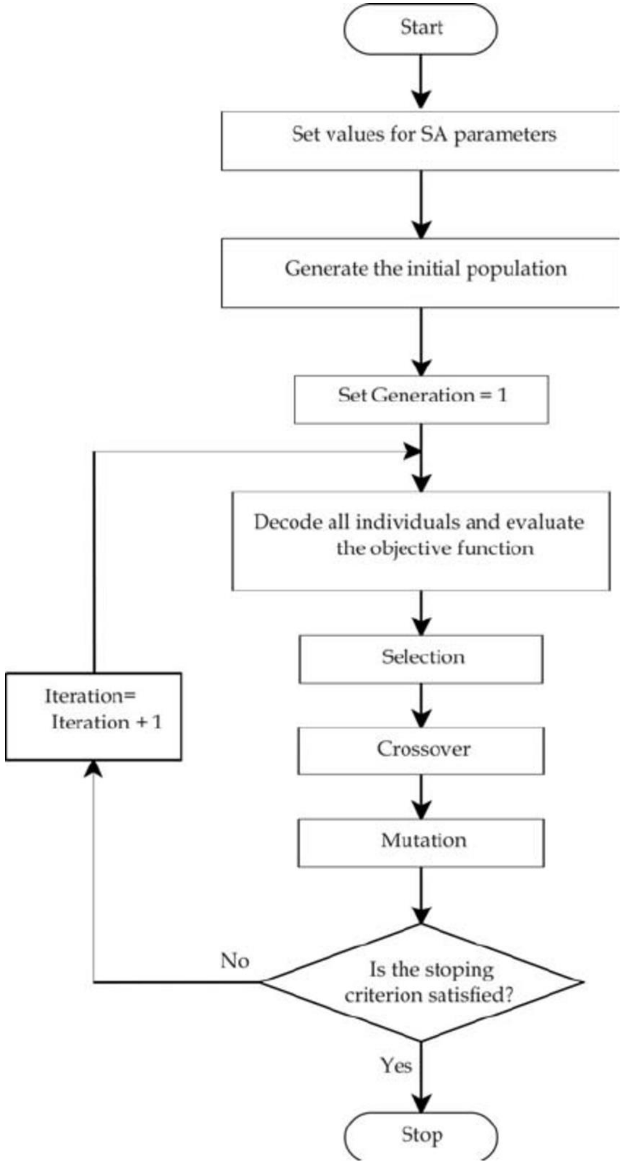


Figure 1.
An illustrative global optimization model.

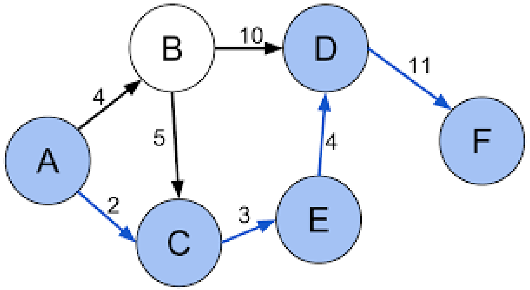
Eck, Bradley & Mevissen, Martin. Fast Non-Linear Optimization for Design Problems on Water Networks. World Environmental and Water Resources Congress 2013. 696-705.

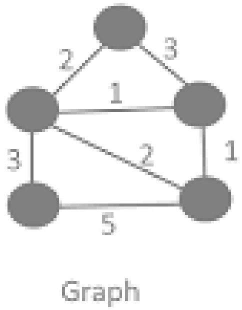
Genetic algorithms

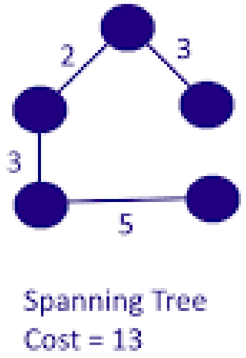


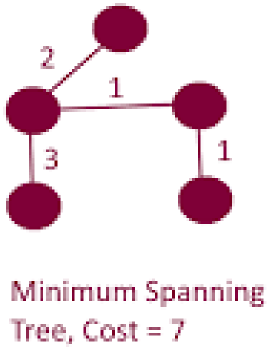
Haupt, Sue & Haupt, Randy. Genetic Algorithms and their Applications to Environmental Sciences. Utah State University, 2003

Network models









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 $V(\boldsymbol{x}, \boldsymbol{u})$

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

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

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

General nonlinear control problem

2

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

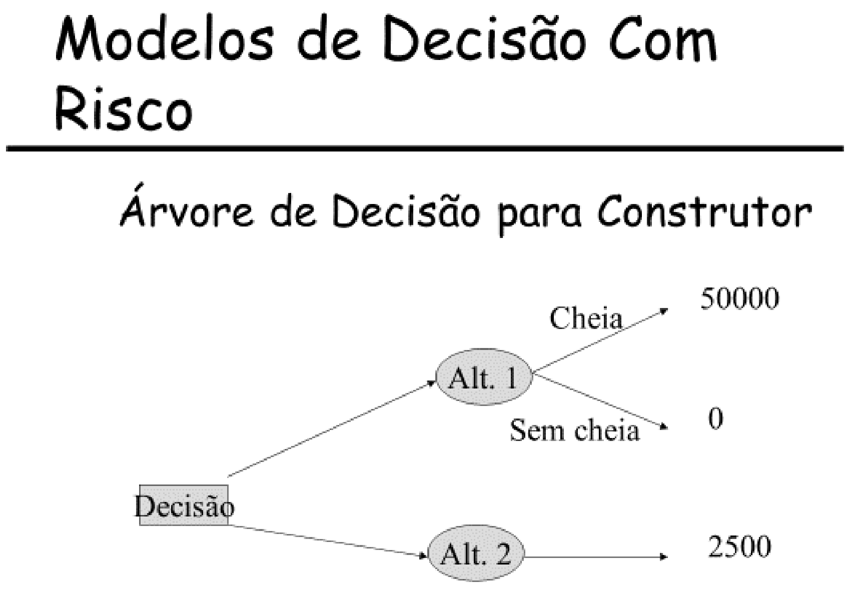
Modelos de Decisão com Incerteza

Grau de eficácia para socorro de catástrofes em três regiões

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

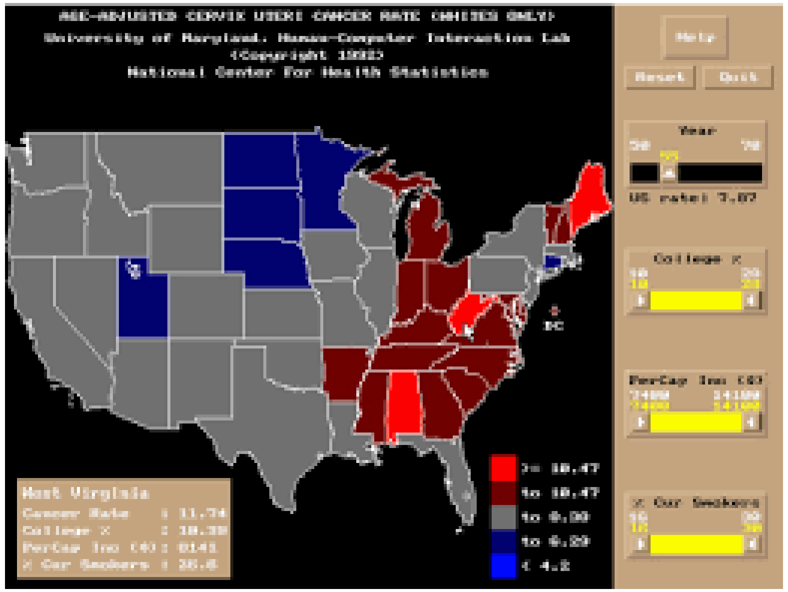
J. Najera, The Basis for Game Theory, 2019

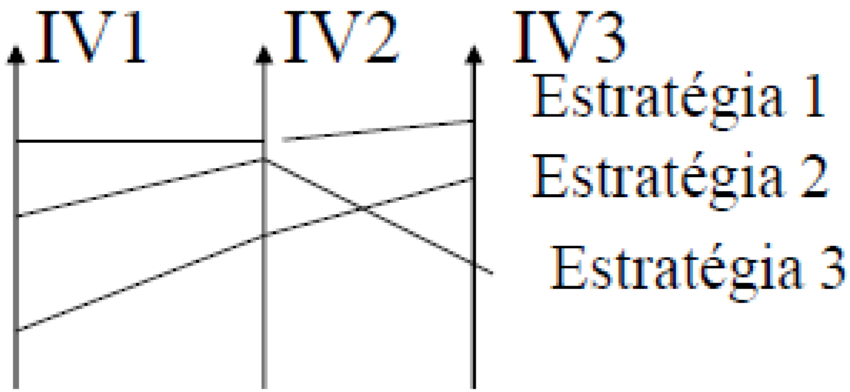
Decision trees



R. Bird, Introduction to Decision Trees, 2018

Multi-criteria decision making





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

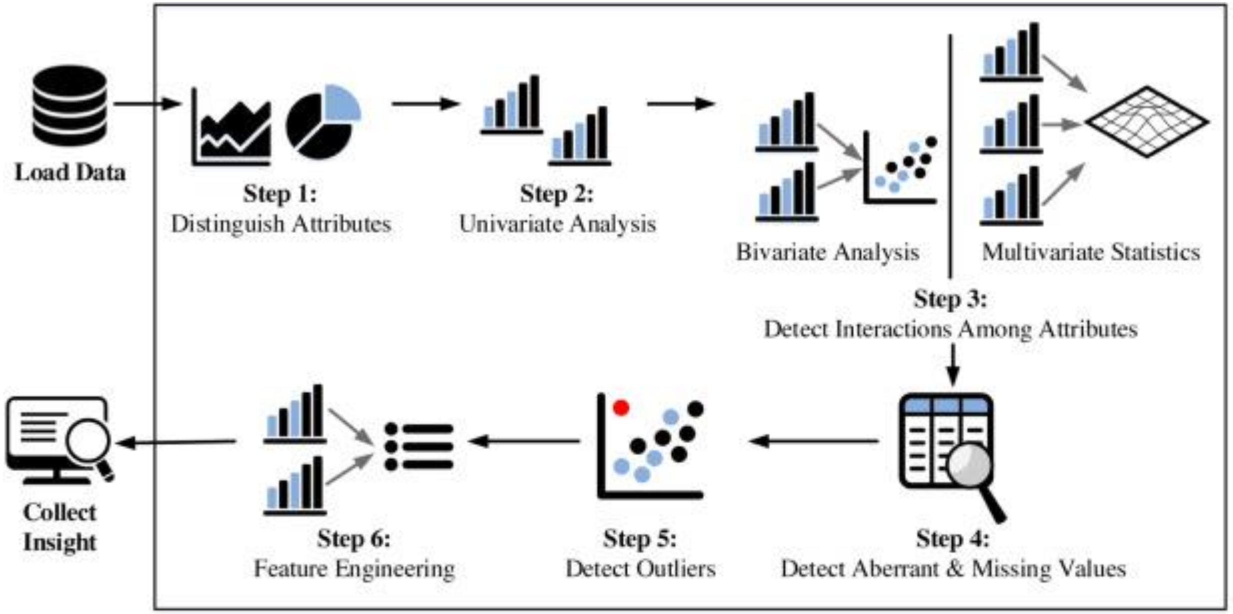
Modelling

Statistical modelling

Exploratory data analysis
Sampling
Relationship analysis
Time series analysis
Spatial analysis

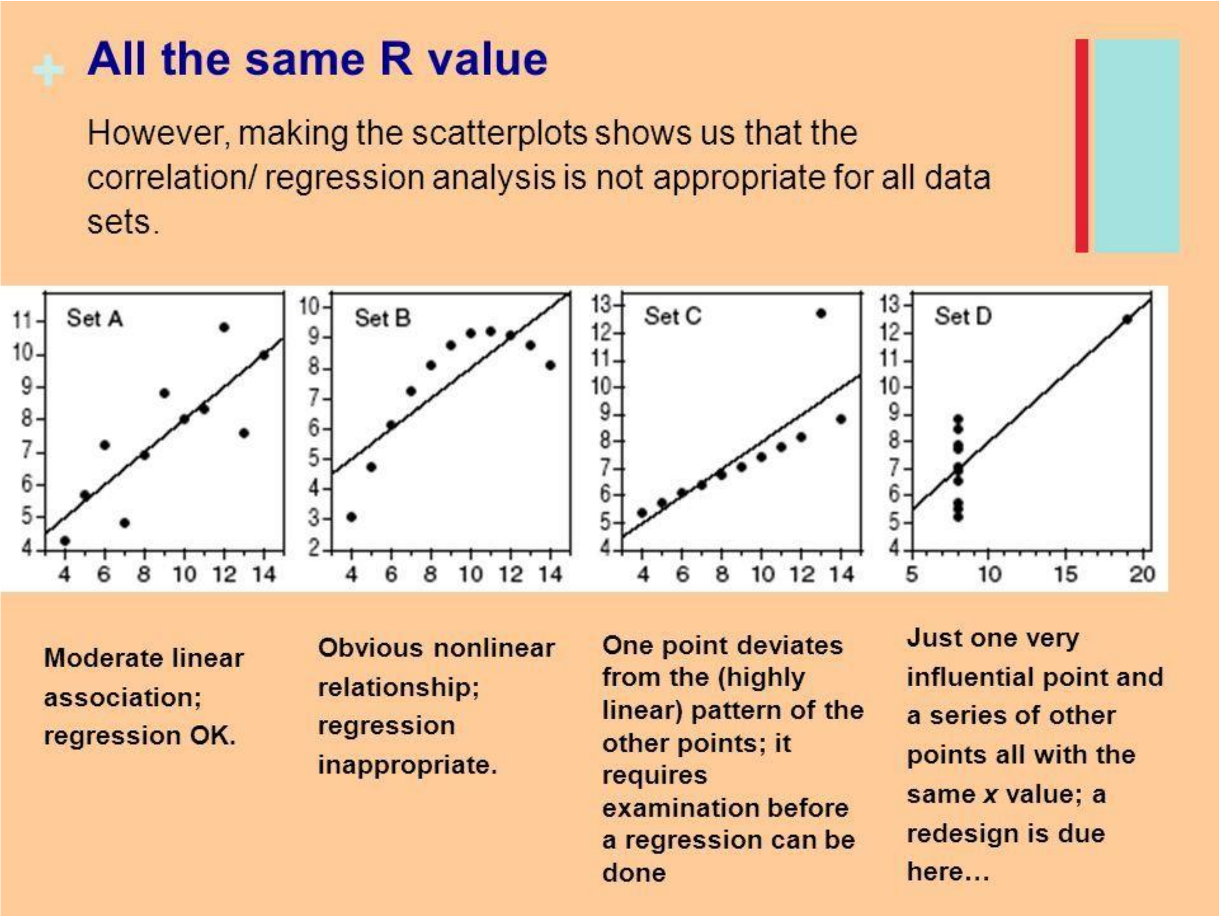
Statistics and machine learning will be approached in a future class

Exploratory data analysis



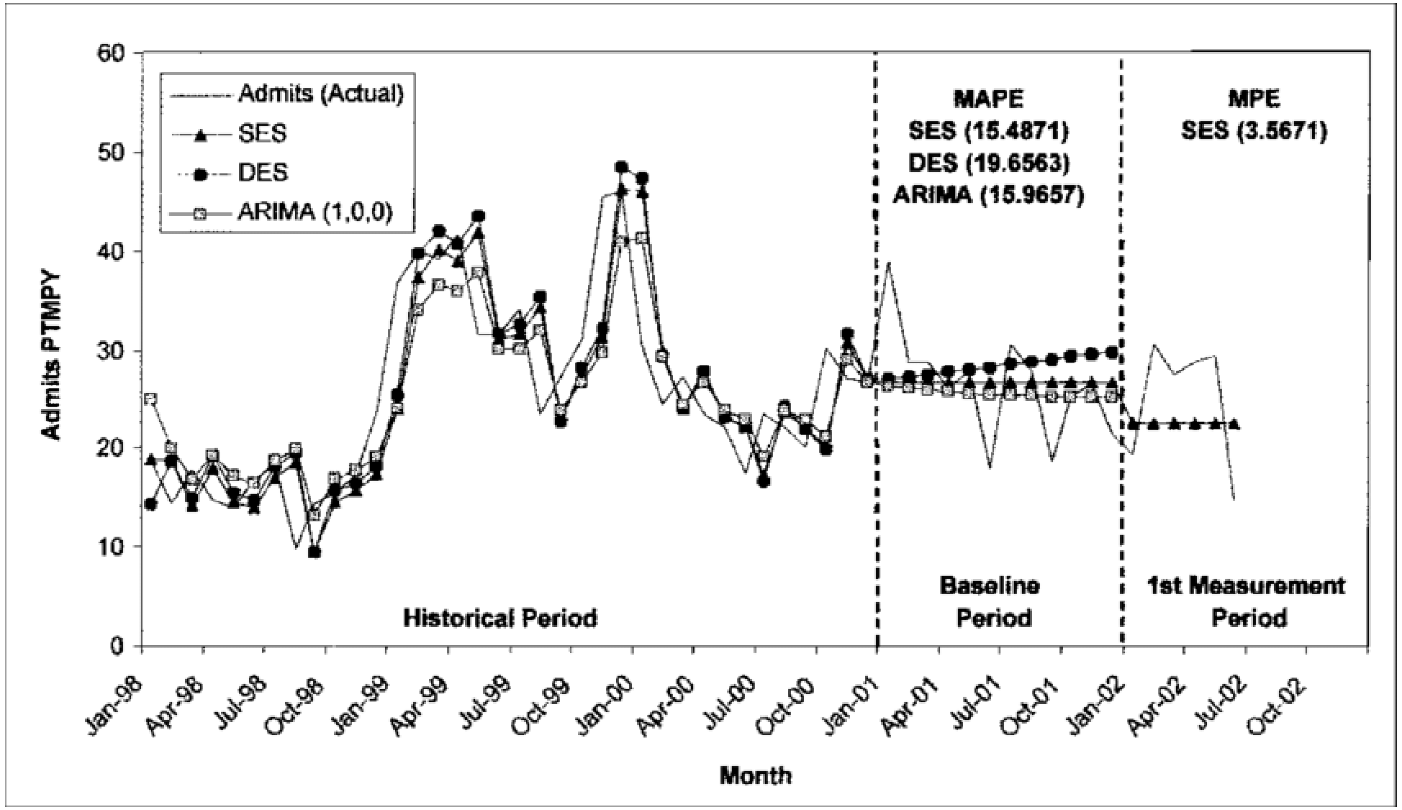
Water Quality Australia. [Monitoring data preparation and exploratory analysis.] 2020

Relationship data analysis



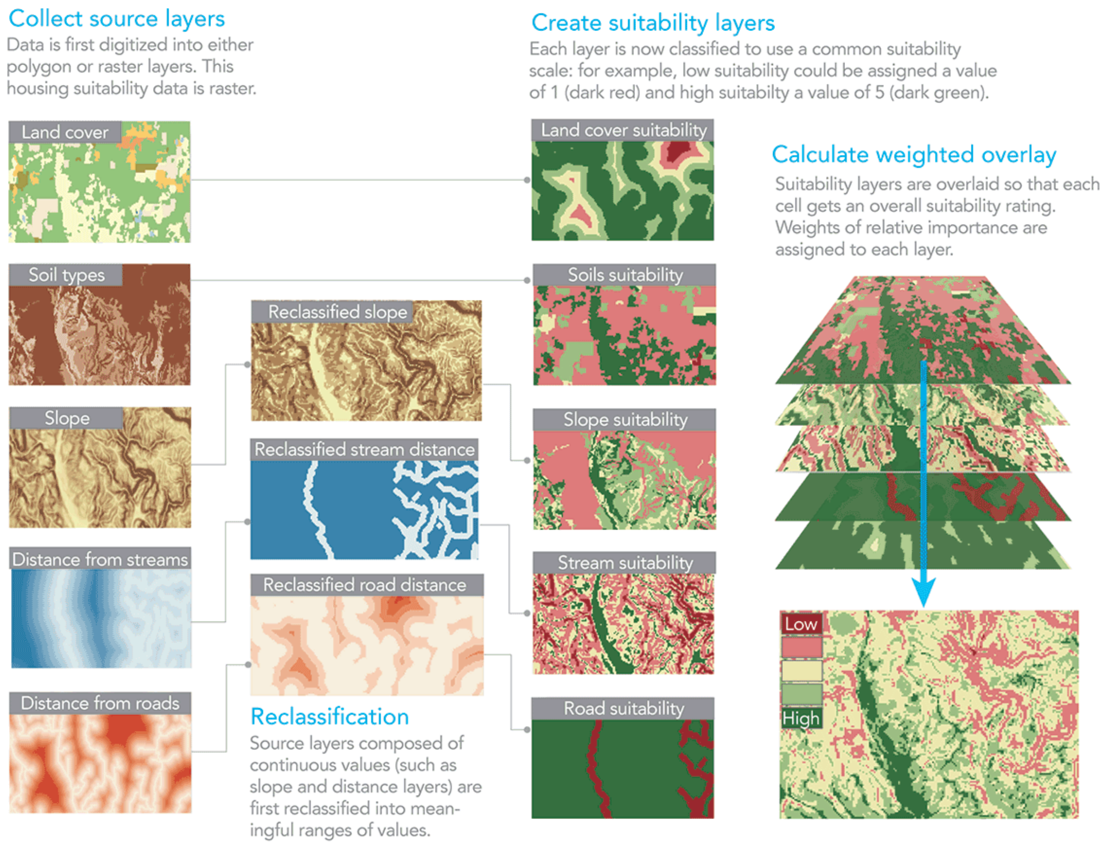
Bruce Kendall and Chris Costello, Data Analysis for Environmental Science and Management, University of California, Santa Barbara, 2006

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



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.

Additional Resources

Registry of EPA Applications, Models and Databases (READ)

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.

On this page:

- Air
- Chemical Safety
- Climate Change
- Ecosystems
- Health
- Human Health Risk Assesment
- 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

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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

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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 Modellig

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