



WHY USE SIMULATION MODELING IN EDUCATION AND RESEARCH

WHITE PAPER



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INTRODUCTION

Simulation modeling is an important method of analysis that is easily verified, communicated, and understood. Businesses and academia use simulation in many industries and disciplines because it gives clear insights into complex systems.

Unlike physical modeling, such as making a scale copy of a building, simulation modeling is computer-based and uses algorithms and equations. Simulation software provides a dynamic environment for the analysis of computer models while they are running, including the possibility to view them in 2D or 3D.

Computer simulation is a discipline that has broken out well beyond its beginnings in the Manhattan Project over seventy years ago. These days, people work as professional simulation modelers and children learn about simulation from an early age and may even be taught about it in school, such as in the [national curriculum](#) of the United Kingdom.

Simulation exists because of learning, that is what it is for. Early uses for simulation modeling pre-date the digital era and included areas such as aviation, with the [Link Trainer](#) from 1927, and clinical healthcare care, with many detailed [examples](#) from the 18th century and before. In each case, simulation gave the possibility to learn from practice in situations that could be problematic in the real world.

With the digitization of simulation, risk-free and low-cost experimentation has become easier to use and more powerful. As a result, simulation is now applied widely outside of its original domains, including in areas such as business

management, for example, [investment risk management](#), and social research, such as in the study of [social network message propagation](#).

The widespread adoption of simulation in different disciplines and specializations is also reflected in commerce. Businesses commonly use simulations for tasks such as [process optimization](#), [marketing analysis](#), [supply chain management](#), and [more](#). The tools used for simulation in business are the same as those used in academia, meaning an easy transition for students to apply their skills.

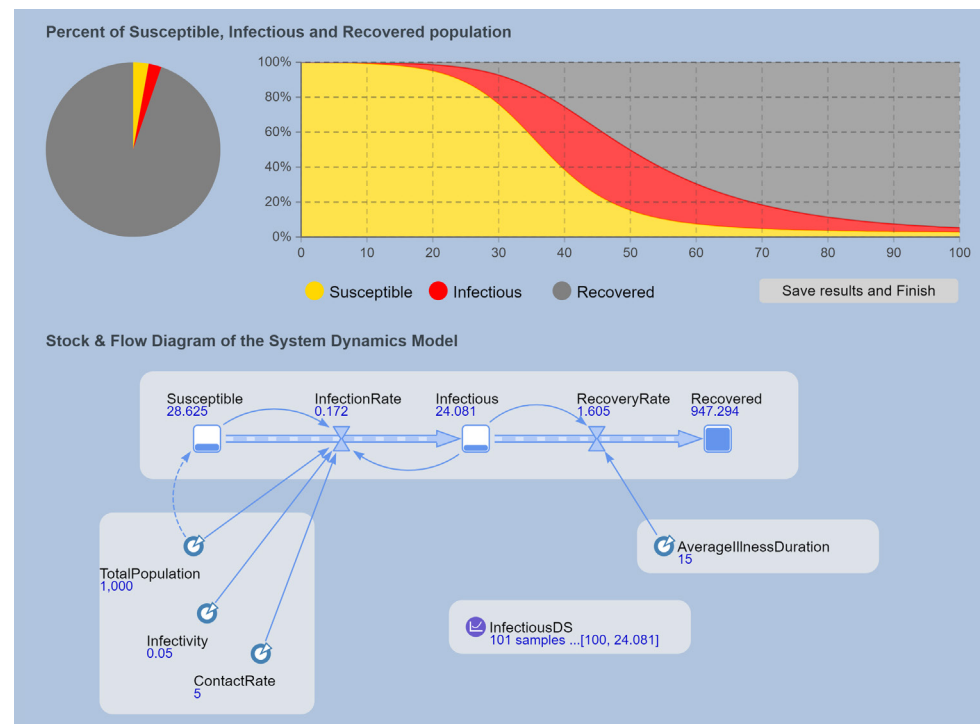
Tutors, students, and researchers in all kinds of fields and at institutions around the world now benefit from simulation modeling. In this paper, we will show why simulation is used in teaching, how it assists research, and how to choose the right tool for your simulation modeling needs.

WHY SIMULATION IS USED IN TEACHING

01

WHY SIMULATION IS USED IN TEACHING

There are two main reasons for using simulation in teaching. Firstly, computer simulation modeling is taught in science and engineering courses as a method for modeling and analyzing systems. Students learn tools such as AutoCAD in architecture and engineering, or MATLAB, which can be found in areas such as aerospace and wireless communications.



Susceptible, Infected, Recovered (SIR) model interface

For business management sciences, simulation tools help analyze and optimize business processes. For example, students learn how to apply simulation for supply chain analysis on the [MITx MicroMasters Supply Chain Management](#) course.

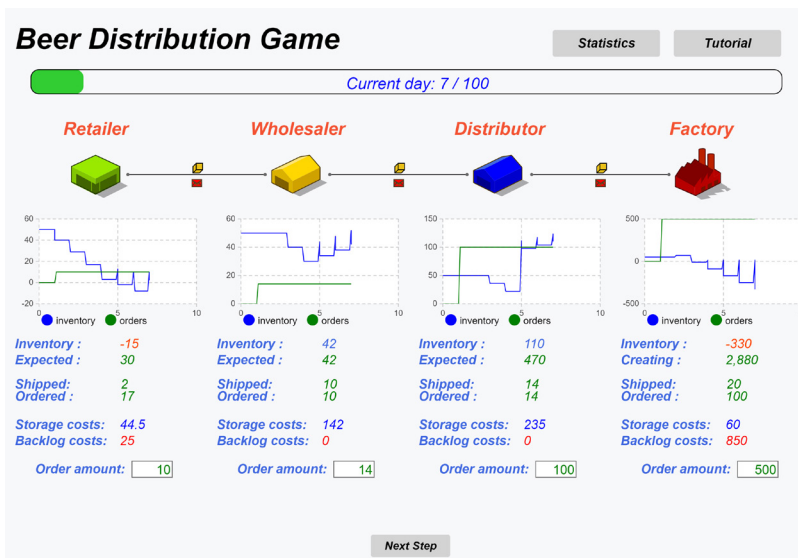
The second main reason for using simulation modeling in teaching is to illustrate processes so that students may more easily understand concepts and theories – this is common throughout disciplines. A well-known example in epidemiology is the [Susceptible, Infected, Recovered \(SIR\) model](#).

Computer-based simulation is not just used in academia for learning simulation concepts and methods. It is used across disciplines to demonstrate processes and ideas, to investigate hypotheses, and for when conducting experiments on a real system is impossible or impractical.

Simulation modeling can be used for active learning strategies and game-based learning. Groups and individuals can follow tutorials interactively, learning the subject at hand by interacting with a representation of it. Here are some examples:

BEER DISTRIBUTION GAME

A well-known simulation model that is often used for teaching in supply chain and network management is the [beer distribution game](#). The aim is not to learn simulation but to investigate relationships in the supply chain and to discover how to minimize costs.



Interface of a Beer distribution game model

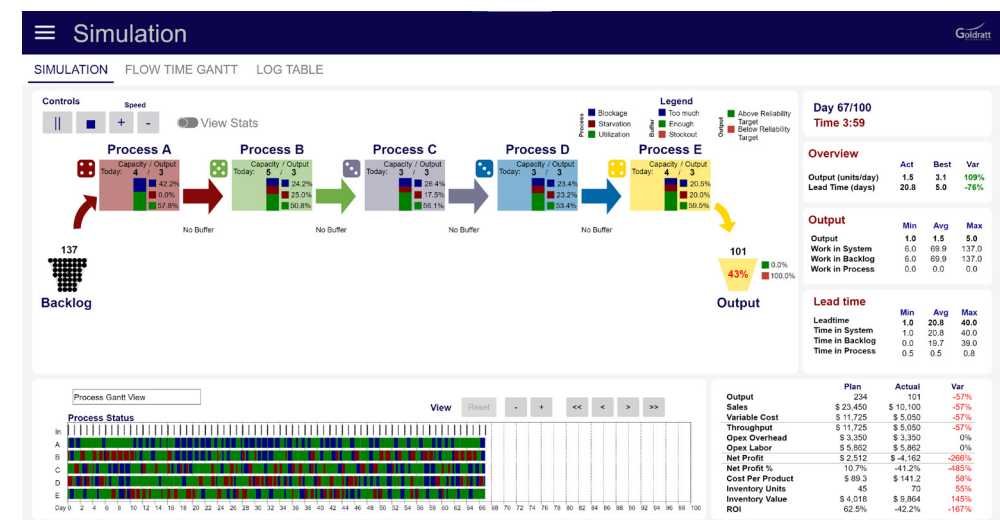
The game helps teach supply chain and network management through requiring players to minimize costs by balancing retail, wholesale, and distributor parameters. It is based on agent-based and discrete event modeling methods.

The Technical University of Berlin takes this concept further and has created several models to assist in teaching various [supply chain scenarios](#).

THEORY OF CONSTRAINTS

Teaching theory is better done interactively. When a student can interact with a model that represents a theory, they are better able to understand its behavior and get a feel for how it works. That is the motivation behind Goldratt Research Labs's interactive illustration of the Theory of Constraints in manufacturing with

their [Dice Game](#) model. With the simple interface, it is possible for anyone using the model to begin experimenting and learning the effects of their changes without having to learn simulation modeling themselves. The game is based on discrete-event modeling and teaches the impacts of bottlenecks, and how best to manage them, in the context of manufacturing. The answer is not always to just remove them – for risk of creating other imbalances.



Dice game model interface

URBAN DYNAMICS

In the sphere of urban planning, Dr. Gonalo Correia from Delft University of Technology created the Urban Dynamics Educational Simulator ([UDES](#)) to teach agent-based land use and transport interactions. Again, no knowledge of simulation modeling is needed from the student for them to begin working with the [simulator](#).



Using an agent-based model, the simulator shows how various parameters, such as transport costs, can change where businesses and people locate themselves. Many variables and parameters are considered and students can compete using many different strategies.



Interface of an Urban dynamics educational simulator

These interactive methods increase student engagement and help in the learning of theory – boosting performance.

Simulation helps teach processes and theory in a variety of disciplines. In engineering, computer science, and business management, simulation is integral, but it is not limited to these areas. General simulation is applied in fields such as healthcare, epidemiology, economics, transportation, defense research, and more. Often, only the software limits where simulation helps solve challenges and demonstrate concepts. Furthermore, once familiar with simulation, it becomes natural to apply it in research.

HOW SIMULATION HELPS RESEARCH



HOW SIMULATION HELPS RESEARCH

Beyond teaching, simulation modeling is a powerful tool for research. In fact, teaching and research with simulation often go together. While many graduates will have simulation skills and apply them in research, it is also the case that skills and insights acquired during research feed through into teaching. Either way, the reasons simulation modeling is valuable in research are clear: simulations provide insights into complex systems and help test ideas and findings in ways that are simple and easy to communicate.

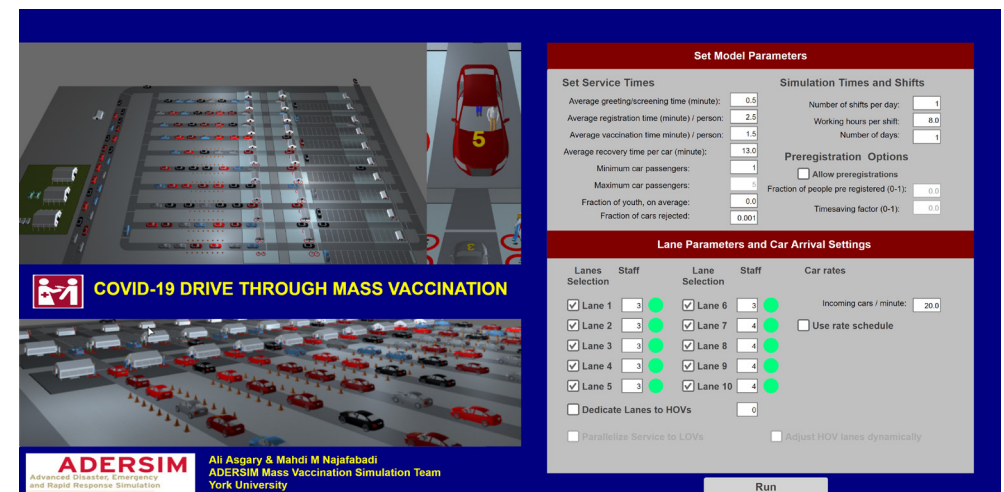
With a valid digital representation of a system, you can conduct experiments without risk. Unlike physical modeling or experiments on a real-world system, simulation modeling is computer-based and provides a dynamic virtual place for experimentation that can return detailed data and have 2D and 3D visualizations.

An advantage of simulation modeling over methods such as Excel or linear programming is the ability to analyze a model as it runs – this can help build understanding and trust because it is possible to inspect and interact with live processes.

Laboratories around the world use simulation modeling as an integral part of their research, commercial activities, and agency work. For an example of the variety of uses for simulation, visit AnyLogic's selection of [papers and articles](#).

Recent examples of work done using simulation modeling:

At York University's Advanced Disaster, Emergency, and Rapid Response Simulation lab ([ADERSIM](#)), Dr. Ali Asgary led a team researching mass vaccination possibilities in response to the COVID-19 pandemic. The lab developed simulation models and showed how public authorities could most effectively vaccinate their populations. In addition to the statistics from the simulations, dynamic [3D and 2D representations](#) allowed easy communication of the methods and setup required for the vaccination proposals. As the implementations made their way into practice, the results were picked up by several news agencies who, thanks to cloud technology, shared the 3D models for the public to inspect – Bloomberg City Lab: [The Architecture of Mass Vaccine Distribution](#).

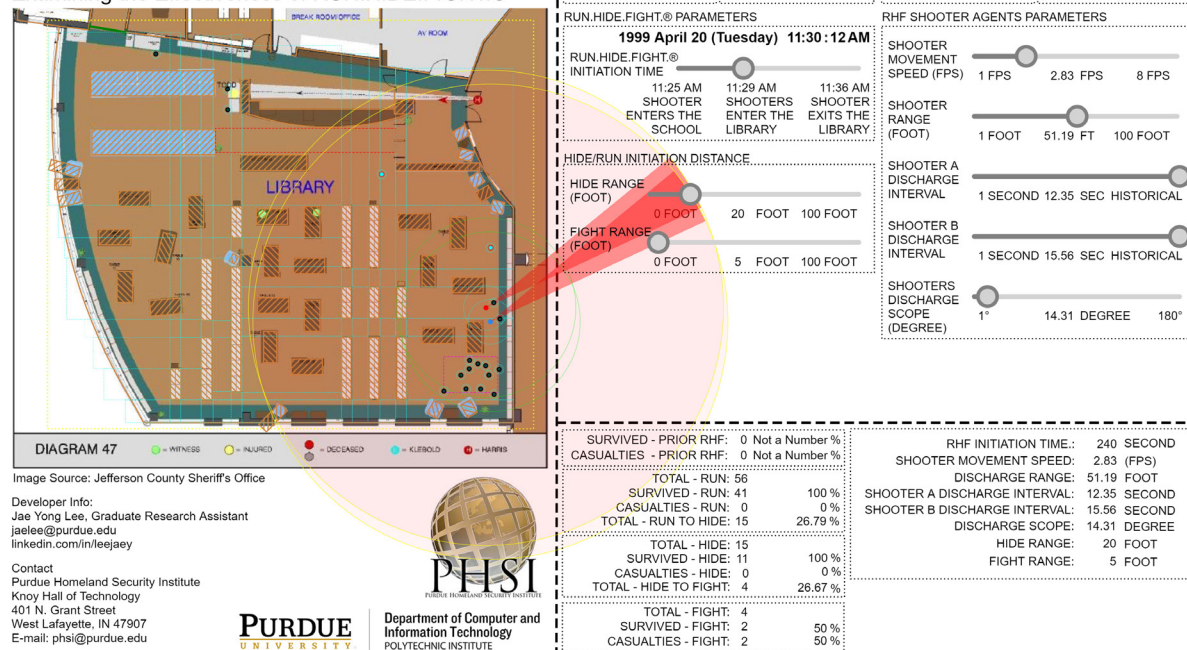


Interface of a Mass vaccine distribution model

The [Homeland Security Institute](#) at Purdue University uses simulation in its work to prevent, protect, respond, and recover from any threat or action taken against its homeland, the United States. An example of their work includes an [assessment](#) of the effectiveness of the RUN. HIDE. FIGHT policy from the Department of Homeland Security. Part of the research includes the [modeling](#) of the 1999 Columbine High School shooting. The research and the model were [presented](#) at the 2019 AnyLogic Conference.

Dr. Nathaniel Osgood leads the Computational Epidemiology and Public Health Informatics Lab ([CEPHIL](#)) at the University of Saskatchewan, Canada. The lab applies simulation, sensing, and artificial intelligence to inform understanding of population health trends and health policy tradeoffs. To help increase insight and transparency, and to remain nimble when faced with evolving uncertainties, the lab uses hybrid models with machine learning that combine the traditional methods of discrete event, system dynamics, and agent-based modeling. The approach was highlighted in the webinar [Hybrid Dynamic Models in COVID-19 Planning and Beyond](#).

Modeling the 1999 Columbine High School Shooting:
Examining the Effectiveness of RUN.HIDE.FIGHT.®



Active shooting model interface

CHOOSING THE RIGHT TOOL FOR SIMULATION



CHOOSING THE RIGHT TOOL FOR SIMULATION

Simulation modeling is a skill that needs to be learned. For computer science and engineering specializations, the process of learning simulation modeling tools is a natural activity. But, for other disciplines, such as management sciences, dedicating large amounts of time to learning simulation is not an option. In these situations, when a simulation is a means and not the end, tutors can create standalone models with custom user interfaces that are suited to the topic under study.

A key factor to consider is how applicable a simulation modeling tool is for different challenges. A tool that can be applied in different scenarios means skills do not have to be relearned and that there will be a deeper pool of user knowledge.

A further consideration is how well-adopted the simulation tool is in industry. If it is used commonly in industry, the skills learned in academia will be valuable for students when they seek employment.

In all cases, a well-developed, documented, and fully supported tool with a thriving community can significantly help success.

In fact, while add-ons and extensions can make a tool applicable in a variety of scenarios, it is important to consider the flexibility of a tool, that is, its applicability to various industries and research problems. In practice, this transforms to supporting multiple modeling methods, or paradigms. Furthermore, a modeling tool should assist practitioners in the modeling process, such as with industry-specific libraries that ease and quicken modeling.

The tool should also enable easy sharing and collaboration between peers, tutors, and students.

AnyLogic is an enterprise-grade multimethod simulation platform that is free to learn and established in academia. With it, users are never limited by a single modeling paradigm – they can always choose the most efficient method, or combination, to best address a problem or to show theories in practice. Combined with industry-specific modeling libraries, AI integrations, and cloud platform capabilities, AnyLogic is the number one general simulation platform for finding solutions and communicating complex ideas.

AnyLogic simulation software was [first released](#) in 2000 and has its [roots](#) in academia where it has a long history in both research and active learning. Research laboratories that use AnyLogic find it easy to transfer their experience using the tool into the teaching environment. It is supported by textbooks, online materials, and a broad community of simulation modeling practitioners.

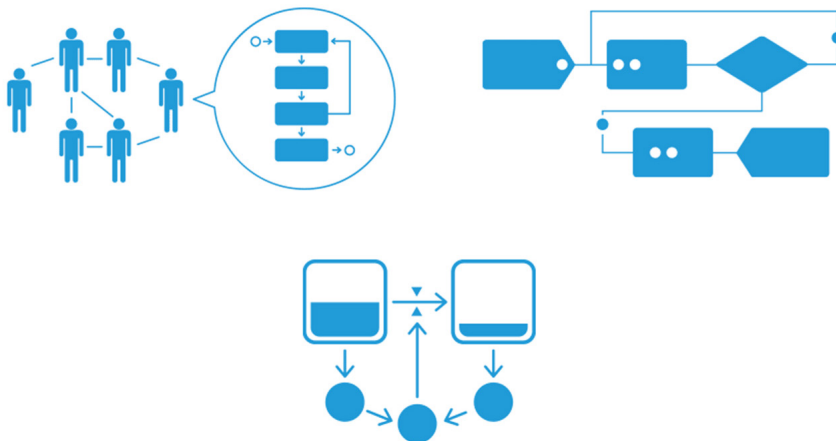
Read on and discover why academic institutions around the world use simulation, see examples of their teaching and research, and get started with AnyLogic – the most powerful general simulation software for academia.

MULTIMETHOD SIMULATION WITH ANYLOGIC

AnyLogic is a powerful multimethod simulation modeling environment with industry-specific libraries, AI integrations, and built-in cloud computing capabilities.

There are three common simulation modeling methods:

- **Agent-based modeling** – for capturing the interactions of many independent objects such as in supply chain, social networking, and asset management.
- **Discrete event modeling** – for describing a sequence of events through time, and helping diagnose business or manufacturing process issues.
- **System dynamics** – for considering global dependencies without fine detail. They are used for modeling at a macro scale, such as for populations or economic systems.



Agent-based, discrete event, and system dynamics modeling

Each method has characteristics that make them suitable in different situations. Applying just one method will likely require unnecessary compromises. Unnecessary because with a multimethod approach each part of a system can be captured appropriately – so there is no need for exclusions or workarounds.

Beyond combining the three main simulation modeling methods, AnyLogic offers built-in industry-specific libraries that let modelers work more quickly and easily:

- **Material Handling Library** for manufacturing and warehouse processes.
- **Rail Library** for rail transportation, terminals, and yards.
- **Pedestrian Library** for pedestrian flows in airports, stadiums, stations, or shopping malls.
- **Road Traffic Library** for car, truck, and bus movement on roads, parking lots, and factory sites.
- **Fluid Library** to simulate bulk cargo and liquid transfer in industries like mining or oil & gas.
- **Process Modeling Library** for generic business processes or workflows.

See how the Material Handling Library helps speed up modeling in this short spiral conveyor [how-to video](#).

For more technical research projects, AnyLogic features Java-level extensibility. This allows the creation of complex and reusable custom objects, experiments, and libraries. Model designers do not need to reinvent the wheel with every project. They can reuse components and even develop libraries for their specialization.

This extensibility combined with data interoperability provides flexibility for modelers. Models can read or write to spreadsheets and databases or integrate more deeply with external platforms via API.

Integrated GIS mapping functionality lets models use routing and location-based data, both online and offline, as well as connect with other mapping services.

A powerful set of experiments are available for conducting analysis: Monte Carlo, Sensitivity Analysis, and Parameter Variation experiments help find how randomness and parameter changes affect model behavior. In addition, simulation optimization, an advanced but increasingly popular approach, helps find better solutions based on constraints and requirements.

ANYLOGIC CLOUD

Collaboration and learning are made easy when we can share common resources. AnyLogic simulation models can run in the cloud – with just a link, they can be shared and reviewed with peers, tutors, and fellow classmates. With AnyLogic Cloud, it is easy to share teaching simulators with students, so that they can run these models on their laptops, or even phones, in the classroom or at home and learn from experimenting with the model without installing any additional software.

AI INTEGRATIONS

AnyLogic's open API helps easily integrate with AI projects, while integrations with powerful machine learning platforms from Microsoft, Pathmind, and H2O.ai provide easy access to the possibilities they offer. To learn more about the synergies between AI and simulation, and how projects benefit, read more on our dedicated [AI page](#).

SUPPORTING RESOURCES



SUPPORTING RESOURCES

Simulation modeling is a powerful tool for analyzing and developing complex systems that can provide unique insights and support. But how do you get started?

If your institution or faculty has not used simulation modeling before, it can be difficult to know where to begin. AnyLogic has many resources to help ease researchers and students into simulation modeling and the software itself. To get started quickly, it will be an advantage to have a background in areas related to systems analysis and integration. For advanced features, it will also help to have some knowledge of programming.

AnyLogic Personal Learning Edition (PLE) is free and has Windows, Mac, and Linux installers, so students can begin immediately on their computers. Tutorials with accompanying models are included in the application and there are also how-to videos, how-to blogs, webinars, and in-depth downloadable books. The software and many of the supporting materials are available in multiple languages, including Chinese, Japanese, Portuguese, Russian, Spanish, and more.

- [The Big Book of Simulation Modeling](#)
- [AnyLogic in Three Days](#)
- [The Art of Process Centric Modeling with AnyLogic](#)
- [Complex Project Management](#)

For in-depth research purposes, AnyLogic provides a discounted and fully functional University Researcher edition, which will allow scholars to build industrial strength simulations.

To learn more about using AnyLogic and for simulation modeling support materials, download the [AnyLogic Academic Toolkit](#).

These institutions trust us



USE SIMULATION TO EMPOWER RESEARCH AND TEACHING



USE SIMULATION TO EMPOWER RESEARCH AND TEACHING

Researchers, tutors, and students use simulation in a variety of fields for tackling complex problems, demonstrating theories and processes, analyzing management decision-making, and applying machine learning. In all cases, simulation modeling complements specialist knowledge with data analysis possibilities not available with simple spreadsheet-based or linear programming methods. Simulation modeling allows its practitioners to tackle complex challenges and provide clear insights.

With AnyLogic simulation modeling, tutors can support learning and researchers can analyze complex systems. Models used in teaching can be interactive and have interfaces customized to the topic, helping easily communicate and learn concepts. Researchers can model complex systems without compromise using industry-grade simulation modeling that is fully extensible. In all cases, AnyLogic offers a range of experiments and methods for analysis, including reinforcement learning integrations, that aid analysis and deepen insight.

The multimethod approach to modeling offered in AnyLogic combines the three main modeling paradigms: discrete event, system dynamics, and agent-based. Combining these methods with industry-specific libraries allows systems to be modeled in detail and without compromise.

Using AnyLogic, researchers and students apply simulation modeling to many different challenges, helping insight and learning in all kinds of disciplines.

The software is supported by a vibrant community and a variety of multimedia resources. Furthermore, to support collaboration and remote study, AnyLogic PLE and Public Cloud are free.

AnyLogic leads the field of general simulation and is well established in academia. AnyLogic University Researcher and AnyLogic Personal Learning Edition allow you to start today in research and teaching. With AnyLogic, academic institutions are empowering their staff and students in their studies and learning, ensuring they are meeting the demands of modern research and education. We look forward to supporting your simulation modeling.



ADDITIONAL RESOURCES

- | [AnyLogic for Academia](#)
- | [Books](#)
- | [Academic Articles](#)
- | [Videos](#)
- | [White Papers](#)
- | [Case Studies](#)
- | [Seminars and Training](#)
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