



MATERIAL HANDLING SIMULATION

WHITE PAPER



TABLE OF CONTENTS

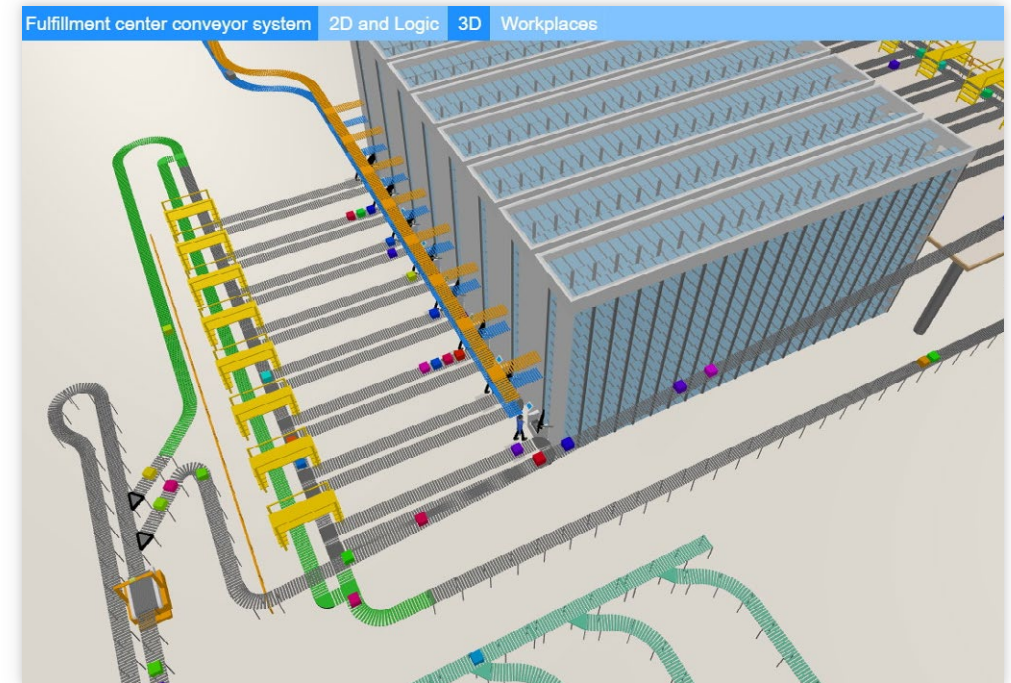
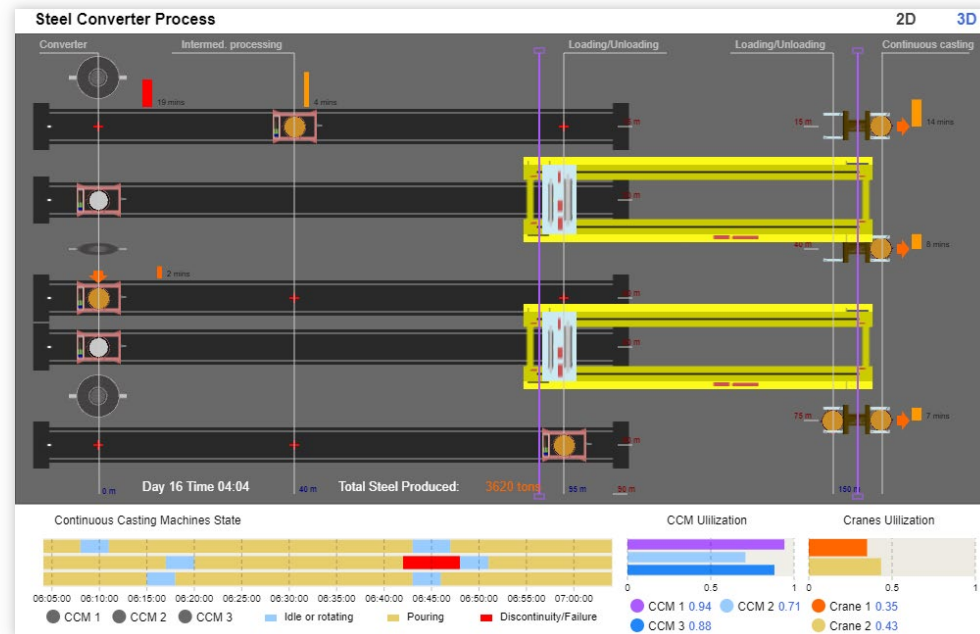
01	Why Use Simulation in Material Handling?	02
02	Key Material Handling Challenges	05
03	Modeling How Your Organization Works: Simulation Versus Linear Programming and Spreadsheets	10
04	Walmart's Alphabot: Designing a Material Handling System with Simulation	13
05	Improving Reliability and Profitability for a Large European Steel Manufacturer	18
06	How to Get Started with Simulation	23
	Conclusion	25
	Additional Resources	26

WHY USE SIMULATION IN MATERIAL HANDLING?



WHY USE SIMULATION IN MATERIAL HANDLING?

Material handling in facilities as diverse as steel mills and retail fulfillment centers is benefiting from simulation-based analysis and design. Detailed process insights and forecasting advance decision support beyond spreadsheet-based and top-down analysis. When working to resolve material handling problems such as debottlenecking, balancing storage constraints, and optimizing production plans, simulation modeling provides advantages not offered by traditional techniques.



Simulation modeling is effective for complex and large-scale systems where dependencies might be unclear. It solves real-world problems safely and efficiently in a virtual environment and, thanks to detailed statistical and visual outputs, enables analysis which is easily verified, communicated, and understood. For material handling operations, simulation modeling gives detailed and clear insights for well-informed decision making.

Key uses of simulation for material handling include:

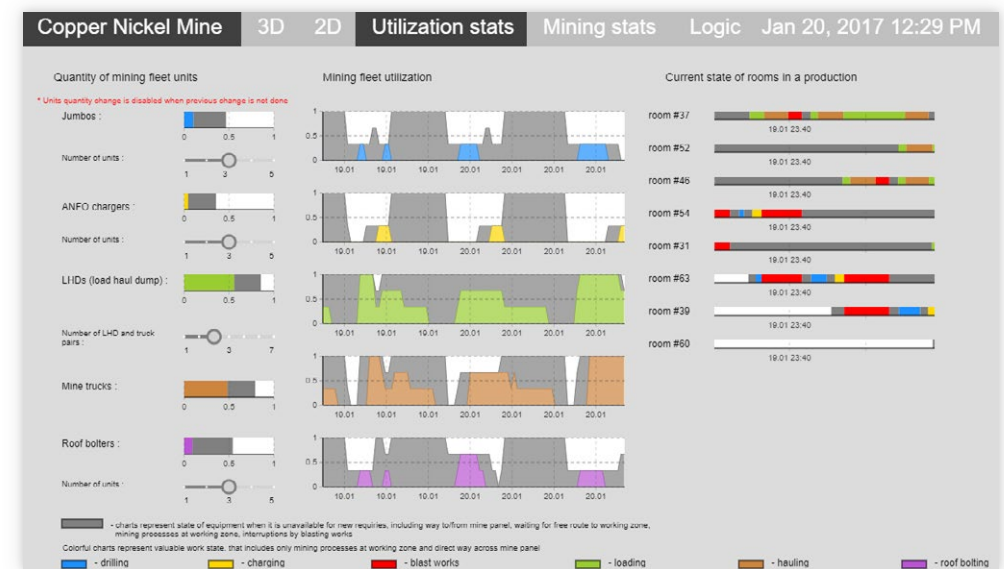
- Facility design and capacity planning to improve ROI or throughput
- Process and scheduling optimization to increase production and service levels
- Equipment usage analysis for calculating ROI
- Bottleneck analysis when trying to mitigate and balance constraints
- Inventory planning when seeking lower waste and increased productivity
- Determining staff and equipment requirements to meet production flow demands
- Performance metric analysis

Simulation modeling is especially useful when making speculative changes on a real system is impossible or impractical because of costs or time.

The ability to analyze a model as it runs sets simulation modeling apart from other methods, such as those using Excel or linear programming. The freedom to inspect processes and interact with a simulation model in action helps quickly build both understanding and trust.

Overall, organizations that make use of simulation modeling are more informed and agile when it comes to making changes to how they work and are better prepared and resilient in the face of disruption.

If you or your organization has yet to try simulation-based material handling analysis, it is easy to get started. Learning is free with [AnyLogic PLE](#) and there are many [resources](#) to help you along the way. Read on to discover more about material handling simulation and how organizations use it to solve business challenges.



KEY MATERIAL HANDLING CHALLENGES



KEY MATERIAL HANDLING CHALLENGES

Material handling operations present many challenges that benefit from simulation modeling and analysis.

to low machine availability, delivery processing times, and storage capacity. Balancing end-to-end material flow requirements is important for controlling costs and increasing profit.

Failing to capture the details necessary to accurately analyze and forecast production or warehouse operations can lead to incorrect insights and decision making. Some problems with traditional spreadsheet-based throughput analysis include:

- Fixed data snapshots can make troubleshooting difficult. For example, daily stock level snapshots may make bottlenecks caused by storage and retrieval inefficiencies hard to find.
- Numbers and charts do not allow processes to be visually verified. Analysts and managers with experience of material flows in a facility will need time to apply their operational knowledge to static tables of numbers and charts.

Reliable information about current and predicted performance makes it easier to optimize processes and implement changes. Simulation makes good throughput analysis and optimization possible because it can authentically represent a system's underlying details, dynamics, and dependencies. Beyond static tables and charts, simulation provides dynamic views and process visualizations based on the capture of a facility's processes and workings.



THROUGHPUT ANALYSIS

The throughput of a facility depends on economic, environmental, and equipment-related factors which are often complex, dynamic, and interconnected. Examples include staffing levels, production bottlenecks due

SCHEDULING AND SEQUENCING

Production and storage facilities involve elements that are subject to external factors such as suppliers, purchasers, and transport. Even inside a facility, accurate forecasting and optimization can become complex. Challenges include maintenance requirements, seasonal demand fluctuations, customized production, and finding optimal order picking and processing algorithms.

Manual or constraint-based scheduling based on spreadsheets or mathematical models can miss important details or relationships, especially in large systems. Difficulties can be found in the following common areas:

- Order driven manufacturing means coordinating many dynamic operations and processes. In a JIT, or lean manufacturing environment, meeting scheduling KPI can quickly become too complex or time-consuming. Simulation makes clear the behavior of a system and does not need a complete mathematical model because it accounts for each element and how they interact.
- Machine maintenance scheduling may not account for the state and wear of machinery, leading to unnecessary or unexpected downtime. With the simulation of machinery, the processes governing usage and maintenance can be captured so that adaptive and more efficient maintenance scheduling can be applied.
- The spatial requirements of people and machinery are difficult to include when planning changes using traditional scheduling methods. With simulation, the dimensions of machinery and spatial requirements for staff can be made part of the model.



Simulation-based scheduling accounts for time-based and causal dependencies and can accommodate large scale systems made up of numerous entities. It shows the behavior of a system and the possibility to derive a schedule by modeling each of a system's components and how they interact. When a system

is non-linear and dependencies are unclear, simulation-based scheduling is a powerful tool for analysis and testing.

PLANNING FOR NEW EQUIPMENT

When introducing new equipment such as automated guided vehicles (AGV), conveyors, cranes, heavy machinery, and automated storage and retrieval systems (ASRS), it can be difficult to accurately predict their wider impact and return on investment. But, without a good understanding of the effects the introduction of new equipment will have, it becomes impossible to optimally configure a facility.

Simulation offers an alternative method of analysis when traditional methods, such as those based on spreadsheets, are unable to scale sufficiently or cannot represent a system's behavior accurately. Examples include:

- Large scale facilities with complex interactions such as at ports, on production lines, or in warehouses.
- Accounting for the impact of new equipment on a project's overall profitability.
- Determining the environmental impact of workflow changes related to new equipment.

With simulation, a digital replica of your current systems can be made so that extensive testing and planning is possible without affecting ongoing operations. Decision-makers and managers can use simulation as a 'what-if' tool that allows

them to understand the likely impact of new equipment and determine how best to integrate it into facility workflows.

OPERATIONS AND POLICY ANALYSIS

Experimentation with live operational processes and policies can be disruptive and counterproductive. Safety and cost considerations can also limit real-world testing. The alternative is to plan and test a system using a model. However, while spreadsheets and linear programming offer some virtual testing capabilities, they cannot properly account for stochastic events such as machine failure or time-based interdependencies like customized orders that involve multiple production lines. For cases like those, simulation can provide a solution.

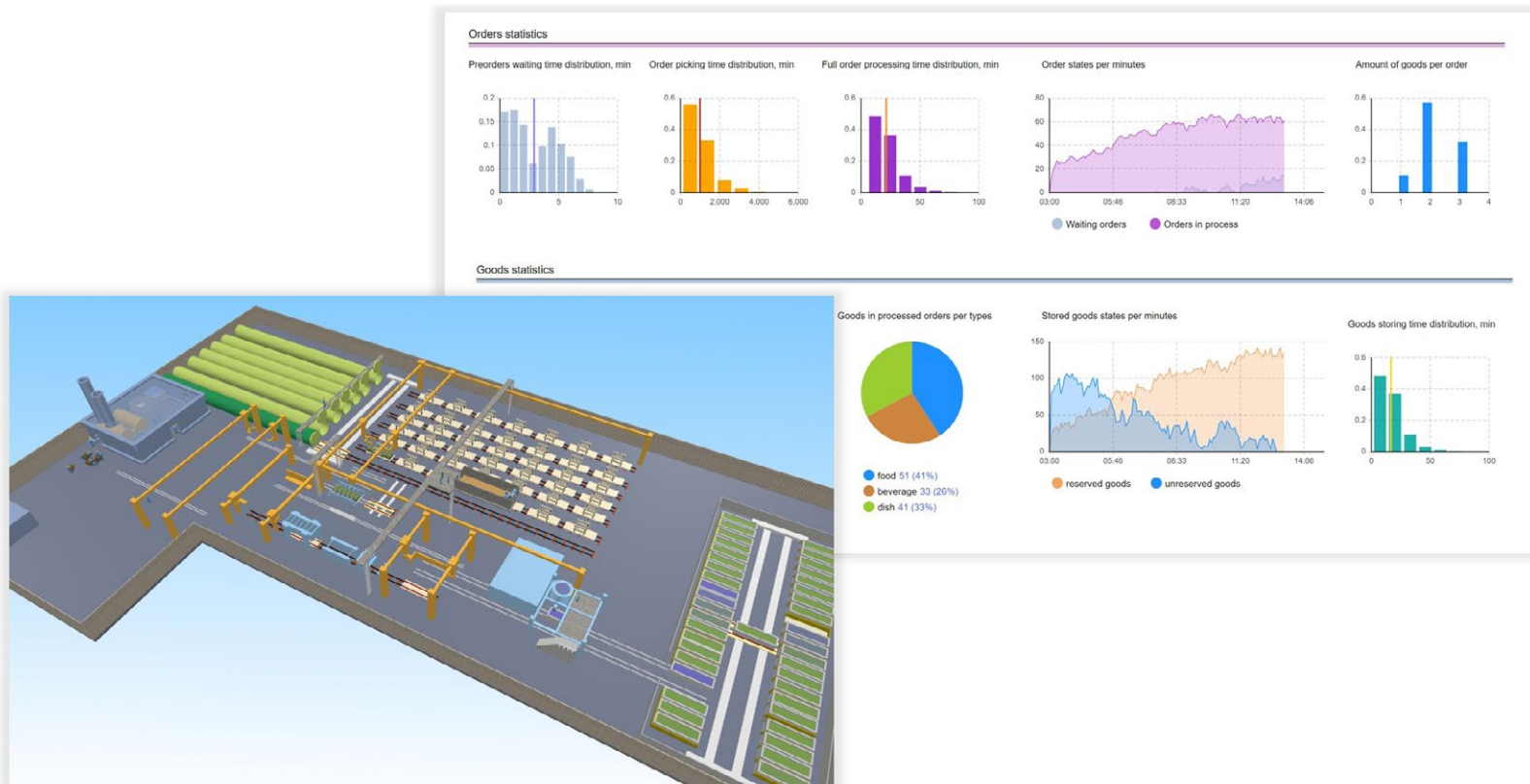
A simulation model of a factory, port, or warehouse will represent each process-element, how these elements operate, and the rules that determine their interaction. This capture of a facility's processes enables experimentation and analysis in a risk-free environment. Policy experiments can be conducted using the model and, when they look promising, they can be refined and tested against forecasts and historical data. The result of using simulation to analyze and develop policies is more agile decision making and greater implementation success.

Simulation modeling is used when:

- Carrying out Material Requirements Planning (MRP)
- Debottlenecking storage and retrieval systems

- Evaluating alternative Bills of Materials (BOM)
- Applying a theory of constraints approach to manufacturing operations
- Testing machine learning developed maintenance policies

Before committing to changes, their consequences should be predicted, analyzed, and understood. Beyond spreadsheet-based and linear modeling techniques, simulation can provide a method that accounts for stochasticity and complexity as well as easing verification with 2D and 3D visuals.



**MODELING HOW
YOUR ORGANIZATION
WORKS: SIMULATION
VERSUS LINEAR
PROGRAMMING AND
SPREADSHEETS**



MODELING HOW YOUR ORGANIZATION WORKS: SIMULATION VERSUS LINEAR PROGRAMMING AND SPREADSHEETS

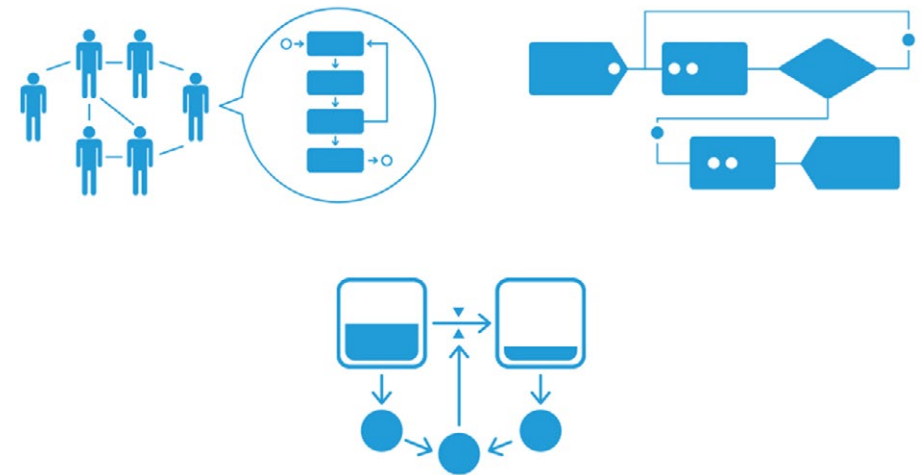
The importance of spreadsheet models in business planning is clear from their widespread use.

However, despite their importance, more than 90% of spreadsheets contain errors and around 50% of spreadsheet models in large organizations contain material defects (EuSpRiG). As a result, companies can put themselves at unnecessary risk by acting on the outputs of these spreadsheets.

A more reliable method of modeling that helps inform decision making is linear programming and it is widely used to help optimize planning and production. It is a more reliable method because the work required to model a system with linear programming helps overcome many of the problems spreadsheets have with their lack of verification.

To model a system with linear programming requires knowledge of its functional dependencies from input to output. Often these dependencies are not clear because they are causal, time-related, or just because the model is large. In the end, these system models become hard to manage, difficult to communicate, and generate low-value insight.

For complex material handling problems, simulation offers an alternative method of analysis to spreadsheets and linear programming. The strengths of simulation



Agent-based, Discrete event, and System Dynamics modeling

come from it being a verifiable method of modeling that can deal with large complex systems, time dependencies, and stochasticity.

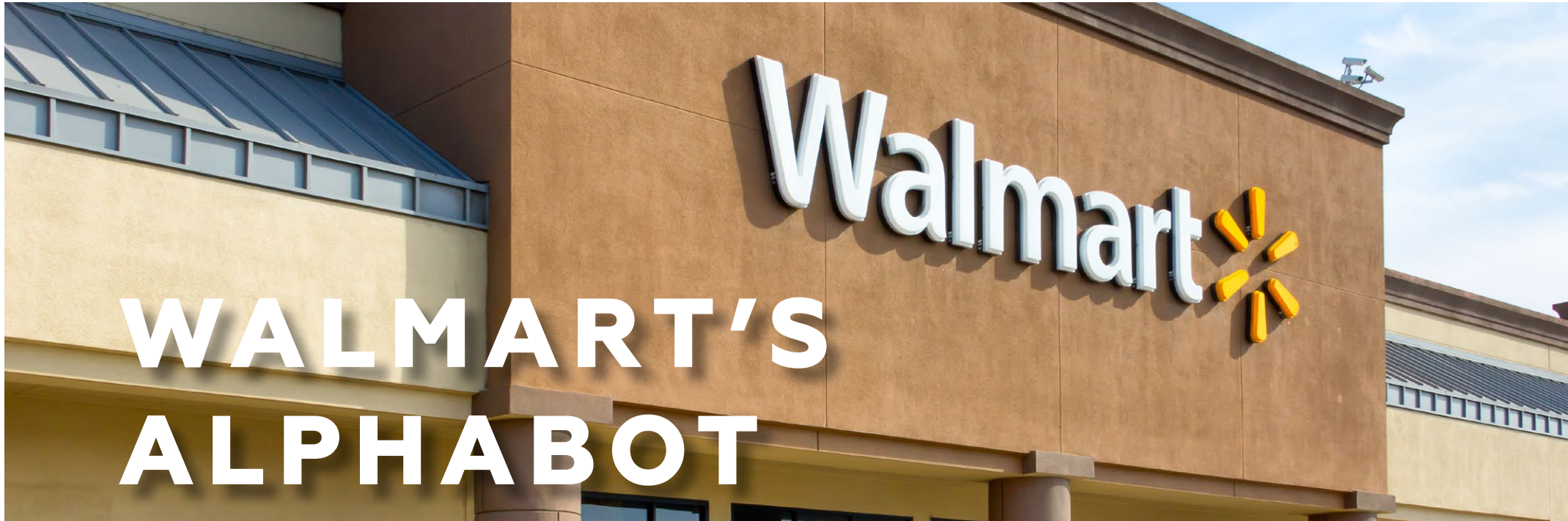
Simulation models work by capturing the characteristics and behavior of a system's components. Then, by observing how the components interact, it is possible to see the behavior of the whole system. A simulation can output

tables of data and charts as well as animated 2D and 3D visualizations. With the possibility to inspect the logic of each element and to verify behavior with visualizations, a simulation model can easily be checked and communicated at multiple levels.

Simulations developed in AnyLogic can combine the three main methods of simulation modeling: agent-based, discrete event, and system dynamics. The combination of these methods means a simulation model can accurately reflect the elements of a system, their processes, and how they interact.

With simulation, you have a method of analysis for material handling challenges that involve dynamic and stochastic processes in large-scale complex systems. Examples include developing an autonomous AGV order fulfillment system for Walmart and improving returns on investment at a larger European steel manufacturer, as can be seen in the following case studies.





WALMART'S ALPHABOT

DESIGNING A MATERIAL HANDLING
SYSTEM WITH SIMULATION

PROBLEM

Walmart, the world's largest retailer by revenue, was looking for an automation technology for its fast-growing online grocery business that would help complete orders faster and at a lower cost. They chose to evaluate Alert Innovation's Goods-to-Person (GTP) concept, Alphabot® – a system that can automate online grocery at the store level by using autonomous mobile robots that are capable of operating in all three dimensions of a multilevel storage structure. Alphabot robots are self-driving vehicles that can gather items from the ambient, chilled, and frozen temperature zones of a high-density storage system and bring them to associates who are picking items to fulfill customer orders. Alert Innovation invented Alphabot® to make in-store fulfillment of online orders faster and more efficient.

The retailer wanted to evaluate the feasibility of the Alphabot® concept, and its suitability for Walmart, before making a financial commitment towards product development. Alert Innovation had already made some static spreadsheet calculations for the project, however, both Alert Innovation and Walmart agreed that the spreadsheets could not be relied upon due to system complexity and variability in demand and execution. As a result, and before making a financial commitment to deployment, MOSIMTEC, a simulation consulting firm, was tasked with designing a material handling simulation model for an independent technology feasibility assessment. The goal of this initial modeling assessment was to:

- Understand the throughput and turnaround time capabilities of the Alphabot® system during peak customer demand periods and assess service levels.
- Understand any potential performance weaknesses of the Alphabot® system with realistic demand data and variability.



- Identify the best configuration for the racking structure, automated bots, and picking workstations required for different store profiles.
- Compare the capital expenditure requirements predicted by the model against the business case spreadsheets.
- Use model throughput and turn-around-time results to compare the proposed performance of Alert Innovation's Alphabot® with other industry-leading Automated Storage and Retrieval Systems (ASRS) and Goods-to-Person (GTP) technologies.

Material handling simulation would not only help understand the true cost of rolling out the system in the real world, but also identify store-specific requirements for the potential deployment of Alphabot® across Walmart's other stores in the future.

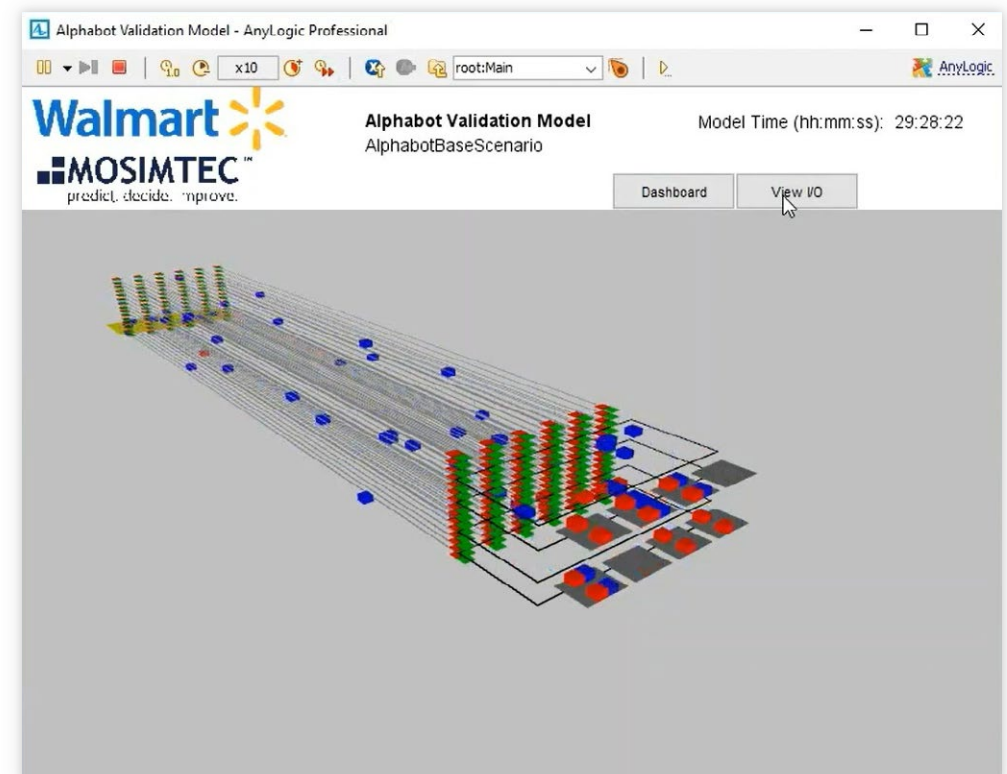
SOLUTION

To model Alphabot®'s behavior and operations in a computer simulation, with real-world complexity and variability, MOSIMTEC chose AnyLogic simulation software. MOSIMTEC used AnyLogic's abilities to dynamically build facility layouts from input data to help cut model development time and enable faster evaluation of multiple Alphabot® configurations.

Furthermore, Alphabot®'s programmers needed to develop numerous control algorithms and AnyLogic's Java capabilities meant algorithm ideas could be tested quickly and easily.

Stage 1: Material handling simulation model animation including AGV simulation

Walmart's initial goal was to make a go/no-go decision about the Alphabot® project. To support this decision making, MOSIMTEC learned the system,



designed initial bot control algorithms, built a material handling simulation model, conducted an analysis, and presented its findings to Walmart's leadership.

In the final delivered model, Walmart managers could specify different inputs like the number of bots, their length, width, acceleration, and speed in different areas. Physical racking configurations such as the number of aisles, levels, the space between levels, and the number of workstation tiers, along with other physical components of the system, were also configurable. Control-logic parameters, including those for work-assignment and for setting various thresholds, were also exposed and made available.

Stage 2: Material handling simulation model animation including AGV simulation

Model input and output statistics were connected to an Excel front-end so that users could easily configure and run the model. At this concept evaluation stage, MOSIMTEC also incorporated a 3D model animation that was scalable based on the layout defined by the user within Excel. The output results in Excel included a summary report with key metrics, log files, scenario comparisons, charts, and graphs.

After completing the independent analysis of system capabilities, MOSIMTEC transitioned the AnyLogic material handling design model to Alert Innovation for long-term use in fine-tuning software control algorithms for eventual production deployment. Based on the outcome of Phase 1, Walmart proceeded with its Alphabot® system development. Alert Innovation engineers used the Phase 1 model as the foundation for Phase 2 which increased the level of detail and testing of control algorithms to simulate different system design alternatives. Model enhancements included:

- More bot-specific movement logic: bot paths, reservations, collision avoidance logic, and movement profiles, using AnyLogic agent-based modeling and Java capabilities.
- Separate temperature zone storage system logic for shelf-stable, refrigerated, and frozen items.
- Inventory tracking functionality within the racks to track every item in the system.
- Bot sequencing logic to help simulate robots sorting items.

With the updated material handling simulation, engineers were able to validate the original system design assumptions and provide feedback to Alphabot® product development teams. The Alphabot system model including AGV simulation

OUTCOME

The initial material handling design model helped make the business case for deploying Alphabot® more widely by showing the equipment requirements needed to meet various target turn-around-times. The simulation model also quantified system performance limits when subjected to unconstrained demand and showed that Alphabot® would be able to pick 95% of real-world online grocery orders in less than eight minutes, with an average picking time of under five minutes.

As the project progressed, the initial model was updated and expanded to better understand the impact of various detailed design alternatives. The model helped Alert Innovation determine which design alternatives would result in the greatest ROI and how the system can be configured for future deployments.

Walmart and Alert Innovation launched a proof-of-concept pilot of Alhabot® at a Walmart supercenter in Salem, New Hampshire in March 2019.



Watch the [video](#) of Amy Brown Greer, Dr. Christian Hammel, and John Lert presenting this case study at The AnyLogic Conference.





GOLDRATT RESEARCH LABS

IMPROVING RELIABILITY AND
PROFITABILITY FOR A LARGE
EUROPEAN STEEL MANUFACTURER



PROBLEM

One of the largest and oldest European steel manufacturers was trying to use lean manufacturing tools to improve service levels and returns on investment. Customers and investors were demanding much higher performance, but efforts were falling short and significant challenges remained. Their initiatives ended up in repeated debottlenecking and a stable system seemed unobtainable. The company called on the assistance of Theory-of-Constraints specialists Goldratt Research Labs. Together, they decided to transform and optimize the company's supply chain, taking into account its high degree of fragility to external changes, low profitability, and low ROI.

Complexity made supply chain changes difficult and it was risky to try new policies and rules because outcomes were unpredictable. The company's static decision support tools, such as their enterprise resource planning system and various spreadsheets, did not help because of difficulties working with the complex operational and business environment.

To fully consider all the interdependencies, constraints, dynamics, and variability in the system, the system analysts and engineers decided to use simulation modeling. The engineers could capture the complex details of the manufacturing supply chain, determine the causes of performance gaps, and test possible solutions in a digital environment. Simulation modeling would help management make faster, better decisions and predictions, and turn these predictions into reliable manufacturing optimization commitments for investors and customers.

SOLUTION

Several models were built that together could represent the whole integrated steel production process. The developers took advantage of AnyLogic's multimethod modeling capabilities which made it possible to reflect the components, processes, and interdependencies in the system. The models could show outcomes for single scenarios, conduct sensitivity analysis for various parameters, and provide direct scenario comparison.

AnyLogic can work with external data and self-configure models and, in this case, ingested more than 70 Excel worksheets' worth of data from the enterprise resource planning and enterprise management systems. AnyLogic ability to create self-configurable models from external data helped cut development time significantly.

The manufacturing process simulation models have detailed 2D and 3D animation. The AnyLogic platform provides easy-to-use interfaces and the ability to export models as standalone applications to run any computer, without the need for special software.

Furthermore, mobile work and collaboration were facilitated by the browser-based AnyLogic Cloud.

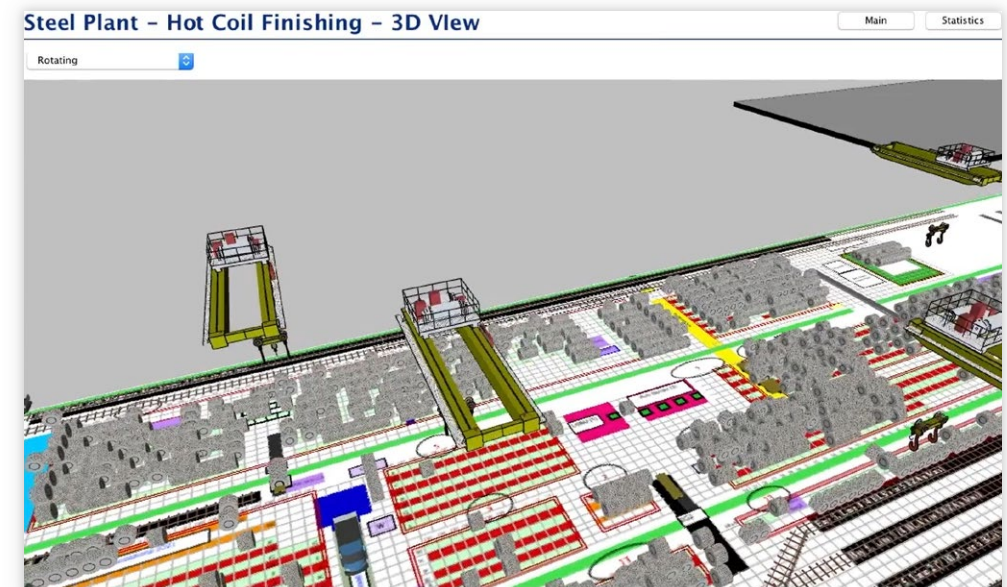
Hot Coil Finishing Simulation Model

The hot coil finishing area was significantly congested and there were constant coil movements related to coil retrieval. Even the car park was filled with coils. The need for change was acute.

A model was created that could show the location of all the coils in the system. For each coil, the type, the destination, and the storage location were specified.

With the coil locations and movements known, the model helped identify efficient options for congestion reduction based on throughput, in-process inventory, and cost impact. Operational changes, including increasing hot strip mill output and coil width doubling, were tested for better production planning and control.

The model also helped find the best way to upgrade and optimize the wagon fleet. In the future, management plans to use the model for testing operational rules that allow full automation of the hot coil management process.



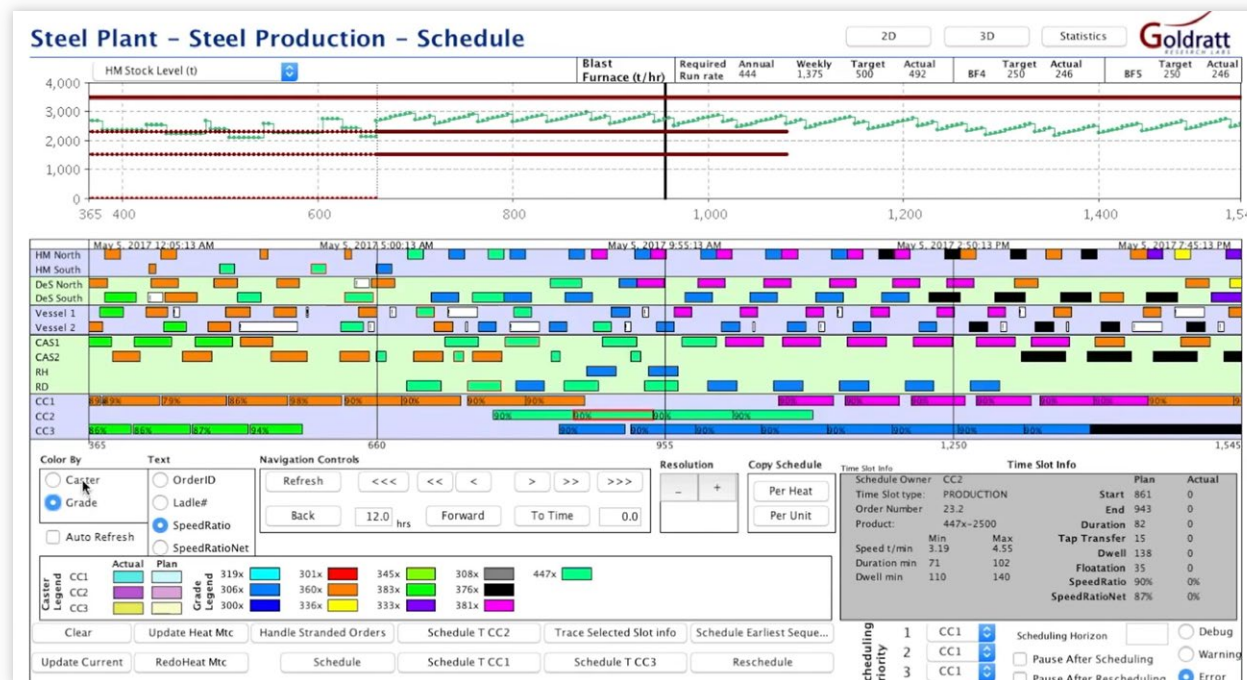
Steel and Slab Simulation Model

Steel production operations and their scheduling are both very complex and it is very difficult to predict the impact of changes in product mixes or operational rules. To test them and improve efficiency, a specific model was needed.

The model that was developed captured all the elements of the manufacturing system. In the 2D animation, clicking a crane or product shows its operational status. At the heart of the model is the logic for production planning and the scheduling of operations. The required product mix and other parameters can be set and altered as needed.

The steel and slab production simulation model made it possible to:

- Capture and digitize the scheduling and operating rules that different plant operators used. These rules had never been verbalized before and could eventually be lost. Now personnel can learn from shared experience.
- Develop scheduling and operating rules to avoid bottlenecks. For this, different speed restrictions and alternative prioritization rules for different products were tested and analyzed.



- Forecast the operational and financial impact of producing more complex and higher-margin products, which could negatively affect workflows.

OUTCOME

Using the models, the causes of congestion and inefficiency were found. The models provided a safe, low cost, and quick way to test the impact of operational and financial changes. The models were also used to validate each other's results.

The models are now used on a weekly, monthly, and annual basis to analyze workflows and inform critical decision making. The results provide reliable forecasts and enable commitments to be met. Project presentation by Dr. Alan Barnard and Jaco-Ben Vosloo from Goldratt Research Labs.

Other related case studies:



Cardinal Health – [Optimizing Warehouse Operations](#)

Kuehne+Nagel – [Warehouse Picking Algorithm Evaluation](#)

GE – [Real-Time Manufacturing Decision Support](#)



HOW TO GET STARTED WITH SIMULATION



HOW TO GET STARTED WITH SIMULATION

Simulation modeling is a powerful tool for analyzing and developing complex material handling systems that can provide unique strategic and operational insight and decision support. But how do you get started?

If your organization has not used simulation modeling before, it can be difficult to know where to begin. AnyLogic has many resources to help ease development and understand the important factors that need to be considered. To get started quickly, it is an advantage to have a background in areas related to systems analysis and integration, industrial engineering, or manufacturing process engineering. For advanced features, it will also help to have some knowledge of programming.

To get an idea of how simulation modeling is being used by companies to solve material handling challenges, there are case studies and resources available in the [AnyLogic Material Handling Library Pack](#).

For those who wish to start by trying the software, [AnyLogic PLE](#) offers a free way to begin. Included in the application are tutorials with accompanying models. There are also [how-to videos](#), [webinars](#), and material handling specific in-depth tutorial blogs:

- [Conveyors](#)
- [AGVs and transporters](#)

- [Solar Panel Production](#)
- [Cranes](#)
- [Network ports](#)
- [Restricting areas for transporters](#)

The AnyLogic team and our expert partners around the world are experienced in the application of material handling simulation. Find your local [AnyLogic specialist](#), or [contact us directly](#) to find out how simulation can be applied to your challenges.



CONCLUSION

Simulation modeling is an advanced method for analyzing and developing material handling systems. It offers an alternative to the traditional methods of spreadsheet-based analysis or linear programming and can be superior when developing solutions for complex manufacturing and warehouse processes.

Material handling business challenges that can benefit from simulation include throughput analysis, production scheduling, impact assessment for new equipment, and the analysis and development of operations policies.

AnyLogic is [multi-method simulation](#) software that combines the three main modeling paradigms: discrete event, system dynamics, and agent-based. Combining these methods allows systems to be modeled in detail and without compromise.

Specific modeling libraries in AnyLogic also assist modeling. The [Material Handling Library](#), [Process Modeling Library](#), [Rail Library](#), [Road Library](#), and [Fluid Library](#) combine to help capture the details of a system. The combination of multi-method modeling and these libraries is a platform that can capture material handling systems in detail to give unique insights and decision support.

When traditional modeling methods are not sufficient, simulation modeling provides a powerful alternative.



ADDITIONAL RESOURCES

| [White Papers](#)

| [Case Studies](#)

| [Videos](#)

| [Books](#)

| [Download AnyLogic Simulation Software](#)

| [Seminars and Training](#)



CONTACTS

THE ANYLOGIC COMPANY

info@anylogic.com

[Contact your local office >>](#)