anyLogistix
supply chain software

Supply Chain Optimization and Simulation

Technology Overview

White paper

Contents

Introduction

Analytical optimization and dynamic simulation are the two most commonly adopted technologies to solve complex supply chain problems. However, there has been a lot of confusion around the terms *optimization* and *simulation* in the industry. They are often misinterpreted by people and companies offering supply chain solutions, used in the wrong context, or have different meanings.

Many managers question the differences between these techniques, which is better or more efficient, and what problem does each solve? This white paper will help resolve the confusion and explain when it is best to apply each of these methods.

The paper will also show why analytical optimization tools, already employed by many supply chain strategists, should be accompanied by dynamic simulation, and how managers can improve lean and agile supply chain management with this addition.

Supply Chain Problems by Level of Detail

Managing your supply chain means continuously searching for improvements and meeting new challenges. The solutions can involve different areas of expertise, and be from operational, tactical, or strategic management levels. They may also depend on the type of company you are engaged with, a distributor, retailer, manufacturer, or a 3PL/4PL operator.

Challenges linked to supply chain design, inventory and transportation policies, production planning, and risk management include:

Where to locate new facilities – distribution centers or factories?

How would the supply chain change if we introduced a new product?

How would our supply chain withstand a strike or the loss of a supplier?

What service level can we provide customers?

What inventory policies should we use to balance costs and service levels?

What should the capacity of the new manufacturing plant be?

How much product do we have to ship each month?

Should we use our own or rented vehicles for transportation?

These and many other questions can arise when you are working with your supply chain.

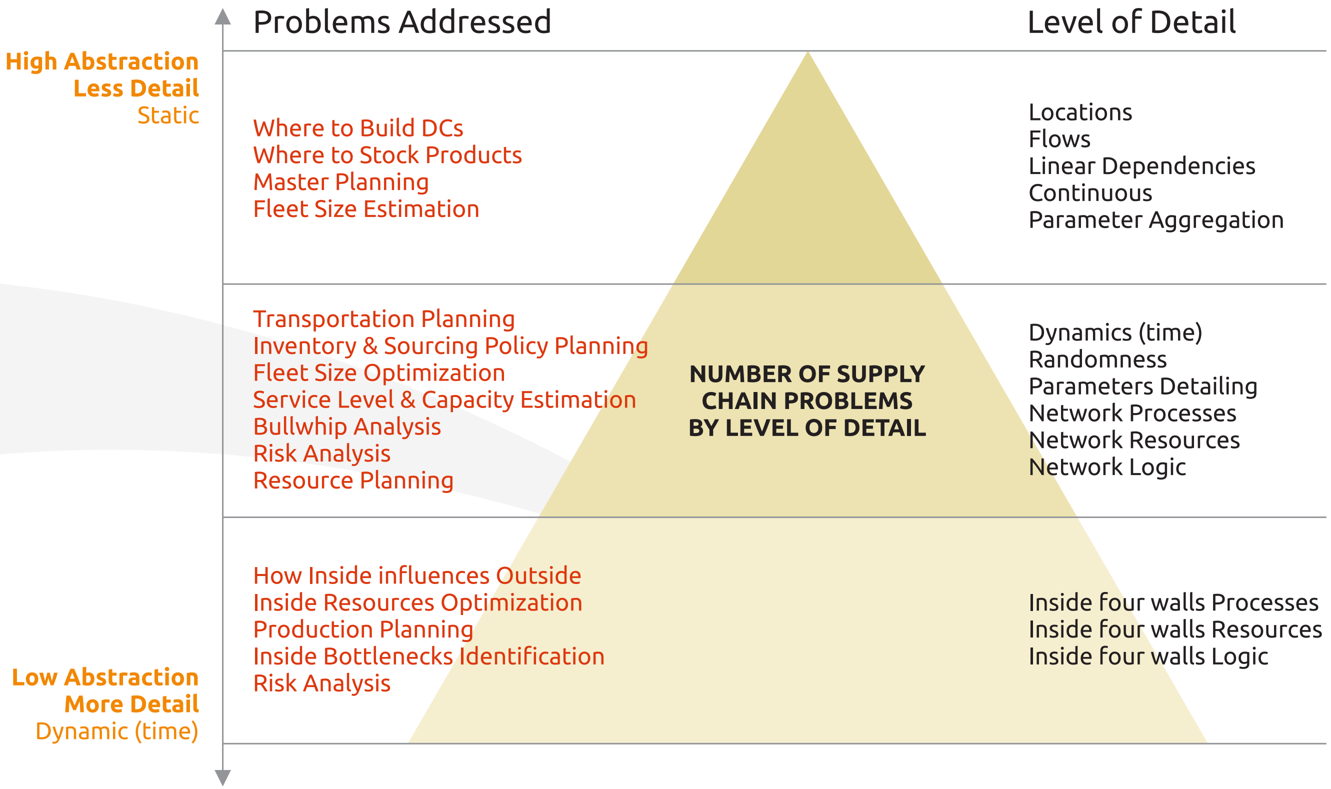
Diverse in both nature and scope, these problems are the responsibility of a supply chain manager. To solve them, the manager must consider many interdependent processes inside and around the organization, and each problem requires its own level of detail when looking at the system.

As with any business, the supply chain devil is in the detail. You can form a general view by considering a few essential details, but to understand more complex problems, you need to consider more factors. That is the difficulty; some problems are too large to include every detail and produce a result in a reasonable timeframe. Success comes from finding the right level of detail to meet the demands of the challenge.

The more details you consider, the more room there is for improvement, including more decision variables to improve and more variations to test. If we map the number of problems by the level of detail, we get a pyramid-shaped diagram, with the highest level of detail at the bottom (see the next page).

The pyramid shows supply chain problems grouped into three sections determined by the level of abstraction.

- **High abstraction level – low detail:** Network-level problems, determined by basic supply chain structure and dependencies.
- **Medium abstraction level – more detail:** The details of supply chain organization, considering policy parameters, resources, process logic, randomness, and operational dynamics.
- **Low abstraction level – high detail:** Determining how processes inside the four walls of your sites influence the whole supply chain, considering on-site processes, resources, and constraints.



Challenges addressed by supply chain models and the level of detail.

The most common way for solving high abstraction level business issues is spreadsheet-based modeling and calculation. Spreadsheets are well suited to solving simple supply chain problems that only require basic formulas, but they lack the ability to cope with issues as complexity grows. For more complex issues, supply chain leaders all over the world leverage analytical optimization and dynamic simulation.

In the next chapters, we discuss these two methods, their advantages and disadvantages, give a set of problems suitable for each one, and show how they can be applied in combination to drive your supply chain ahead of the competition.

Analytical optimization

Analytical optimization

Analytical optimization is probably the most common technique for improving supply chains.

What does analytical optimization mean, and how does it work? Analytical optimization tools allow consultants to visually describe a supply chain as a graph and parameterize it with a set of tables. The consultant then describes the constraints, populates the model with data, and then pushes "solve" to find the optimal, or suboptimal, solution to the problem.

At this stage, the model is converted into a set of linear equations, constituting a linear and mixed integer programming (LP and MIP) problem. These equations are then solved using optimization engines (popular ones include IBM ILOG CPLEX®, Gurobi® Optimizer, or FICO® Xpress Optimization). The results appear in the user interface of the supply chain tool as set of tables with material flows and finances.

When to use optimization?

Analytical models are well-equipped for large-scale data-intensive problems. You can optimize supply chains that include tens of thousands of sites and thousands of product categories. This is the main advantage of this method.

Problems that can be solved using analytical optimization:

- Supply chain design
  - *Where to locate facilities.*
  - *What their throughput should be.*
  - *How to arrange product flows.*
- Master planning by period
  - *Where to produce or stock goods.*
  - *How much to produce and order.*
  - *How to provide for seasonal peaks in demand.*
- Transportation
  - *What size fleet is required.*

In general, analytical optimization is trying to answer:

What is the supply chain configuration and what are the product flows?

Working with analytical models, most of an analyst's time is spent on data preparation. When the data is loaded into the tool, the optimization is run by the engine. The models and data formats are well standardized, so models can be built quickly.

Limits to optimization

To map a supply chain to a set of equations, a supply chain manager must simplify the real-world system and employ certain generalizations and assumptions:

- All the relations are represented as linear dependencies or step functions, a significant simplification of the world.
- Products, orders, and deliveries are modeled as a set of flows between facilities and costs associated with flows, abstracting from unique shipments or product units.
- Time is represented with periods (week, month, year). Disruptive or random change can only occur at the beginning or the end of a period, not inside it. Any event may happen only once within a period (for example, closing a facility). Also, analytical models assume that all parameters are uniformly distributed within a period.
- Analytical models cannot represent actual supply chain behavior, such as process logic, resource availability, randomness, and time-related dynamics.

We have to sacrifice these details for the sake of simplicity, to be able to optimize a really large-scale supply chain. As a result, you should not use analytical optimization for issues that need to consider detailed logic and time.

A MODEL IS A BLACK BOX

An analytical model is a black box. You feed the model some input data, run the optimization, and receive some results in the form of numbers. The problem is that you cannot trace how you achieved these results.

For example, an optimizer can tell you that your model is infeasible, which means that the set of equations underneath cannot be solved. To understand the reason for this infeasibility would be a tedious task, requiring assumptions that cannot be proven directly.

Furthermore, the way the optimizer works is hidden, you can never be sure that the result you get is the best one.

Conclusion

Analytical models are ideal for solving supply chain challenges at the network level, when you don't need to consider operational logic, randomness, and dynamics. If your challenge requires considering any of these, you still can use analytical optimization to get a first approximation of the solution, and then do detailed in-depth analysis with dynamic simulation modeling.

Dynamic simulation

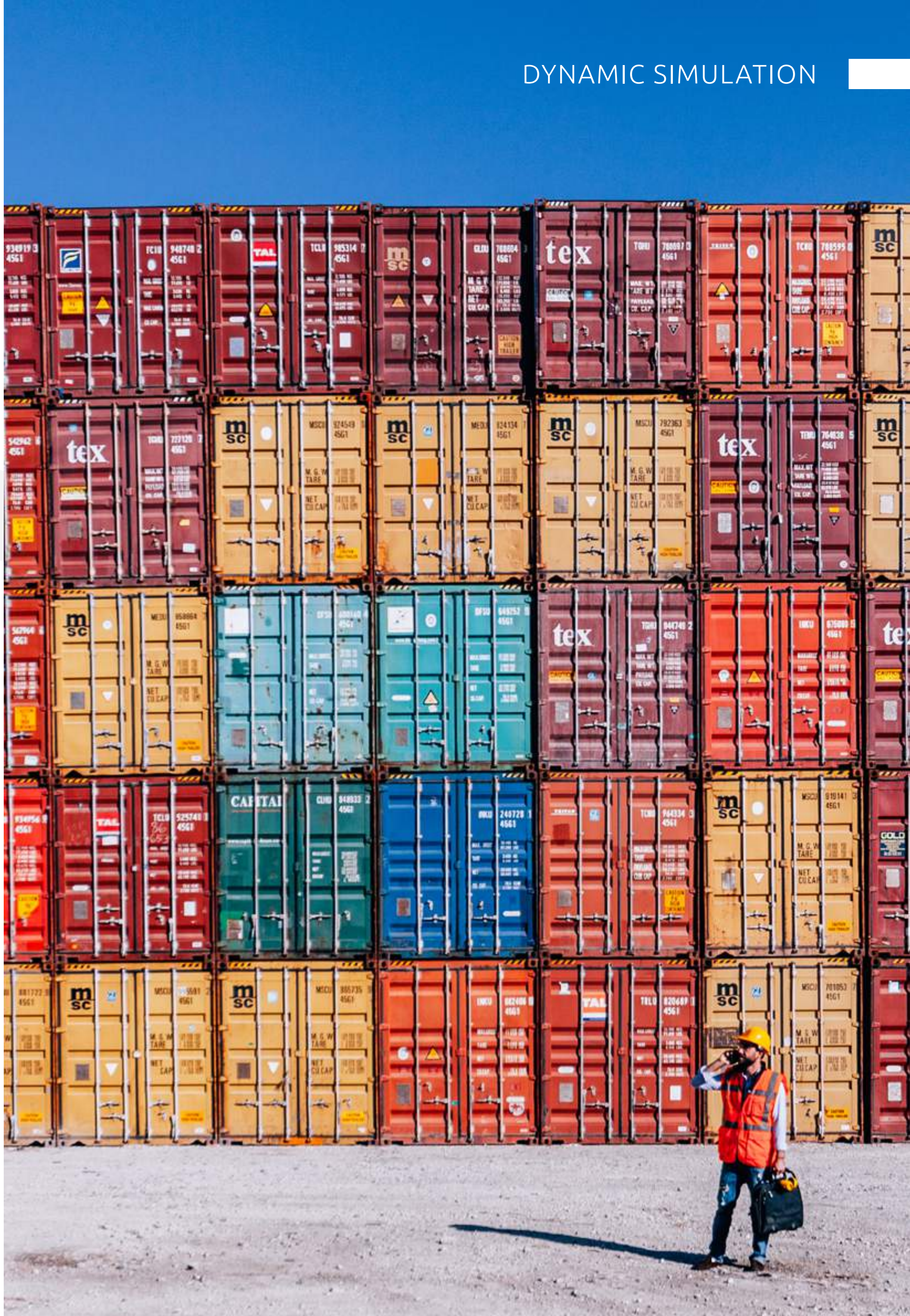
Dynamic simulation

Dynamic simulation has been less commonly used in the supply chain area until recently, but, with the evolution of modern simulation tools, more companies are starting to empower themselves with its diverse capabilities.
What is dynamic simulation?

A dynamic simulation model is the description of a system and the rules by which it operates - business process logic and the interdependencies between system components. A simulation model is dynamic because it is executable, meaning you can run the model and see how the system behaves over time, just like in a computer game.

In fact, a dynamic simulation model is a digital twin of your supply chain that allows you to experiment with new improvements and track metrics.

Using a simulation engine, you can define the logic behind your supply chain. For example, if on-hand inventory is less than 50 units, then the warehouse orders 300 units. The most advanced simulation platforms have prebuilt logic that can be flexibly customized to represent the uniqueness of the supply chain you are working with.



When to use simulation?

Dynamic simulation is especially useful when the operational logic and processes inside the supply chain significantly influence financial efficiency and need to be accounted for during the supply chain design stage.

Simulation helps describe a system with all its details and complexity. Such complexity can be caused by time-dependent, random, and interacting effects within the system, for example, demand fluctuations, lead time variability, or multi-echelon inventory policies[1]. These traits cannot be considered with an analytical model.

Observation of Time

Ability to observe how your supply chain will perform over time

Dynamic Interactions

Incorporate and gain visibility into dynamic interactions between supply chain elements

Real World Variability

Integrate randomness into various supply chain inputs and processes

Actual Behavior

Determine and gain insight into the real behavior of your supply chain

Benefits of using dynamic simulation

1 Heckmann, I., Towards Supply Chain Risk Analytics: Fundamentals, Simulation, Optimization; Springer, 2016. Available at http://www.springer.com/gp/book/9783658148690

Some of the challenges that can be addressed using dynamic simulation:

IMPLEMENTING A NEW SUPPLY CHAIN DESIGN

- *How to introduce a solution suggested by network optimization.*
- *What if a solution suggested by optimization cannot be implemented in the real world?*

UNDERSTANDING SUPPLY CHAIN OPERATIONS

- *To efficiently manage your network, you need to understand how it operates over time and in detail, down to the level of every resource and policy.*
- *Estimate safety stock at each facility for each product.*

EXPERIMENTING WITH SUPPLY CHAIN INNOVATIONS

- *With a high-level network design in place, you may want to know how improve its operational performance.*
- *Ideas can be tested prior to implementation.*

RISK ASSESSMENT

- *What are the risks related to this supply chain structure?*

INSIDE THE FOUR WALLS BUSINESS PROCESS ASSESSMENT

- *How do the internal processes in your DCs or factories influence operations across the whole supply chain?*

A benefit of simulation modeling is information on how your supply chain operates in the conditions you set. Here, we don't optimize anything, we just simulate a certain scenario using the model and see the results. We can inspect model results in depth and understand how the supply chain changes over time. You can test multiple scenarios and come to a business decision based on testing and the evaluation of results.

Unlike analytical optimization, which focuses more on strategic design and planning problems, dynamic simulation tries to answer the question:

How do you achieve operational excellence in your supply chain?

How do simulation and analytical methods differ?

FLOWS V. LOGIC AND POLICIES

Analytical methods describe the system as flows between facilities, while simulation employs the real logic of their communication. This allows simulation models to describe the actual behavior of a supply chain, down to any level of detail.

A flow is the amount of goods or information moved in a period, for example, the number of orders per year, or the number of goods shipped. Logic is a set of rules. For instance, you can send trucks using LTL or FTL policies, base order inventory on the previous week's demand, or schedule production based on resource availability.

All flows in a supply chain are generated from the logic used by the actors involved. So, when you build a model in terms of flows, you must abstract from most of the real processes, which makes the model less accurate. At the same time, representing a flow in a real-world supply chain means finding the right logic to make it work. To overcome these restrictions, we must turn to dynamic simulation. With simulation, you can model any process in your supply chain, including dynamic inventory, sourcing, or transportation policies. You can even simulate processes inside the four walls of your warehouse or factory, down to the detail of every forklift, to see how these processes may influence the whole network.

TIME INSTEAD OF PERIODS

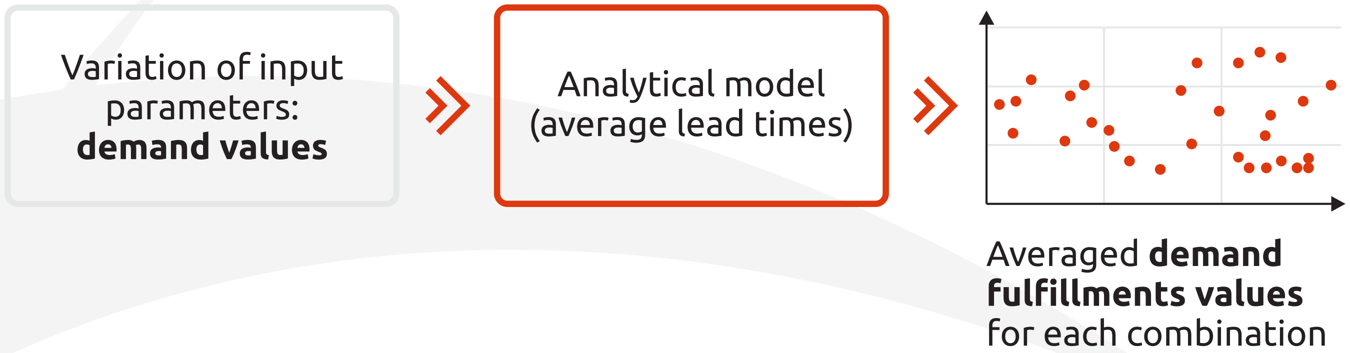
Analytical models represent time as a set of periods (weeks or months), while simulation follows the true passing of time.
In an analytical model, a period is a static thing, there is the beginning of a period and the end of a period. Analytical models do not consider how long a period is, it is treated only as a unit of measure.

Periods are good for high-level problems, where you can abstract from the dynamic nature of reality. If you need to account for days, or even hours, you should use dynamic simulation. In a dynamic simulation model, you can describe the operational logic and analyze the actual dynamics.

Moreover, analytical models assume that all the parameters (shipments) are uniformly distributed within a period. In many cases, in the real world, flows of goods do not come in equal parts every time. This information can be critical for evaluating, for instance, a DC capacity, and can only be considered with dynamic simulation.

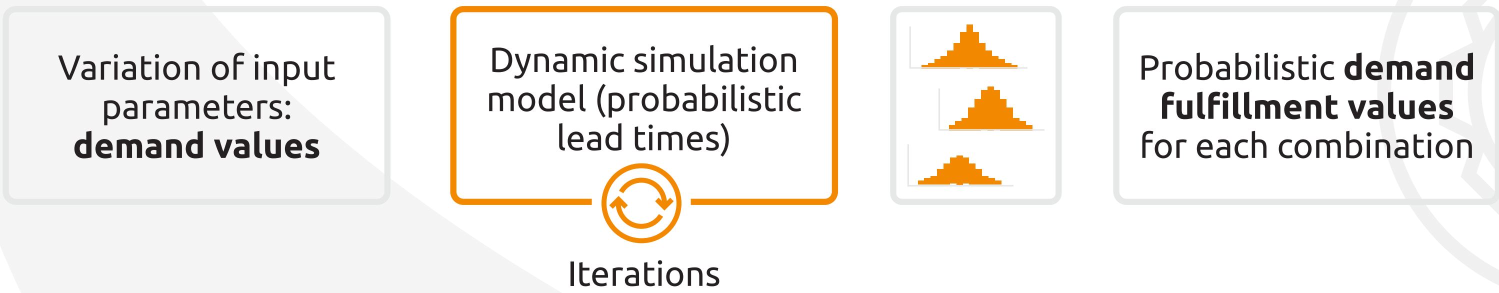
RISK AND UNCERTAINTY

Analytical models are by nature deterministic, which means they do not consider randomness. Every parameter in the model is predefined and averaged, including naturally varying things like lead times or demand. What you can vary are the input parameters: running the optimization multiple times with, for instance, different demand values, and achieving a different result for each variation.



However, to understand how the system will perform in real life, in most cases you will need to vary internal model parameters, like production time for each unit. For example, let us assume production time is four to eight hours instead of an average of six. If we include this uncertainty in the model, so that production times fall in this range each time, the results may not be the same as using the average. To reflect this uncertainty in the model, you must use dynamic simulation.

To make this probability-based model represent the reality more closely, we need to run it multiple times (iterations), varying production times with every run, to get a statistical distribution of results. Such statistics allow us to better understand fulfillment risks for a certain demand volume, providing us with more realistic data and helping us make better decisions.
Risks and uncertainties can only be considered with a probability-based, or stochastic, simulation model.



MODEL TRANSPARENCY

With an analytical model, you may know **what** happens. However, you do not know **why** it happens. A model is a black box, you cannot see what exactly is going on inside.

Dynamic simulation models allow you to see the result and to validate how it was achieved. Models can have interactive animation to show the dynamics of what is happening in the supply chain when the model is running. You can trace the consequences of each event and make conclusions based on real dynamics, checking results instead of trusting them.

MEASURE REAL METRICS

Analytical models are typically built around a single supply chain KPI, such as cost or profit. By contrast, in a dynamic simulation model, many various metrics can be measured at the same time. For example, costs, DC capacity utilization, service levels, fleet utilization rates, the bullwhip effect, and more, can all be calculated within the same model.

Analysts can use this ability to test how changing model parameters may affect different KPIs. This allows you to vary inventory policy parameters and investigate the effects on costs and service levels.

Limits of dynamic simulation

Dynamic simulation is not without its drawbacks.

First, when using dynamic simulation, in addition to data preparation, the analyst would have to invest a lot of time and effort in the creation of the model itself. Building a model from scratch may be a laborious task. However, today there are flexible tools that allow analysts to quickly build simulations using out-of-the-box functionality, without losing the capabilities required for complex challenges and in-depth model customization.

Secondly, to build a helpful simulation model, you must be careful when choosing the level of abstraction, deciding whether you need to include various policies and resources in the model or not. Including too many extra details may increase processing time.

Lastly, with simulation, you cannot calculate the optimum, you only can test different what-if scenarios to see which one is better. Simulation-based optimization exists, but it is fundamentally different from analytical or mathematical optimization. In the case of simulation, the optimization engine is a separate program working in conjunction with the simulation model. The optimizer measures the model output and generates a new set of input parameters based on this data, trying to better achieve the optimization goals. As a result, a simulation model must be run many times to achieve an optimal result, and this can take a lot of time. For data-intensive models on a desktop computer this can take days. However, these problems are now being solved with the emergence of cloud technologies, and simulation model execution is moving to the cloud.

SIMULATION – DO NOT BE CONFUSED BY TERMINOLOGY!

The term simulation, when used by different people, does not always mean the same thing.

In some supply chain tools, simulation means real-time animation of model operations. Others only speak about input parameter variation. In fact, these cover only a small part of what simulation can offer.

When speaking about a tool's simulation capabilities, always consider logic instead of flows, taking into account model uncertainties and the ability to look at the metrics of supply chain dynamics.

Conclusion

Simulation does not produce an optimal solution from multiple combinations, but it allows the analyst to comprehensively study particular dynamic scenarios and supply chain interdependencies. Dynamic simulation should be used when the supply chain is heavily affected by uncertainties, influenced by a sites' internal logic and processes, and requires many details to be considered. It is the only technology available that can solve such challenges.

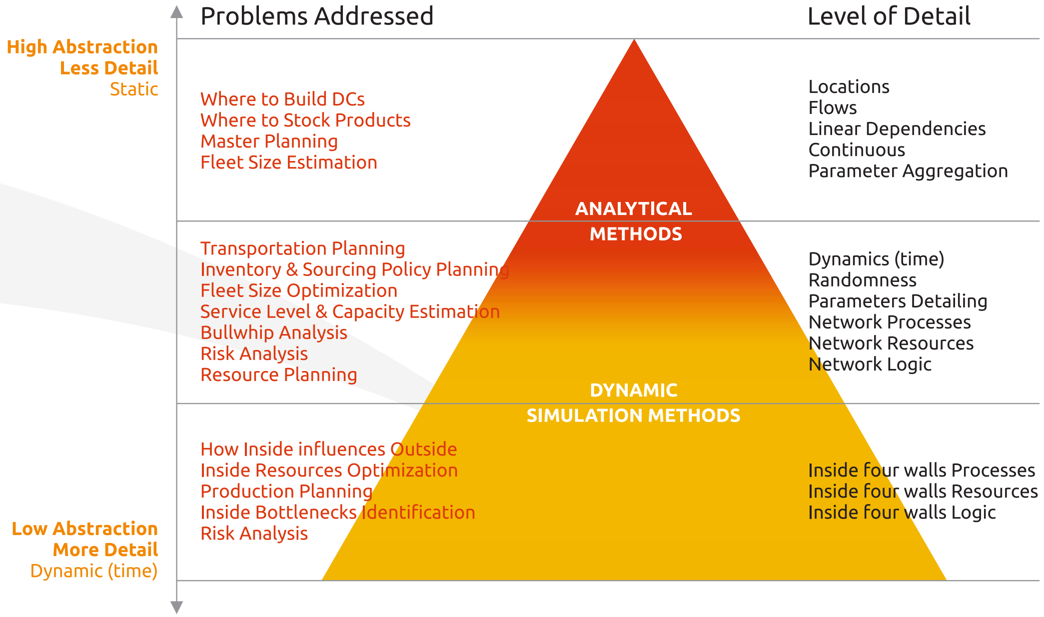
Why should Optimization and Simulation be used together?

Now, back to the pyramid of supply chain problems. Remember, the more details we consider, the more issues we can address. If we map analytical and dynamic simulation methods onto this graph, we can see that analytical methods cover problems with a high level of abstraction, while dynamic simulation allows us to consider more details and solve more issues.

The more details you consider, the more opportunities for improvement you have. The more efficient a supply chain analyst wants to become, the greater is their need for dynamic simulation. It is a crucial tool for analysts striving to make their supply chains both lean and agile.

All that doesn't mean that dynamic simulation is better. It's just targeted at different kinds of problems. It cannot handle challenges suitable for analytical methods well, and vice versa. Analytical methods allow you to handle large-scale problems, while dynamic simulation addresses more details and dynamics to provide deeper supply chain analysis.

To become efficient, the best option is to use these techniques together.



Gartner advises that optimization and simulation can be utilized together in different formats:

- Find the solution with optimization, then check its quality and validity by simulating the resulting scenario.
- Simulate the supply chain to better understand the dynamics of the business system, then create a more tailored optimization model based on these insights.

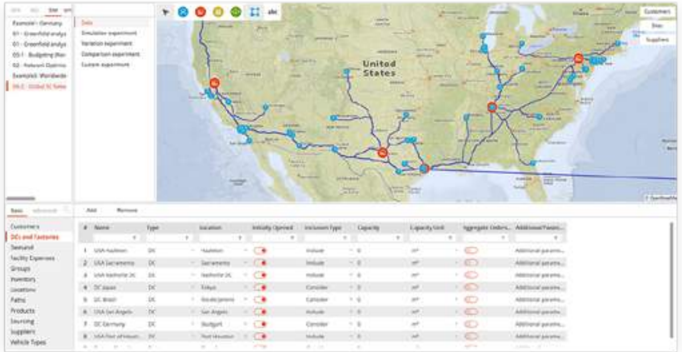
Combining these two methods is critical for building a proficient supply chain analytics toolset, and more companies are acquiring this technique every day.

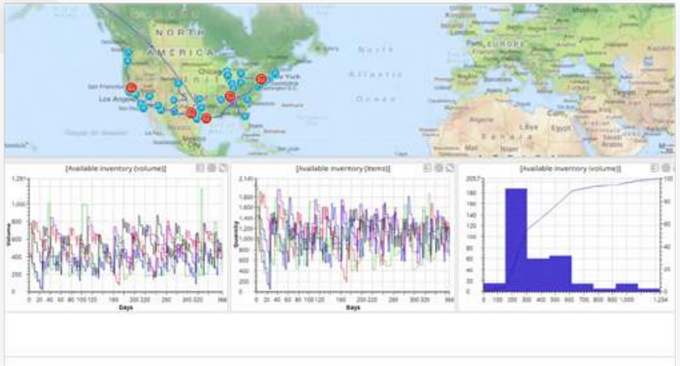
anyLogistix Supply Chain Software

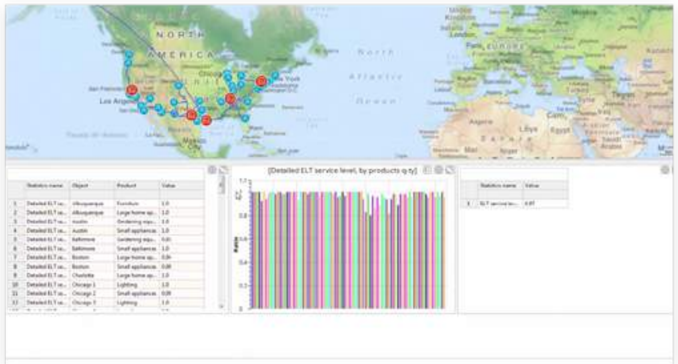
anyLogistix™ (ALX™) software combines powerful analytical optimization approaches with innovative dynamic simulation technologies. This empowers supply chain experts with a comprehensive set of tools for detailed end-to-end network analytics.

ALX provides an environment for evaluating assumptions and testing supply chain innovations. A supply chain model built in ALX is a risk-free space for conducting experiments and testing what-ifs *before* an innovation is introduced. Only after the innovation effects are vigorously inspected in the model, can you start implementing it in the real business system.

anyLogistix is powered by the renowned analytical solver CPLEX™ and the leading simulation engine AnyLogic™.







Why anyLogistix?

01 In ALX, analytical models can be converted in one click to dynamic simulations and vice versa, making the integration of the methods seamless. This allows managers to address large-scale problems while providing a true representation of reality.

02 anyLogistix can represent any unique supply chain logic or behavior in a model, including the detailed processes taking place inside the four walls. This is achieved through integration with AnyLogic simulation software.

03 Supply chain models are all about statistics, and anyLogistix can calculate any required supply chain metric. Max storage capacity used, vehicle utilization rate, or ELT service level by client – with dynamic simulation, everything can be measured in ALX.

04 ALX models can consider uncertainties, giving analysts information about risks and allowing them to come to more robust decisions, enabling more efficient and lean supply chains.

05 Thanks to visualization and live statistics, ALX simulation models are fully transparent, making cause-and-effect dependencies visual and the results traceable.

More information about anyLogistix can be found in the software webinar >>

Conclusion

In today's world, the only way to stay ahead of your competitors, or even to be competitive at all, is to implement innovation. Supply chain is no exception to this rule.

Gartner analysts say that today, across industries, many supply chain leaders "seek to understand cutting-edge trends and adopt innovative technologies to support future business goals". At the same time, to build a successful supply chain, managers must "balance operational excellence with disruptive innovation"[1].

So, staying innovative implies using analytics and forecasting to focus on being lean and agile at the same time. To do so, supply chain experts are adopting analytical optimization together with dynamic simulation. Doing only one of them is not enough to stay at the top: more and more companies are adopting dynamic simulation every day and strengthening their analytical toolset.

Every supply chain is unique. To be innovative and succeed, you need to employ the tools that make it possible to capture your supply chain – at the level of detail you need.

2 Tohamy, N., Combine Simulation and Optimization for More Effective Supply Chain Modeling, Gartner Report, 9 July 2014. Available at https://www.gartner.com/doc/2793018/combine-simulation-optimization-effective-supply

Additional resources

- anyLogistix Webinar
- anyLogistix Demo Video – tutorials
- anyLogistix PLE – free version for self-study and education
- Tutorial book
- White papers
- Case studies

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Contacts

The AnyLogic Company

Choose your local office >>

info@anylogistix.com