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Why Constrained Optimization is the Missing Link in Your Business Decisions

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We all know that the complexity of our businesses is increasing constantly. We serve a more and more diverse customer base, with constantly changing expectations. We collect vast amounts of data in search of the best ways to serve these customers. The changing world around us throws even more complexity into the mix, from the growth in e-commerce to the dramatic impacts of a covid world.

A geometrically expanded diversity in buying behaviors is driving the demand to manage a far more complex supply chain for materials and finished products, as well as new logistics strategies and methods to meet the expectations of faster, last mile delivery.

Constrained optimization has long been a powerful approach to solve an array of problems using applied mathematics to drive better business decisions. Constrained optimization is a perfect solution whenever there is a requirement to allocate or prioritize scarce or important resources within a dynamic and complex environment.

In simple terms, constrained optimization guides you to decide how to do more with less, or how to use less to do more.

As we all know, this is a high priority in any organization.

We Already Use Constrained Optimization, Every Day

Consider some of the ways we already use constrained optimization in our daily lives:

- When we make large buying decisions, they are often constrained by the requirement that we have to be able to afford what we choose to buy.
- Families decide how to prioritize study, work, play, travel, and more based on the constraints of their available time and income/budget.
- We often make decisions on the route we'll drive based on an objective (our destination), constraints (time, traffic number of lights) applied to our variables (the optional routes).

In like manner, the majority of economic business decisions require applying constraints (cost, volume, time) to a set of variables (trucks, SKUs, people) with an objective of minimizing (cost) or maximizing (profit) outcomes. Such economic-driven constrained optimization problems are manifold in an organization.

A few examples:

- Companies often make manufacturing and packaging decisions so that they can maximize their profit margins, within the constraints of finite manufacturing or shelf space.
- Retail stores minimize costs as they are related to the constraints of shelf space, availability, time to ship and more.
- Employers seek to minimize payroll costs while maximizing customer satisfaction during peak seasons by optimizing holiday work schedules based on the above objectives.

As you can see, there are an enormous number of decisions we make every day that are driven by constrained optimization, whether we know it or not.

Why Constrained Optimization is the Missing Link

So why isn't everyone using constrained optimization?

First, let's talk about assumptions and business. Since enterprises have invested so much in big data and IT, the primary assumption they may have is that the reporting and analysis are already in place to make the most informed possible decisions.

That's not necessarily the case.

Many organizations don't have the analytic tools they need to manage large volumes of data and may be missing a very important technique, constrained optimization, to make better decisions for their business.

There are many reasons for this faulty assumption, but let's focus on the top three: the way we've always done it, growing data volumes, and accuracy, or the lack of.

1. The way we've always done it.

We've used paper and calculators, spreadsheets, and more recently business intelligence systems to analyze our information. These tools deliver results that end up being presented to management or decision makers. These folks debate the data and what it means, from their unique perspectives.

That's the problem.

People continue to think and do the way they've always done it and assume it's enough. What's even more of a problem is that constrained optimization techniques can give you the results that show you the obvious decisions, no debate, no personal filters.

2. More data, more insights, more complexity.

We all know that more data means better insights, right?

Not really.

It is true if you can actually analyze all the data. Which is the problem today, and the increasing problem every day hereafter.

Classical computing systems can't process the volumes of data we are collecting. They weren't designed for it. Instead, analysts have to compress and reduce the data to run a computation, which means the results are not as good as they should be. It means they can't use all the volumes of data we are collecting to get those better results.

That's why quantum computing is such a top-of-mind conversation in IT and business circles these days. Before long, quantum computers will solve the issues of big data. They will process large data models to simulate what would actually happen in the real world if you changed different aspects in your business. They will model all your potential outcomes to show you the best decisions you can make, using all of your data.

3. How accurate is accurate?

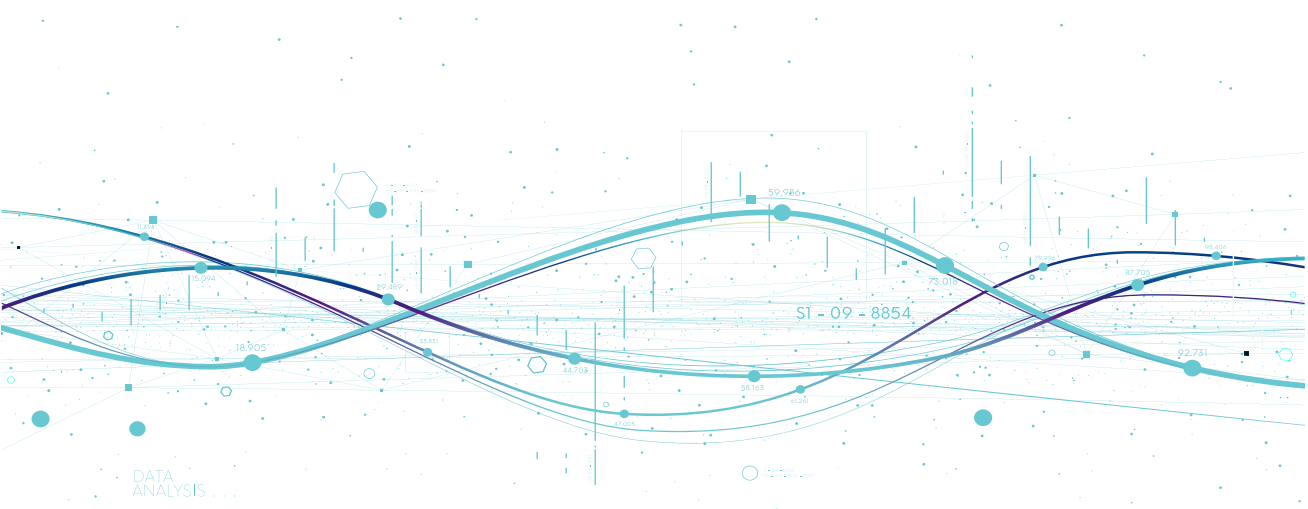
We've always assumed that a computer is the most accurate method to do any form of analysis. That's changing, thanks again to big data.

The computers we use today, classical computers, are designed to process binary bits (1s or 0s) serially. Their hardware processors have gotten faster and faster, but that's not enough. The massive data volumes, combined with the interrelationships between all our data, have outpaced our classical computers. Not only do they struggle to process the large volumes. They also struggle to give accurate, high-quality answers to optimization requests. If they don't falter completely, they often give only a single probable answer, and it may or may not be accurate.

Consequently, even those who are using constrained optimization are falling behind in optimizing their business goals due to issues with their current constrained optimization approaches. In a nutshell, here's why:

- The volume of business data from which to make better decisions is outpacing our computational capabilities today. Classical computers weren't designed to handle the volume of data we are seeing. And the exorbitant time it takes to analyze large datasets proves it.
- Classical constrained optimization software isn't designed to effectively compute very large variable problems with specific discrete constraints (e.g., one truck vs 1.23 trucks) and objectives.
- In part, because of the computation load required to process any large datasets in a reasonable timeframe, classical computations only deliver one result, rather than a range of possible outcomes that may be more optimal.

That's not the level of accuracy, performance, or direction many businesses need.



Quantum Computing to the Rescue

That's where quantum computing comes in. Quantum computing techniques empower constrained optimization to a new level of accuracy and performance.

Quantum computers allow you to represent the variables, constraints, and objectives within a 3-dimensional state. That means you can use quantum techniques to arrange your data, requirements and goals in a way that represents the real world, including inter-relationships and dependencies. As the data is processed, it changes states to represent the probabilistic cause and effect relationships, and the real-world scenarios that result. So you get to view the probable outcomes of the various business decisions you could make, and select the one that best meets your demands.

Quantum computers process complex computations to return a diversity of answers, not just one. Every answer that meets the optimized state you need is delivered to you. You get exposure to more viable options than with classical processors and can select the one that best matches your specific situation right now. This is a much better way to make decisions vs the classical software approaches that provide a single answer as your only option.

Quantum computers are far more accurate in the answers they deliver to you. The results are a better representation of your real-world complexities and nuances. Unlike classical computations, there's no need for abstractions, assumptions, or data samples compressed to be small enough to process on a classical computer.

Quantum computing offers better insights to make better decisions. That's why there's so much excitement about it.

How do we move forward into the promise of highly accurate, insightful, and profit-driving decisions?

Applying Constrained Optimization for Business

As you can see, the implications to your business, when you apply quantum-ready constrained optimization, could be staggering.

Let's dive a bit deeper into the details around constrained optimization so you can start to apply its mathematics to your business. First, let's focus on how to translate the optimization math terms into business terms.

There are three mathematical aspects to any constrained optimization problem.

1. Variables

Variables are the data you want to optimize. In business, these are things like assets, materials, or routes, and they vary by industry. For example:

- **Logistics/Delivery:** Logistics operations optimize things like trucks, docks, warehouses, centers, orders, or products.
- **Manufacturing:** Manufacturers optimize things like stock, parts, raw materials, components, or vendors.
- **Airlines:** Airlines or cargo shipment optimize their fleet, passengers, cargo, etc.

Your business variables are the things that you need to be sure meet your objectives, while also conforming to the limits (constraints) placed on them. This brings us to the second math term.

2. Constraints

Constraints are the rules you have to follow as part of your optimization. In our personal lives, we have constraints, or limits, including affordability, time available, family schedules, etc. Business has constraints too. Here are a few:

- **Time:** Time is the most obvious and frequent constraint in a business. In some cases, missing a time constraint can have enormous consequences. Time-based constraints are found throughout the business. Expected delivery date or time, on-shelf time, hours worked, hold times, route-times, and Service Level Agreements (SLAs) are just a few examples of time-based constraints.
- **Costs:** Cost is also a common constraint in business. How much inventory to hold, how much labor to allocate, how much delivery cost to manage. Each of these affect how you optimize your processes, people, and products. Your processes need to deliver a specific outcome within a cost (and likely time) constraint. Your product availability is a constraint since you have to have a product to be able to sell or ship it. Your employees are a constraint as well. You have to have a pilot and crew, must have workers to load trucks or manage warehouses, and employees available during peak demands on your business.
- **Offers:** Promotional or other offers can be a constraint. If you're running a country-wide promotion for a specific product or bundle of products, you have to be able to effectively meet the objectives of the promotion within the limits of product availability, delivery times, and stocking levels.

Constraints are any limitations you need to place on the business variables that you want to optimize. But now you need to set your optimization objective.

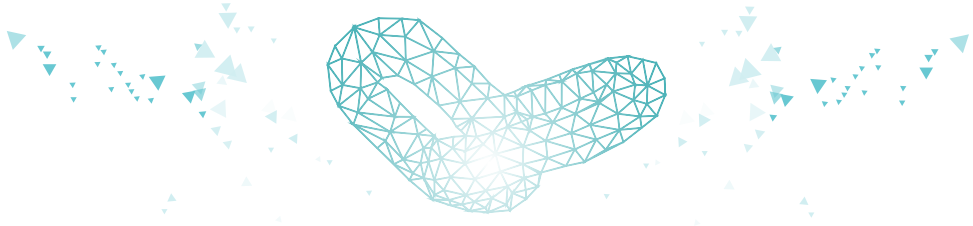
3. Objectives or Goals

These are the results you must obtain as part of the optimization. They drive your business success. Typically, optimizations are performed to either minimize or maximize a specific variable, and often with multiple objectives: minimizing one variable, and maximizing another. Some examples:

- **Minimize:** Most constrained optimization problems focus on minimizing a business aspect or aspects. Examples include costs (products, people, delays, out of stock,) time (delivery, route, downtime, delays, production, SLA responses.)
- **Maximize:** Of course, we also want to maximize some aspects of our business, like our profit margins, margins/individual SKUs on products, on-time deliveries, and on-time SLA responses.

Applying constrained optimization techniques to your business is a powerful way to improve your operational decisions and bottom-line results. Understanding the underlying math and how that translates into business variables, constraints, and objectives is key to identifying other areas of your business that can be improved through the use of constrained optimization.

Now, let's talk about some specific examples of how you can apply constrained optimization to your supply chain and logistics operations.



Applying Constrained Optimization for Manufacturing Supply Chains

One of the obvious application areas for constrained optimization is in managing a supply chain. The global pandemic has demonstrated how vulnerable our manufacturing supply chains are to **dynamic market conditions.**

Constrained optimization helps manufacturing supply chains by identifying the best path forward as dynamic conditions change sourcing options and buyer requirements.

As a simple example, constrained optimization can identify:

- The probable combinations that will result in the minimum supply chain cost for a specific product or a set of products, where the cost is constrained by other costs, such as raw materials, labor, or other resources involved in creating that product.
- The combinations of vendors and materials to best achieve this lowest cost.
- Logistics options to assure on-time, lowest-cost, least warehouse costs for delivery of products as they are manufactured.

How Manufacturing Supply Chains Benefit

Let's look at other ways constrained optimization benefits manufacturing supply chains, from inbound raw materials to outbound distribution.

- **Transportation Efficiency.** Constrained optimization is used to identify optimal locations for plants, distribution facilities, and other logistics hubs. Even a mile difference in placing a plant can make a significant difference in the costs and productivity of the overall network.
- **Warehouse Management and Distribution Services.** Constrained optimization is applied to optimize global and local shipping and loads, warehousing and delivery for lowest cost, optimum efficiency and productivity. Imagine having to schedule shipments of thousands upon thousands of computers, televisions, or cars across the globe using a piece of paper or a spreadsheet.
- **Inbound Logistics.** From order levels to delivery to the production line, optimization can drive maximum production levels at the best cost. Even one lost shipment or forgotten vendor can wreak havoc on a production line. Now imagine having to schedule and maintain all of the parts of a car, computer, TV, refrigerator or ATV using a spreadsheet, especially when you're managing hundreds of thousands of units. That's what constrained optimization makes easy... without the spreadsheet.

A Major Chip Maker and Constrained Optimization

Consider how a major chip manufacturer utilizes constrained optimization to reduce supply chain costs significantly for a new low-cost chip.

When it began the process, supply chain costs were approximately $5.50 per chip. When units were selling for $100, that was a reasonable cost. However, its newer chip was to be sold at a fraction of that legacy price, at about $20.

The only way to meet the margins needed on the newer chip version was to reduce the levels of inventory. Inventory had been maintained at a high level to support the rather lengthy nine-week order cycle. To achieve the supply chain cost needed for a profitable new chip, the cycle time and resulting inventory costs/time needed to be reduced dramatically. Through the power of constrained optimization computations, the chip manufacturer identified the optimum cycle time and how to adjust to meet this new, reduced order time of two weeks.

The result? A supply chain cost reduction of $4+ for each new chip, fulfilling the required cost to deliver the profit margin the innovative chip required for mass success.

Now let's look at optimizing the other end of the supply chain, logistics.

Applying Constrained Optimization for Retail & Logistics

Like most industries, a major retail logistics challenge has traditionally been ensuring that the right products get to the right places for the lowest costs. In retailing environments, providing on-shelf availability of product has been a critical success factor.

The shift to e-commerce was already happening as companies like Amazon challenged the traditional brick and mortar retailers like Wal-Mart and others. The global pandemic has only accelerated the adoption of e-commerce shopping and, along with it, higher consumer expectations and even greater logistics challenges.

As online purchases soar, customers expect unlimited product selection and availability at the lowest price. The emerging differentiator for e-commerce businesses is quickly becoming delivery time.

The staggering 154% compound annual growth in same-day delivery points to the importance of supply chain management logistics. Ensuring next-day or a same-day delivery with zero delays and errors requires end-to-end optimization of the entire distribution process, all the way to the customers' front door.

These challenges are great application areas to apply constrained optimization to analyze complex logistics information and recommend the best possible methods to assure fast, effective delivery and the best possible customer service.

Focusing on E-Commerce Efficiency

Constrained optimization has been an important method to address retail logistics challenges. And today's dramatic growth of e-commerce drives the use of constrained optimization beyond product lifecycle management to focus on effective, low cost, and fast delivery. For example:

- Network design factors, including the location, number, and characteristics of distribution facilities must be optimized for rapid last-mile delivery.
- Facilities and processes must support online order profiles; a much larger volume of orders with a smaller number of items for each order must be optimized.
- Since many Internet retailers must provide a wide range of diverse products, inventory segmentation within internal and third-party distribution networks must be optimized.
- Finally, distribution logistics must be optimized for fast, on-time delivery of high volumes of orders to end-user customers across geographies.
- All of the above must be done while maintaining costs to support profit margins.

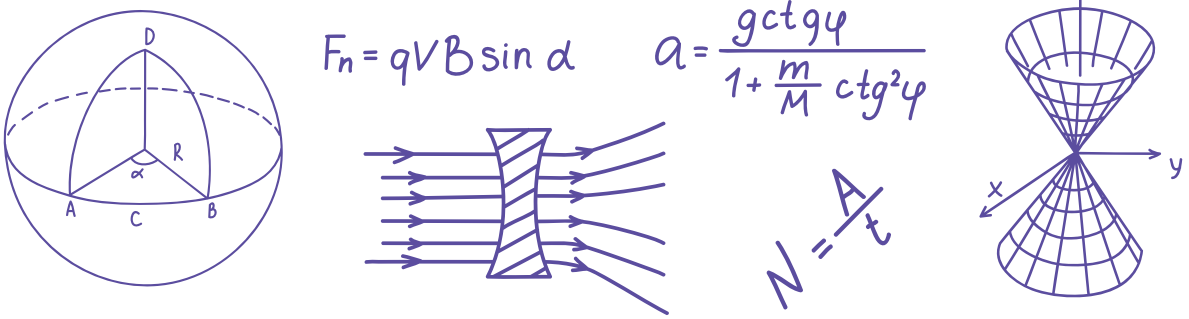
Constrained optimization computations solve these problems. The challenge is that our dramatically growing data volumes are overwhelming classical computing architectures. They can't effectively process all the data. Tactics that compress, shrink, or sample the data to be able to process a smaller computation only serve to reduce the accuracy of results.

That's where quantum computers can bring an extraordinary advantage.

Quantum computers analyze data and run simulations in a 3-dimensional space that matches how the real-world actually works. As a result, they will have the ability to run more large-scale, accurate simulations. Currently, most simulations are held back by the vast amounts of processing power required to run them, as well as a lack of accuracy.

Applying quantum computing to logistics optimization means that the number of variables (data) they can analyze simultaneously grows dramatically, allowing computations that would take classical computers years or even decades to run, if they could run them at all.

Even better, quantum computers also return a diversity of results, offering more and better opportunities to find the best possible solution in different situations, with much higher accuracy.



The Bottom Line

You may be thinking, "But quantum computers aren't ready for prime time yet." And you're right, they aren't.

But that doesn't mean doesn't mean quantum isn't valuable right now. It is.

Because of the novel way quantum computers operate, they hold the promise, as previously discussed, to analyze vastly more data than conventional computers can today.

Consequently, the scientists at QCI have applied quantum methods to create a powerful new way to conduct constrained optimization--even with today's conventional computers.

So you no longer have to wait for quantum computing to become mainstream to take advantage of the technologies that have been developed to support it. Even on classical computers, the constrained optimization engine in Qatalyst can deliver even greater performance, accuracy, and diversity of results than traditional solvers. And it's available all in the cloud.

To learn more about how Qatalyst can help your business, **visit our website.**