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# 4 Key Advantages of Using Mathematical Optimization Instead of Heuristics

*Management Paper*



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**When attacking a complex and challenging business problem, operations research (OR) professionals, software developers, and data scientists today have many different weapons in their algorithmic arsenals to choose from.**

**Broadly speaking, the two most common problem-solving approaches are heuristics and mathematical optimization. Although these two approaches share the same aim – to provide a solution to a complicated, real-world business problem – their fundamental techniques and their final results are significantly different.**

## Two Different Problem-Solving Approaches

Heuristics is a popular and practical problem-solving approach that employs techniques designed to provide a fast and feasible (but not necessarily optimal) solution to a specific problem.

Commonly used in computer science, heuristic algorithms are capable of providing satisfactory solutions to business problems in a relatively short timeframe, but in doing so often sacrifice optimality and accuracy.

Metaheuristics is a widely-used type of heuristics that came to prominence in the 1990s. It's designed to identify, develop, or select a partial search algorithm that may produce a reasonably good, approximate

solution to an optimization problem. Many common metaheuristics, such as genetic algorithms, simulated annealing, and ant colony optimization, are actually inspired by natural phenomena.

In contrast to heuristics, mathematical optimization is a declarative, algorithmic problem-solving approach that is capable of consistently delivering the best possible solution to business problems.

With mathematical optimization, companies can capture the key features (decision variables, constraints, and business objectives) of their business problems in an optimization model. Using a mathematical programming solver like Gurobi, they can generate globally optimal solutions and use them as the basis to make optimal business decisions.



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## Expanding Capabilities, Changing Perceptions

In the past, many companies opted to use heuristics because they were seen as both easier and faster to implement and able to quickly provide “good-enough” solutions. Historically, mathematical optimization technologies were often viewed as too complex (requiring specific technical expertise) and not able to scale well for real-world problems.

This perception has changed immensely over the last few decades with the improvements in computing power and parallelization. In addition, the introduction of cutting-edge algorithms have made mathematical optimization technologies much more widely accessible and applicable. Now, we see [a rapidly increasing number of companies](#) across an ever-expanding range of industries (including supply chain, electrical power, finance, aviation, retail, telecommunications, and sports scheduling) applying mathematical optimization and achieving significant business benefits.

Still, many companies continue to develop and use heuristic solutions – which may be a part of legacy systems that have been in place for some time – to address their business challenges. More and more of these companies, however, are finding that heuristics are not able to meet their needs and are looking for an alternative algorithmic approach.

In this Management Paper, we highlight the four key advantages of using mathematical optimization rather than heuristics as a problem-solving approach.

### **Key Advantage #1: Mathematical optimization gives you the capability to rapidly and consistently generate a globally optimal solution.**

Mathematical optimization solvers like Gurobi are able to efficiently process all available data and consider an astronomical number of combinations of all relevant decision variables, constraints, and business objectives. They automatically and swiftly produce the globally optimal solution that maximizes your company’s efficiency.

With heuristics, there’s no guarantee that the solution will be optimal. In addition, it is very difficult to detect the infeasibility of optimization problems with a heuristic.

Mathematical optimization has been used to tackle many of the world’s toughest business challenges, like the highly complicated scheduling problem faced by the [National Football League \(NFL\)](#).



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Up until the past decade, the NFL's planners utilized heuristic tools and techniques (they actually hung a wooden, 6-foot square board on the wall and used it to map out who would play whom, when, and where) and it took them 10 weeks just to figure out a few feasible schedules for their 17-week season. The NFL decided to implement Gurobi's mathematical optimization solver in 2013. Now, they're able to automatically create and compare over 10,000 feasible schedules that take into account their numerous decision variables and constraints and find the optimal schedule that meets all their business objectives.

This is just one example of an organization that has made the switch from a heuristics-based approach to mathematical optimization and reaped tremendous business benefits. A large number of businesses around the globe and across various industries have decided to utilize mathematical optimization algorithms rather than heuristics to address their business challenges.

When it comes to the quality of the solution delivered, heuristics simply cannot compare with mathematical optimization, which is capable of generating a globally optimal solution to any real-world business problem. Even in business situations where finding the optimal solution is not required, the mathematical optimization technology user can set a parameter called the optimality gap that defines how close from the optimal objective function value a solution can be to stop the optimization process. This is not possible to do with heuristics.

## **Key Advantage #2: Mathematical optimization applications are easier to maintain than heuristics.**

In today's volatile and complex business world, companies need to have the ability to quickly adapt and react to constantly changing business conditions. Mathematical optimization gives them that capability due to its declarative nature.

As mentioned previously, mathematical optimization captures all the key features (decision variables, constraints, or objective functions) of a business problem as an optimization model. These features are fed to a solver, like Gurobi, that automatically churns out the optimal solution. When business conditions change, all you need to do is modify the model and make the necessary adjustments to these key features since the underlying mathematical programming engine and algorithms always remain the same. This flexibility makes mathematical optimization applications easier to maintain than their heuristic counterparts.



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Indeed, changes in the business environment can wreak havoc on heuristic algorithms, often making it necessary for you to make major modifications or even rewrite the whole heuristic from scratch.

Such algorithmic tuning is not required with mathematical optimization, which is able to easily incorporate and accommodate changes to business conditions and continuously meet your company's evolving business needs.

**Key Advantage #3: Mathematical optimization can be used in conjunction with heuristics – and can actually strengthen and improve them.**

Deciding whether to use heuristics or mathematical optimization doesn't have to be a "one or the other" choice. The two approaches can be deployed in a complementary manner.

A heuristic algorithm can be fed into a mathematical optimization solver, which is able to:

- Automatically generate an optimal solution for the heuristic, or
- Decompose the problem into subproblems, each of which is formulated as a mathematical optimization problem, solved to optimality, and then combined to generate the heuristic solution for the original problem, or

- Provide a systematic solution with bounds on how close that solution comes to the optimal one.

Through this hybrid solution approach, mathematical optimization solvers can actually strengthen heuristics.

It's important to note that heuristics can also be used to help mathematical optimization by finding feasible solutions to determine bounds and enhance the pruning of the solution search tree of the mathematical optimization approach.

Many companies – especially those that have been using heuristics as a part of a legacy system – do not want to totally abandon the heuristics approach. By adopting this hybrid solution approach and running their heuristics through a mathematical optimization solver, they can solve their heuristics (or pieces of them) to optimality and improve the overall quality of their solution.



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## **Key Advantage #4:** Mathematical optimization enables companies to achieve the highest levels of efficiency.

Mathematical optimization automatically and rapidly generates the best possible solution for your real-world combinatorial problems, then suggests a course of action that optimizes the efficiency of your business processes. But what exactly do we mean by “optimizing efficiency?” That depends on your company’s business objectives...

In a mathematical optimization model, you can define exactly what it means to “optimize efficiency” depending on your business objectives. Those could be maximizing profits, minimizing costs, maximizing on-time performance, or other objectives. Often, companies have numerous (and sometimes conflicting) business objectives and mathematical optimization solvers enable them to optimally balance the tradeoffs between these objectives.

No matter what your company’s business objectives are or how complex your business problems are, mathematical optimization is able to provide a globally optimal solution or tell you how close from the optimal objective value your current solution is. In any case, you can use mathematical optimization to make optimal or near optimal decisions that maximize your efficiency and overall profitability.

The heuristics approach simply cannot guarantee such a solution.

Mathematical optimization is being used by leading companies around the world and [across numerous industries](#) to solve their complex, real-world business problems, make optimal business decisions, and reach new heights of efficiency.

For this reason and the reasons highlighted above, proponents and practitioners of the heuristics approach would be wise to explore the capabilities of mathematical programming solvers and experience the power of mathematical optimization.



