GUROBI DAY
KOREA

Gurobi Optimization Updates – Decision Intelligence

Juan-Carlos Mani

April 18, 2024

GUROBI
OPTIMIZATION

Agenda

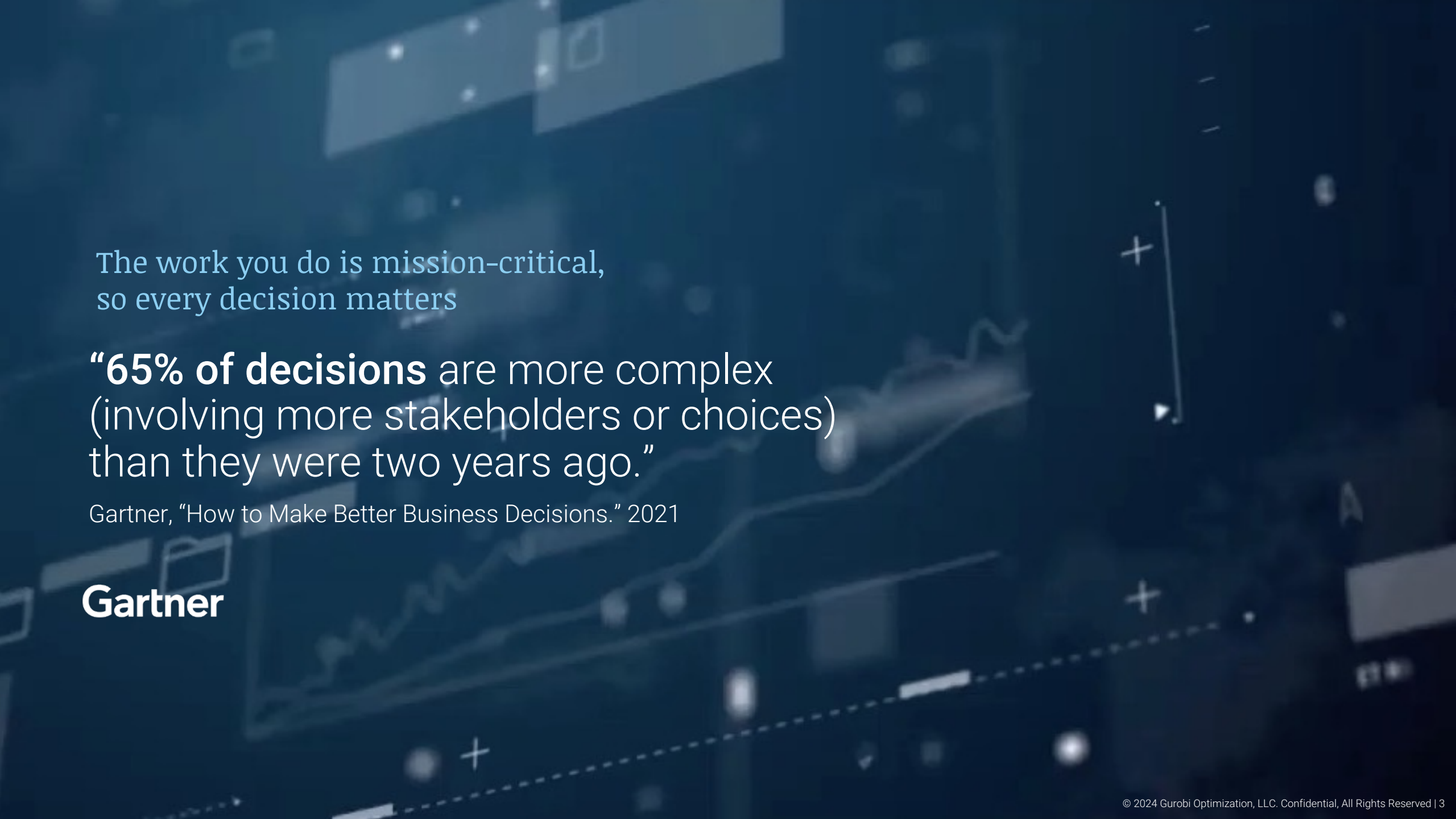
Decision Intelligence

- How to address complex and changing problems
- Combination of Optimization with Machine Learning (combine best of both worlds)

Computing Power & Optimization

Gurobi at a Glance

- Proven benefits



The work you do is mission-critical, so every decision matters

“65% of decisions are more complex (involving more stakeholders or choices) than they were two years ago.”

Gartner, “How to Make Better Business Decisions.” 2021

Gartner

BI and machine learning made big promises, but they have fallen short

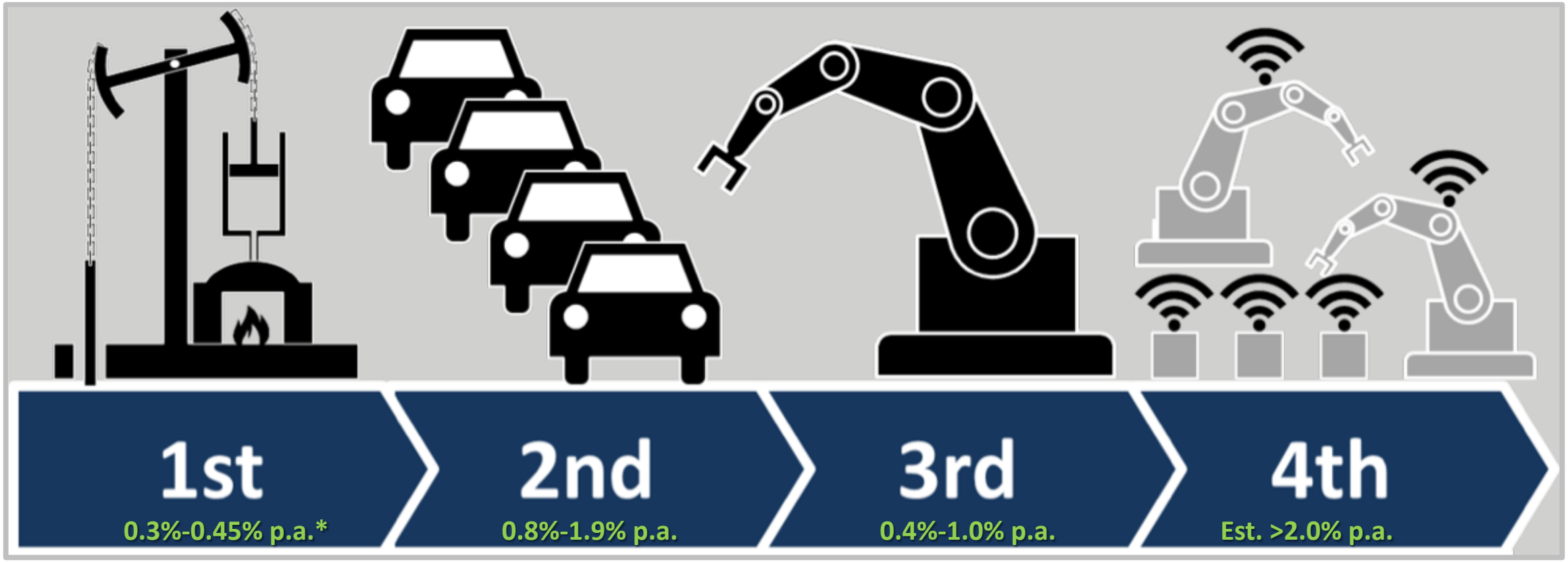
"[Business intelligence and machine learning] have stopped short of recommending specific decisions or actions, and ultimately, they have failed to improve business outcomes."

Gartner, "When and How to Combine Predictive and Prescriptive Techniques to Solve Business Problems." August 11, 2020

Gartner

The Birth of Decision Intelligence

Multi-factor productivity gains



Industrialization

Electrification
- Mass production
- Industrial Statistics
  - Quality control

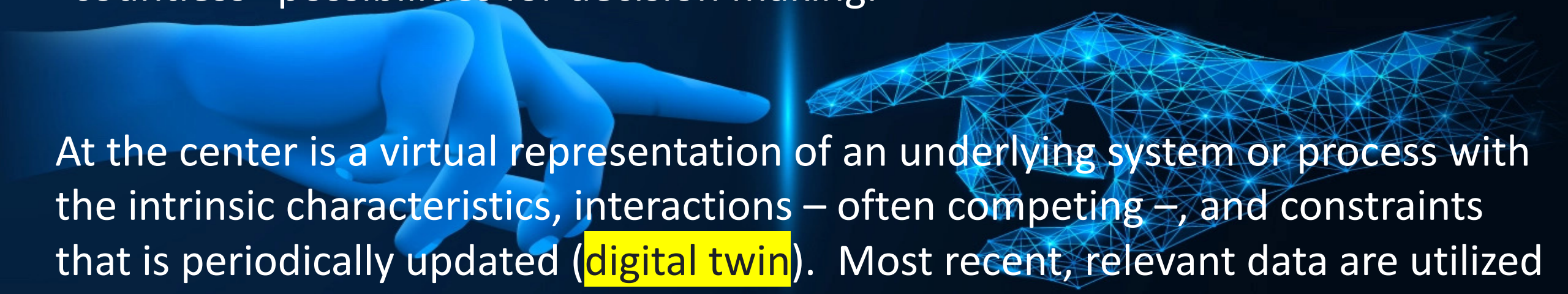
Computerization
- **Stable Supply Chains**
- Big Data | Data Science
- Descriptive & Predictive Analytics (Simulation)

Informatization
- **VUCA** (disruption is the new norm)**
- Right-time knowledge – historical data alone are unreliable predictors
- **Digital Twin**
- **Decision Intelligence**

* Source: OECD, McKinsey Institute; Supply Chain Insights
** VUCA: Volatility, Uncertainty, Complexity and Ambiguity
https://en.wikipedia.org/wiki/Volatility,_uncertainty,_complexity_and_ambiguity

Decision Intelligence

Determine the best possible and most unbiased course of action within often “countless” possibilities for decision making.



At the center is a virtual representation of an underlying system or process with the intrinsic characteristics, interactions – often competing –, and constraints that is periodically updated (digital twin). Most recent, relevant data are utilized (often outcomes from Machine Learning and other types of AI).

GUROBI OPTIMIZATION

Optimization = Decision Intelligence

Optimization analyzes your business situation and recommends ("prescribes") your best course of action.

- At the core of **Optimization is Mixed-Integer Programming (MIP)** with the unique capability to combine *action* and *thinking*
- Intrinsic capability to deal with changes and disruptions and as business rules change over time
- Generic ability to effectively address a wide range of different business problems in all major industries
- **Delivered by a mathematical solver – Gurobi Optimizer**

Understanding the Difference

Mathematical Optimization and the Gurobi Optimizer (“Solver”)

Mathematical Optimization

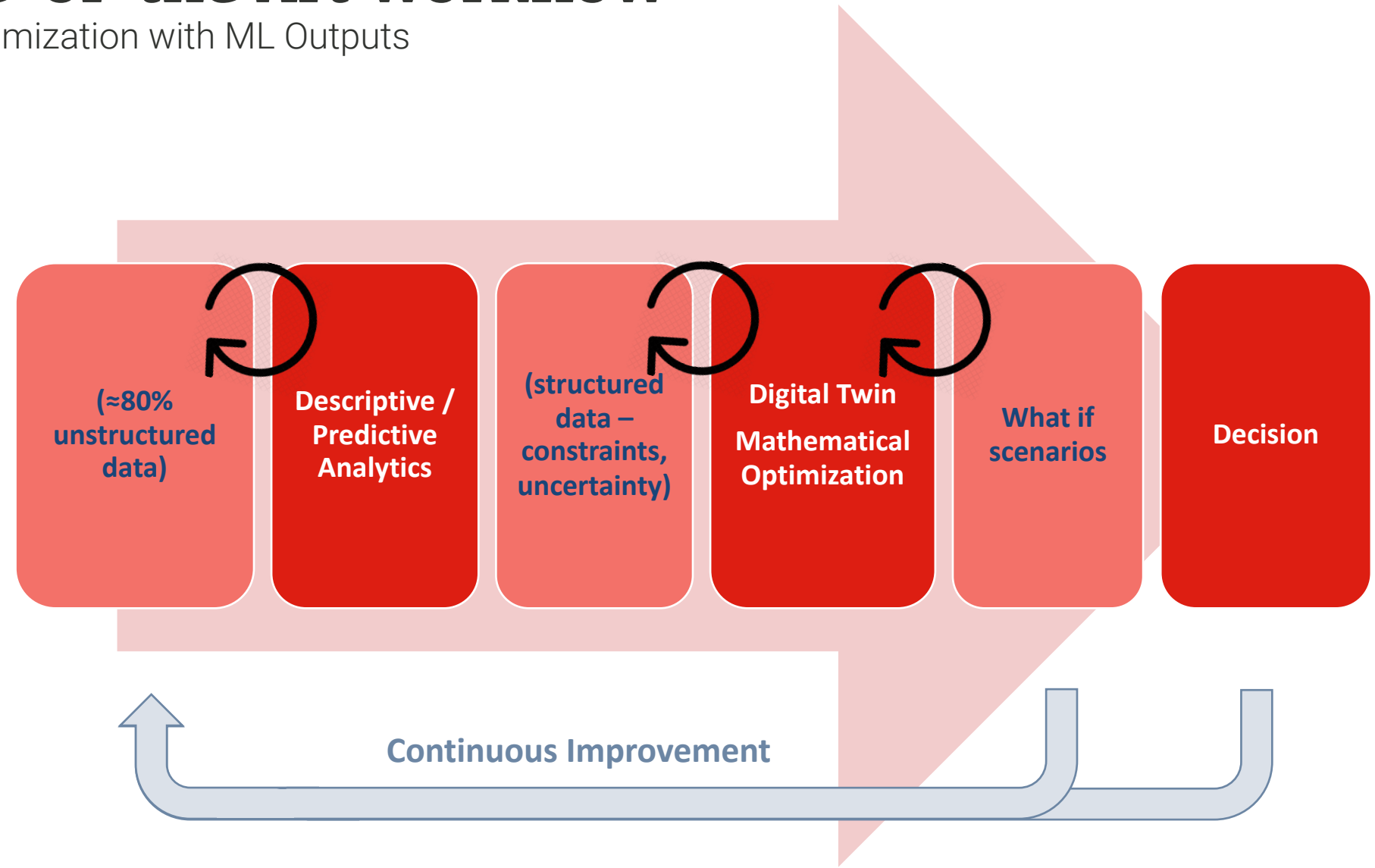
The industry proven **method** for addressing your business problem, both holistically and quantitatively.

Gurobi Optimizer

The **tool** that solves your mathematical optimization model—faster and more reliably than any alternative.

State-of-the Art workflow

Feed Optimization with ML Outputs



Example: Planning of Service Resources at HP

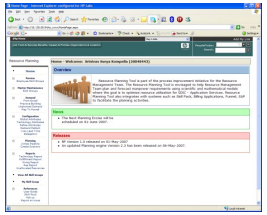
Workforce Optimization under Demand & Supply Uncertainties

C. Santos et al., "Adaptive Employee Profile Classification for Resource Planning Tool", Proceedings of SRII Global Conference, IEEE Computer Society, 544 (2012)

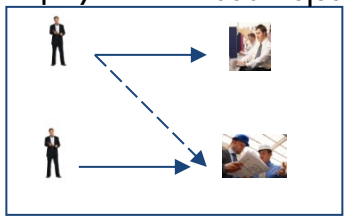
- Challenge: Continuously match resources (skilled professionals) with project jobs
- Solution: Two stage process – *Integration of Machine Learning with Optimization*

Machine Learning

Input
- List of priority opportunities
- Job-Opportunity requirement
- Employee Qualifications, Trainability (incl. job rotation), Locations, Industry domain
- Job attrition rates
- Workforce type (regular, contingent)



Demand & Supply Consolidation



Supply/Demand matching scores

Optimization

Input
- Hiring & training lead-times
- Job replacement requirements due to attrition
- Opportunity/Project revenue & profitability
- Constraints, e.g., budget, hardware, min. revenue and profitability
- Employee satisfaction "soft" factors (e.g. varying work times, family responsibilities, …)

$$Min \sum_{j \in J} c_j x_j$$

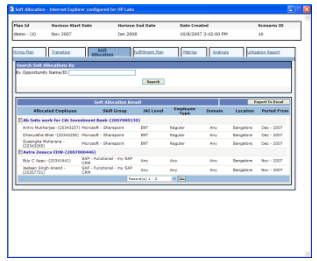
Subject To:

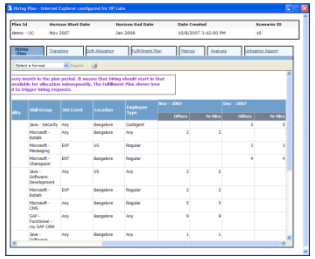
$$\sum_{j \in J} a_{i,j} x_j = b_i \quad \forall\, i \in I$$

$$x_j \in S, \forall\, j \in J$$

Maximize utilization of current staff over time

Gurobi





1) Allocation Plan **3) Hiring Plan**

2) Workforce Transformation Plan

Authors reported ≈12% improvement over manual, rule-based approach

Computing Power & Optimization

- Single threaded CPU performance

  1991-2022: ≈ 1,542x speed-up

Source: https://www.eejournal.com/article/fifty-or-sixty-years-of-processor-developmentfor-this/ (accessed 22-Mar-2023)

- Optimization Algorithm/Software performance

  1991-2022: ≈ 2,035,000x speed-up

Source: - Bixby, R. E. (2010) "Mixed Integer Programming: It Works Better Than You May Think,"
- Gurobi Optimization, v10 corporate presentation

- Performance gain CPU & Optimization together

  1991-2022: ≈ 3,138,000,000x (3.14bn) speed-up

Simple illustration: An Optimization business problem which would have taken **100 years in 1991** to solve would do so **today in 1s**.

Electrical Power Industry

Example of industry transformation by Optimization

- Industry report, June 1989:
  - "Mixed-integer programming (MIP) is a powerful modeling tool. They are, however, theoretically complicated and computationally cumbersome"
- 7-day Unit Commitment model couldn't be solved
  → Resort to approximation methods
- Electrical power deregulated in USA & Western Europe in late 1990's
  → Rush to create a market
- Concurrently, significant improvements in hardware and software technologies

  Sep-1999: Solved, proven optimality in **22 min** (CPLEX)

  Jun-2011: Solved, proven optimality in **85 sec** (Gurobi v4.5)

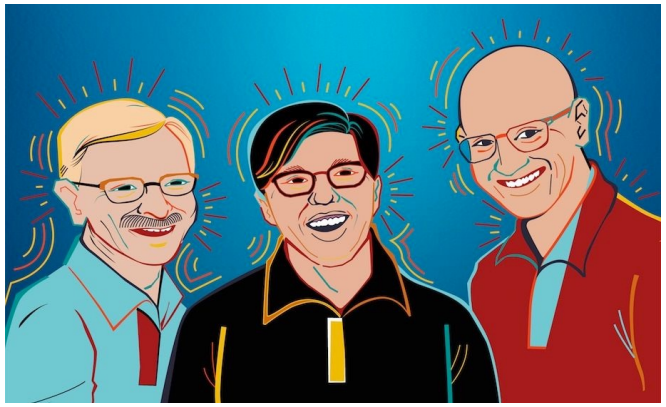
  Feb-2017: Solved, proven optimality in **17 sec** (Gurobi v7)

  Jan-2022: Solved, proven optimality in **5 sec** (Gurobi v9)

- Today, MIP optimization almost exclusively used in USA, Western Europe, and Japan
  - Only methodology to handle the time-dependent combination of renewables (incl. storage) with fossil and nuclear fuel energy sources

Gurobi at a Glance

- Origins go back to 1987 when CPLEX was founded by Robert Bixby and Janet Low
  - Mixed Integer Optimizer introduced in 1991
- CPLEX acquired by ILOG in 1997
  - Zonghao Gu, Ed Rothberg, and Bob Bixby come together at ILOG
  - CPLEX wins first INFORMS impact prize in 2004
- IBM acquired ILOG in January 2009
  - Driver is a business rules software called J-Rules, not CPLEX



- Gurobi is founded in December 2008 by Gu, Rothberg, and Bixby
  - Simple Vision: Build the world's most powerful Decision Intelligence technology
  - Focus Areas: Solver – Technical Superiority, Ease of Use, Customer Centricity
  - Largest R&D/Technical team in the market. Continuously pushing limits – performance & functionality
  - Today, 1,150 active customers in all major markets and ≈50 industries.
    - Americas, Europe from 2013
    - Australia (2020), Singapore (2022), Korea (2022), Japan (2023)
    - Korea: Dr. Kang Ju Lee, Dr. Chung-Kyun Han

The World's Most-Trusted Brands Run on Gurobi

TRUSTED BY

50%
OF FORTUNE 100

70%
OF BIGGEST EUROPEAN COMPANIES (BY REVENUE)

70%
OF TOP GLOBAL TECH COMPANIES

60%
OF TOP POWER & UTILITY COMPANIES (US, EUROPE, JAPAN)

"[Gurobi] has met our high expectations, and the support they provide has been fantastic."

Michael North, Sr. Director, National Football League (NFL)

VIEW CASE STUDIES

Decision Intelligence Across Industries

Common use cases

Supply Chain

Facility locations, truck routing, container unloading, inventory placement

Manufacturing

Production planning and scheduling workforce planning

Airlines

Crew scheduling, flight to aircraft assignment

Energy

Balancing supply and demand, optimal energy resource planning to meet CO2 emission targets

Finance

Investment portfolio optimization, cash allocation and management

Sales & Marketing

Marketing campaign optimization, sales territory allocation

The Total Economic Impact™ of Gurobi Optimizer

VIEW REPORT

ROI	Average Annual Benefits of analyzed use cases	Payback
518%	$4.30M	<6 months

Better Decision-Making Starts Here

Agility

Know with certainty how to respond to changing business conditions, as they happen.

Efficiency

Align your resources and forecasted demand in an uncertain business market.

Resiliency

Explore what-if scenarios and evaluate long-term risks and opportunities.

Q & A

Thank you for attending.

