CS3121 - Introduction to Data Science

Prescriptive Analytics

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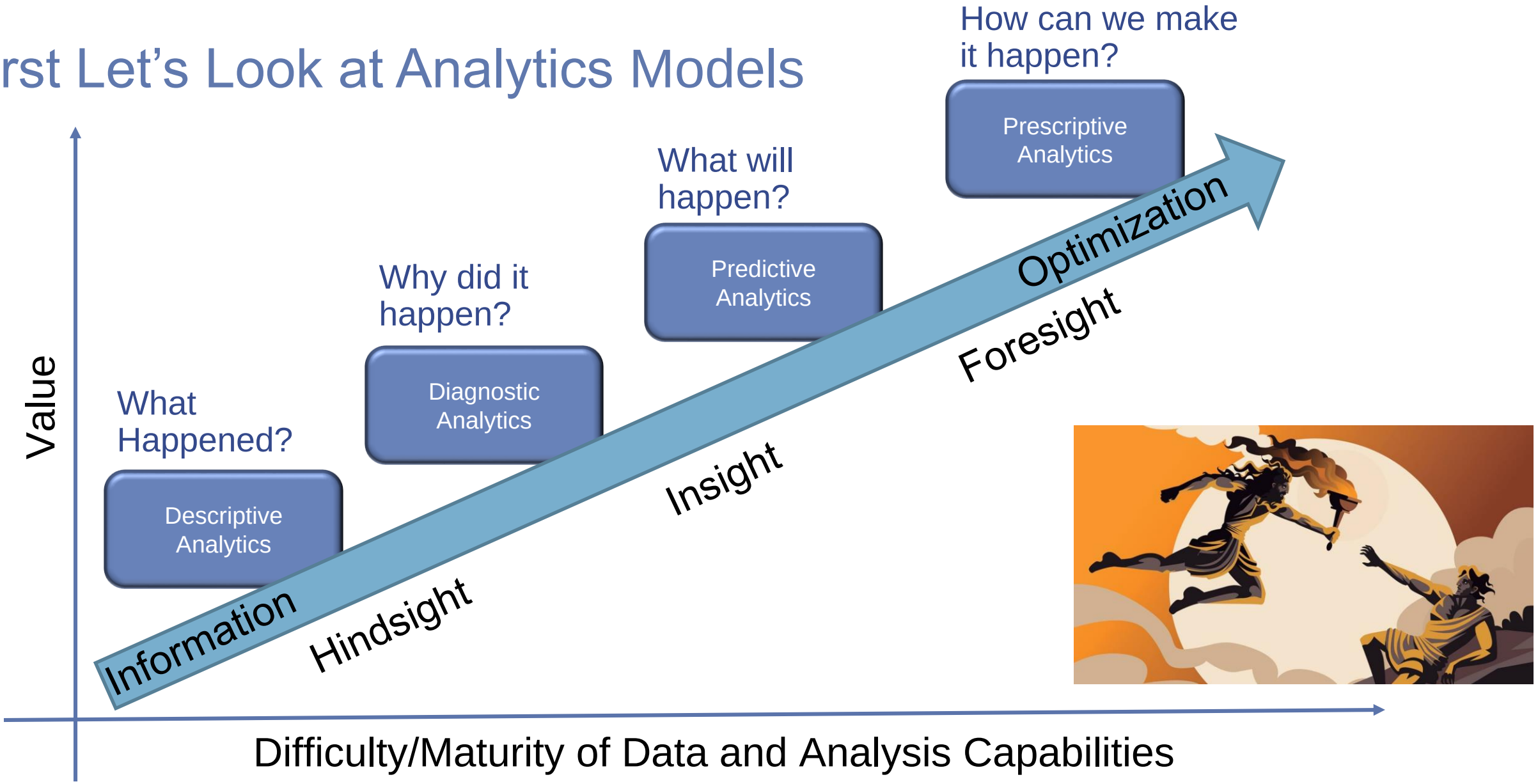
What do we Want to Know?

First Let's Look at Analytics Models



Prescriptive Analytics

- Prescriptive analytics are often referred to as advanced analytics.
  - Decision making support
  - Automated decision making
- Often for the allocation of scarce resources
- Optimization
- What should occur?

Prescriptive Analytics: What should occur?

Example

Prescriptive analytics can benefit healthcare strategic planning …

by using analytics to leverage operational and usage data combined with data of external factors such as …

economic data, population demographic trends and population health trends …

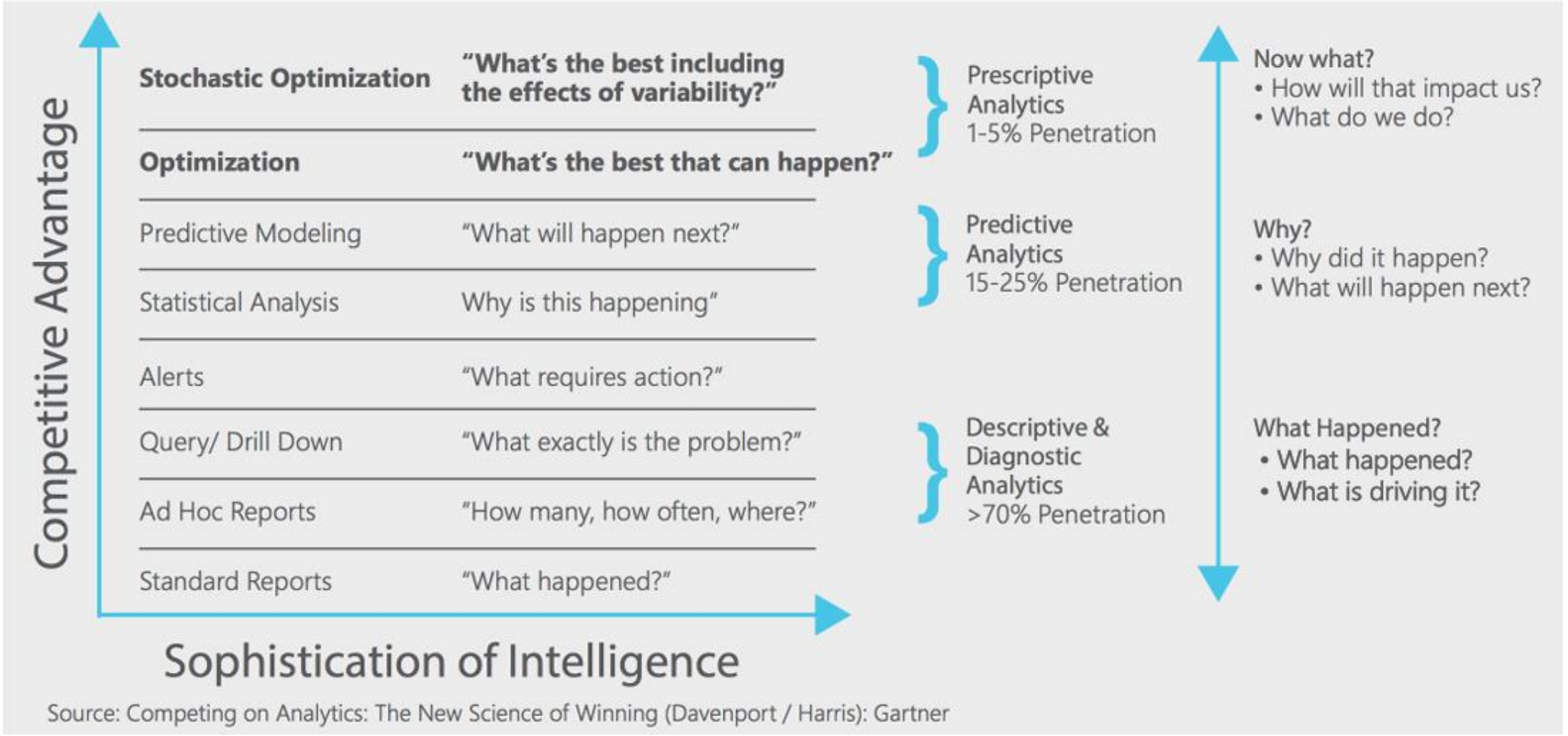
to more accurately plan for future capital investments such as …

new facilities and equipment utilization as well as …

understand the trade-offs between adding additional beds and expanding an existing facility versus building a new one.

What is Prescriptive Analytics?

Understanding Where Advanced Analytics Stand Today



Source: Competing on Analytics: The New Science of Winning (Davenport / Harris): Gartner

What is Prescriptive Analytics?

Gartner's Definition

"Prescriptive analytics is the application of logic and mathematics to data to specify a preferred course of action. While all types of analytics ultimately support better decision making, prescriptive analytics **outputs a decision rather than a report**, statistic, probability or estimate of future outcomes."

- Gartner, "Forecast Snapshot: Prescriptive Analytics, Worldwide, 2015

- Gartner defines two types of prescriptive analytics
  - Heuristics
  - Optimization

What is Prescriptive Analytics?

- Prescriptive analytics ingests hybrid data, a combination of
  - Structured data (numbers, categories)
  - Unstructured data (videos, images, sounds, texts)
  - Business rules
- Helps predict what lies ahead and to prescribe how to take advantage of this predicted future without compromising other priorities
- All three phases of analytics can be performed through professional services or technology or a combination.
- In order to scale, prescriptive analytics technologies need to be adaptive to take into account the growing **volume**, **velocity**, and **variety** of data that most mission critical processes and their environments may produce.

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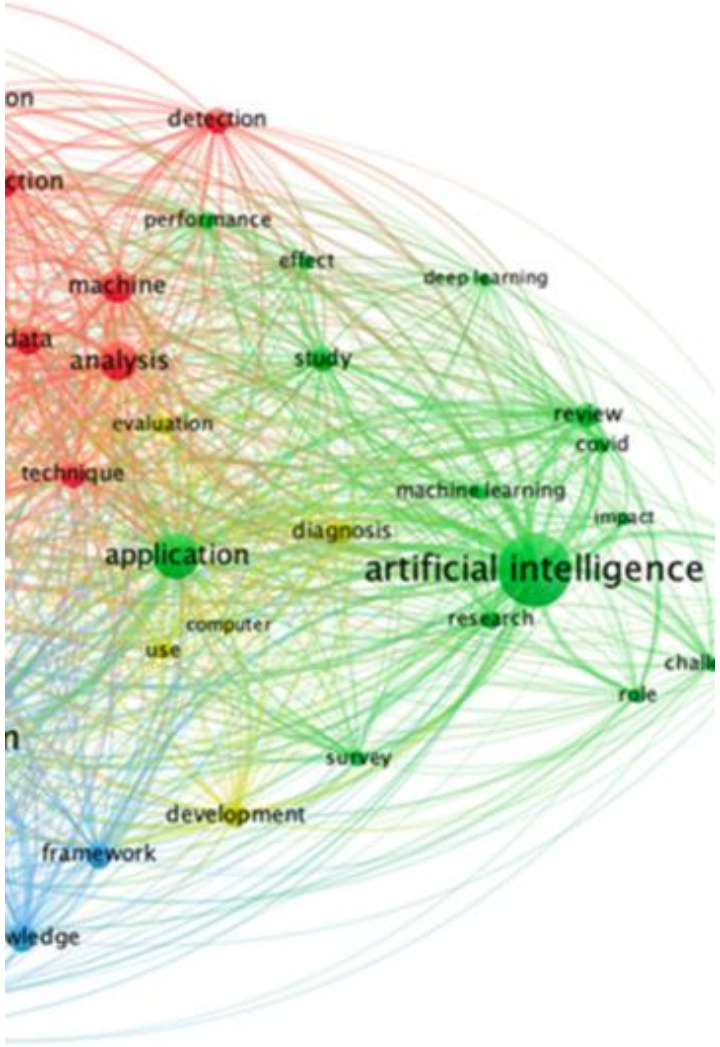
What is Prescriptive Analytics?

- The data inputs to prescriptive analytics may come from multiple sources:
  - **Internal:** such as inside a corporation
  - **External:** also known as environmental data
- Prescriptive analytics software can accurately predict prices by modeling internal and external variables simultaneously and also provide decision options and show the impact of each decision option.

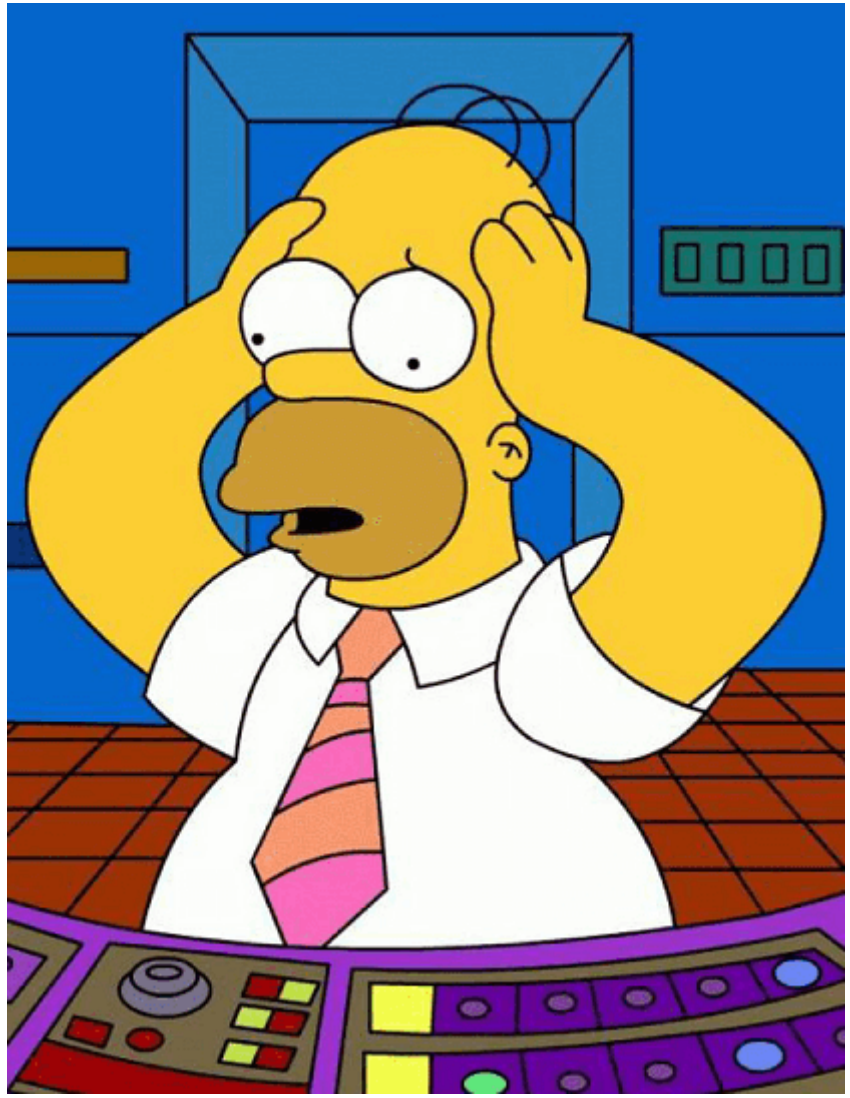
Benefits of prescriptive analytics

- **Effortlessly map the path to success**.
  - Prescriptive analytic models are designed to pull together data and operations to produce the roadmap that tells you what to do and how to do it right the first time.
  - Artificial intelligence takes the reins of business intelligence to apply simulated actions to a scenario to produce the steps necessary to avoid failure or achieve success.
- **Inform real-time and long-term business operations**.
  - Decision makers can view both real-time and forecasted data simultaneously to make decisions that support sustained growth and success.
  - This streamlines decision making by offering specific recommendations.



Benefits of prescriptive analytics

- **Spend less time thinking and more time doing**.
  - The instant turnaround of data analysis and outcome prediction lets your team spend less time finding problems and more time designing the perfect solutions.
  - Artificial intelligence can curate and process data better than your team of data engineers and in a fraction of the time.
- **Reduce human error or bias**.
  - Through more advanced algorithms and machine learning processes, predictive analytics provides an even more comprehensive and accurate form of data aggregation and analysis than descriptive analytics, predictive analytics, or even individuals.



What is Prescriptive Analytics?

Role of Optimization in Prescriptive Analytics

- Optimization solvers use algorithms such as linear programming, mixed integer programming, constraint programming, and heuristic algorithms to minimize or maximize some objective while meeting global business constraints.
- Optimization can tackle more complex problems by making use of an explicit analytical decision model to compute the outcomes of each alternative and evaluating trade-offs among multiple objectives and constraints.
- This analytical decision model explicitly computes outcomes for **each decision alternative**, so one knows for every possible choice what the expected outcomes are and, in the end, what the optimal decision is.
- **Prescriptive Analytics is enabled by Optimization**

What is Prescriptive Analytics?

Heuristics or Optimization - “An Answer” vs “Best Possible”

Heuristics (or rules) - based modeling

- **Logic is defined** by users
- Works in sequence
- **Difficult to implement advanced constraints** (i.e. throughput, min. batch production)

- Leads to “an answer” that may or **may not be feasible**
- Takes effort to maintain the rules (not just the data) as conditions change (e.g. product/services mix, throughput)
- Provides **limited insight** beyond the answer

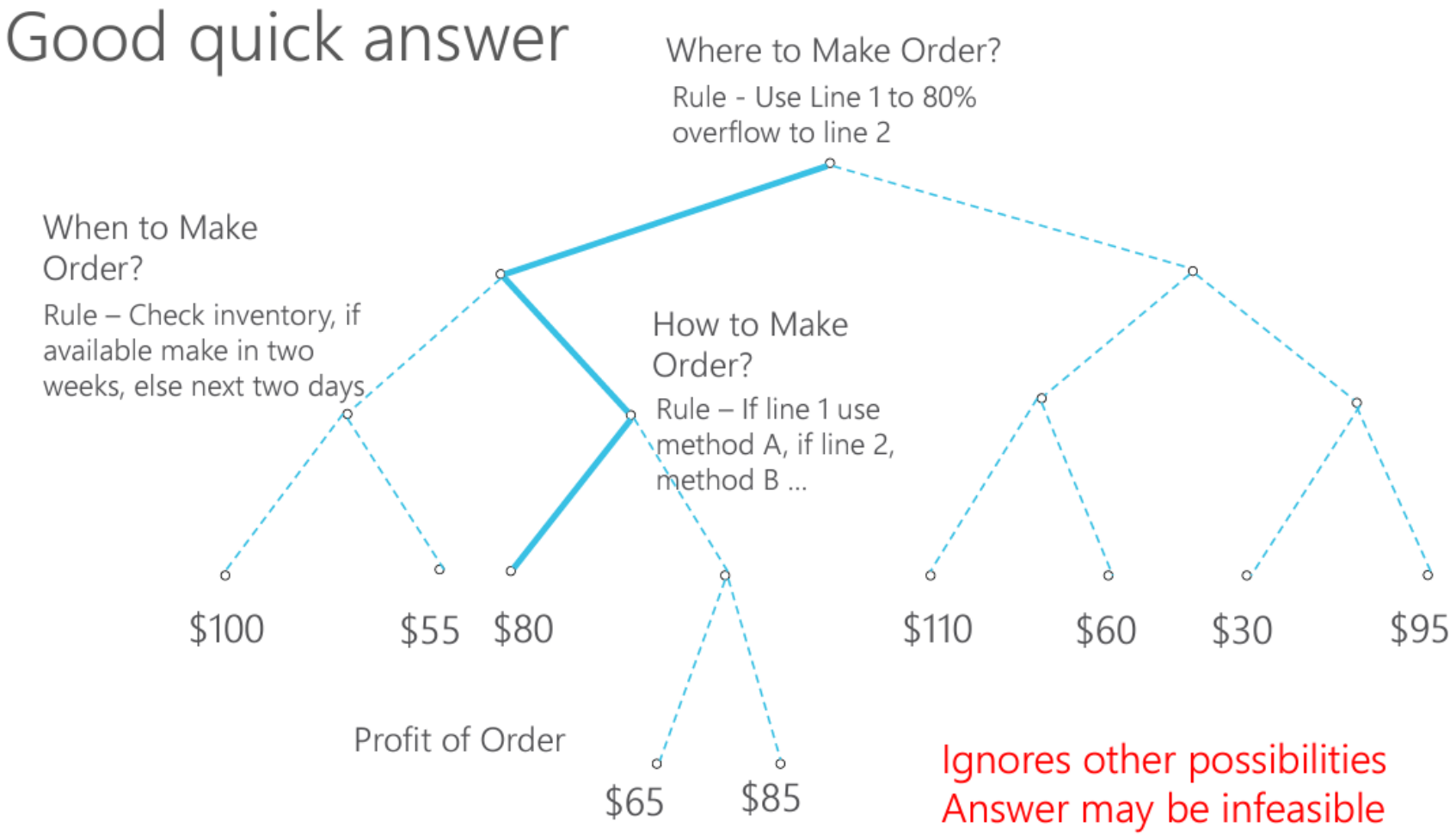
Optimization modeling

- Creates a “map” that **represents reality**; i.e., given limits for sales, logistics, production, stocking…
- Answers “what combination of activity is best?”
- Flexibly maximizes/minimizes objectives (i.e. profit, service level, cost)

- Leads to the “**best possible**” answer o Typical improvement of 10-20% over heuristics based modeling o By definition also doable
- Provides additional insight into **marginal opportunities around demand and business constraints**

What is Prescriptive Analytics?

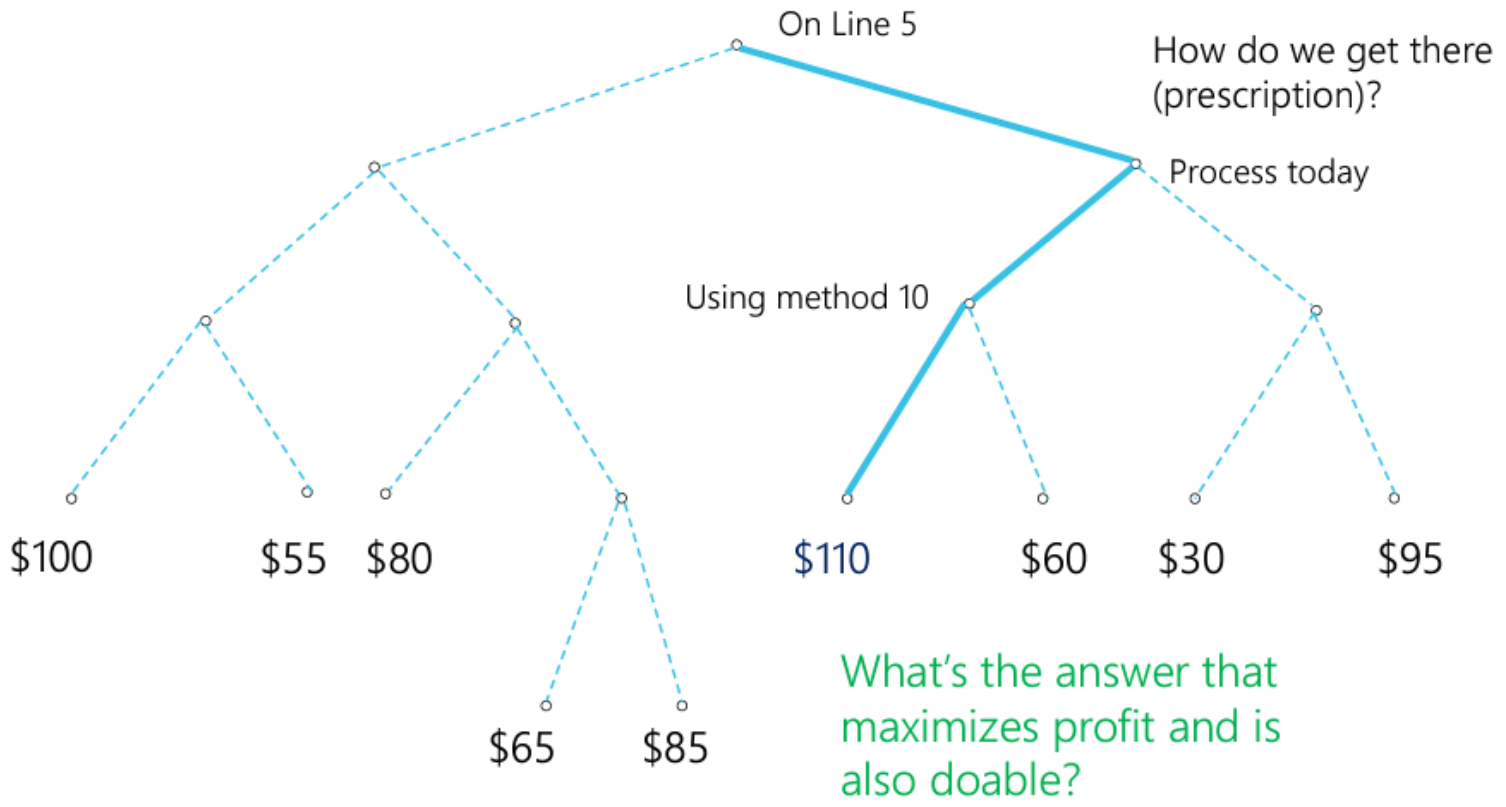
Heuristic Approach



What is Prescriptive Analytics?

Optimization Approach

Best feasible answer



What is Prescriptive Analytics?

Prescriptive Analytics Vs Hypothesis Driven Approaches

Steps for Decision Making	Hypothesis Driven Approach	Perspective Analytics
Process Flow	High-level representation of the problem usually white-boarded. A hypothesis for the problem under consideration is documented at this step that drives the rest of the steps.	Detailed representation of the problem captured in business expert system. No pre-conceived notion of a hypothesis is required.
Decision Flow	Only a representative set of decisions are considered driven by the hypothesis.	Significantly larger number of decision steps are considered due to the visual nature of the model and ease of modeling.
Constraints	Not Applicable	Upper and lower control limits on the key constraints that are modeled and relevant to the decisions.
Prescription	Not Applicable	Model solves for different scenarios. Drives the analysis for which decisions results in highest net income.

How does Prescriptive Analytics Work?

Steps for Prescriptive Analytics

Process & Decision Flow

- Represent the process flow model for the organization (resources, costs, capabilities)
- Determine the range of possibilities for decisions made by the organization

Data

- Input data from representative historical period to feed the model
- Validate the process flow

Constraints

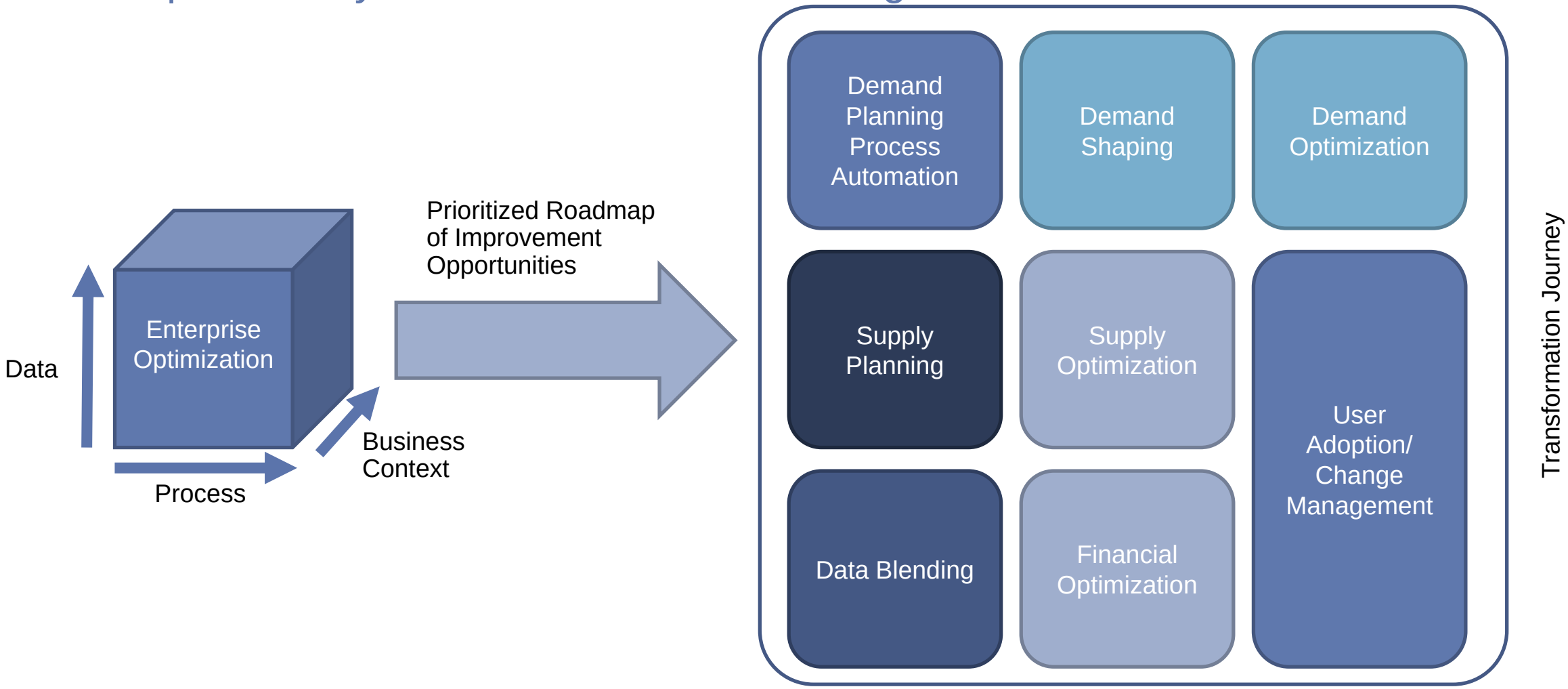
- Define the upper constraint and lower constraint limits for all decision possibilities
- Establish the objective function(s) to be considered

Prescription

- Identify the best way to utilize the resources, costs, and capabilities of the organization that maximizes the defined objective(s)
- Evaluate what-if scenarios

How does Prescriptive Analytics Work?

Prescriptive Analytics Drives Decision Making



Where is Prescriptive Analytics Applied?

Industry	Solution
Financial Services	Cash Management
	Mortgage Services, Strategy & Portfolio Optimization
Aerospace & Defense	Service Contract Profitability Modeling
Healthcare – Providers	Population Management and Accountable Care Organizations (ACO) Transition
	Staff, service, and resource optimization
Health Plans	Health Plan Benefit Design Optimization
	Provider Network Optimization
Utilities	Multiple – Strategic, Tactical & Operational in Water Utility Industry
Consumer Packaged Goods	Trade Promotion Optimization (TPO)
	Integrated Business Planning (S&OP)

Where is Prescriptive Analytics Applied?

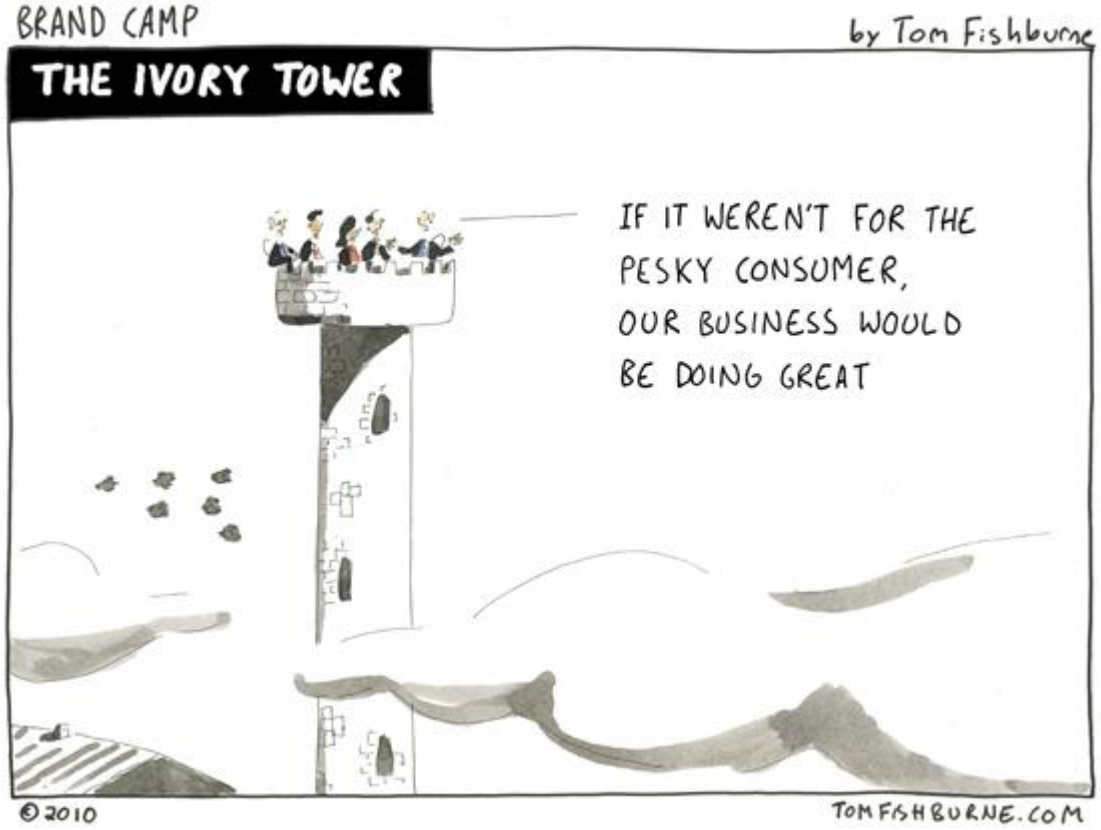
Industry	Solution
Oil and Gas	Logistics Optimization
Transportation & Hospitality	Revenue Management & Logistics Optimization
Retail	Price & Promotions Optimization
High Tech	Integrated Business Planning (S&OP)
Chemicals	Integrated Business Planning (S&OP)/ Capex
Government	Military Recruiting
Natural Resources	Network Optimization/ Integrated Business Planning (S&OP)/ Capex
Metals	Product Mix & Supply Planning
Mining	Supply Chain Planning & Blend Optimization

How do you Identify the Right Use Cases?

- **Policies** that guide **behavior**, where decisions are made out of habit or where people fail to make decisions
  - E.g.,
    - We always source products from this plant to serve this market.
    - We prioritize our customers based on volume/revenue.
  - E.g.,
    - All our surgeries start at 6am because that's how we've always done it.
    - Our oncology clinic opens from 8am-5pm, even though we've never really analyzed why.

How do you Identify the Right Use Cases?

- On-going complex planning processes that are treated **sequentially** today or, even worse, that are made in **isolation**.
- Examples include:
  - Sales & operations planning, where decisions about sales/marketing, manufacturing, procurement, distribution and finance are made sequentially using different tools and/or spreadsheet models (Note: S&OP processes exist in almost every industry)
  - Decisions driven by silo thinking — tactical and strategic decisions involving resources, product/service mix, marketing, etc. — that are made solely within the function



How do you Identify the Right Use Cases?

- Highly **dynamic** situations where **input/product prices** change constantly, regulations evolve, etc. – these situations require dynamic optimization analyses
- Examples include:
  - Commodities industries
  - The U.S. healthcare industry
  - Chemicals
  - Oil & gas
  - Some finance products, etc.

How do you Identify the Right Use Cases?

- High difference in **average vs. marginal** decision making. When there are multiple constraints, volume contracts and output price differentials, very often there can be up to 100% difference in average vs. marginal profitability for the same products

- **Underserved** markets/industries – markets where the problems are relatively complex, but where practitioners over-rely on BI and Excel tools to make decisions.
- Examples include:
  - Some government services,
  - Some US healthcare providers, etc.

Prescriptive Analytics: Examples

Venture Capital: Investment Decisions

- Harvard Business Review tested the effectiveness of an algorithm's decisions about which startups to invest in as compared to angel investors' decisions.
- The algorithm outperformed angel investors who were less experienced at investing and less skilled at controlling their cognitive biases.
- However, angel investors outperformed the algorithm when they were experienced in investing and able to control their cognitive biases.
- This experiment sheds light on the complementary role prescriptive analytics must play in making decisions and its potential to aid decision-making when experience isn't present and cognitive biases need flagging.
- An algorithm is only as unbiased as the data it's trained with, so human judgment is required whether using an algorithm or not.

Prescriptive Analytics: Examples

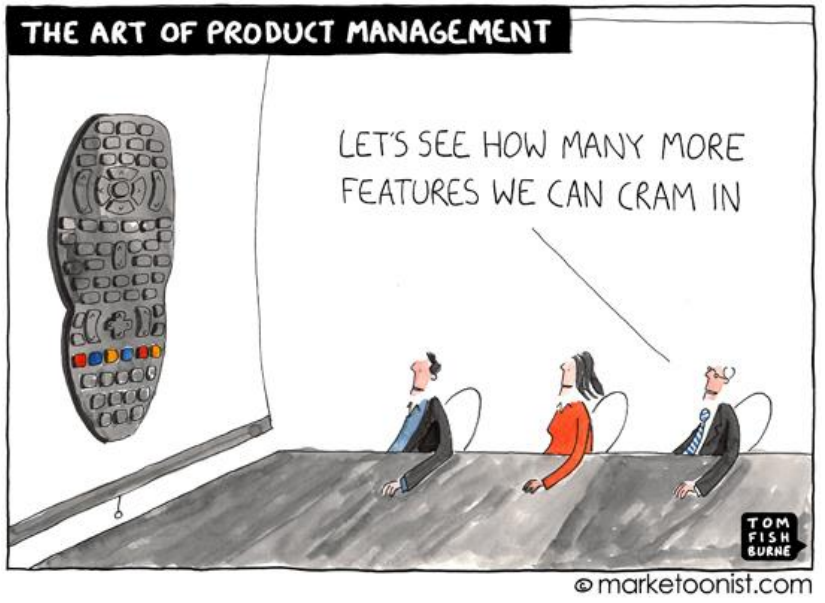
Banking: Fraud Detection

- Another algorithmic use of prescriptive analytics is the detection and flagging of bank fraud.
- With the sheer volume of data stored in a bank's system, it would be nearly impossible for a person to manually detect any suspicious activity in a single account.
- An algorithm—trained using customers' historical transaction data—analyzes and scans new transactional data for anomalies.
- For instance, perhaps you typically spend $3,000 per month, but this month, there's a $30,000 charge on your credit card.
- The algorithm analyzes patterns in your transactional data, alerts the bank, and provides a recommended course of action.
- In this example, the course of action may be to cancel the credit card, as it could have been stolen.

Prescriptive Analytics: Examples

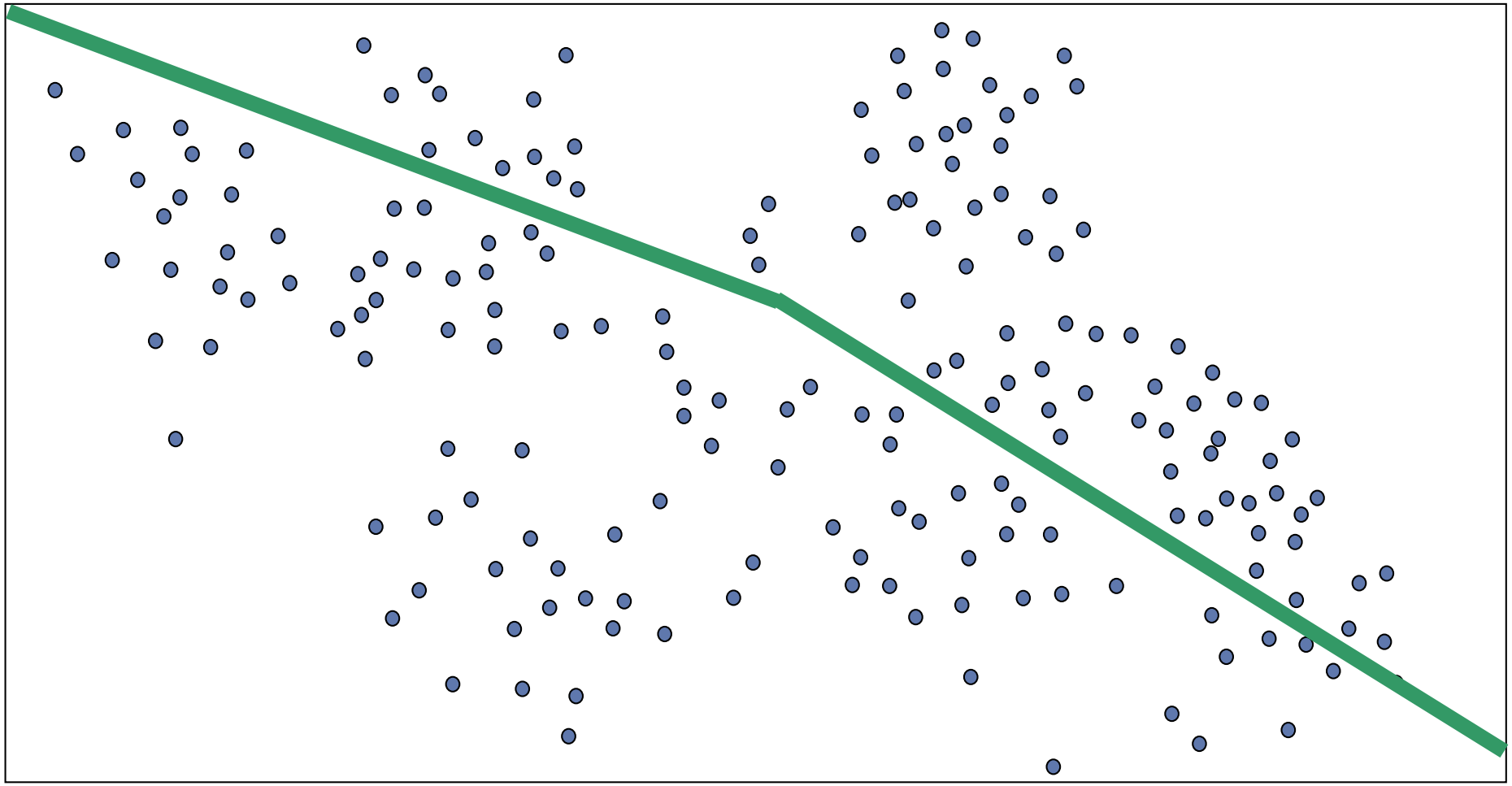
Product Management: Development and Improvement

- Prescriptive analytics can also inform product development and improvements.
- Product managers can gather user data by surveying customers, running tests with a product's beta versions, conducting market research with people who aren't current product users, and collecting behavioral data as current users interact.
- All this data can be analyzed—either manually or algorithmically—to identify trends, discover the reasons for those trends, and predict whether the trends are predicted to recur.
- Prescriptive analytics can help determine which features to include or leave out of a product and what needs to change to ensure an optimal user experience.



Prescriptive Analytics: Constraint-Based Cluster Analytics

ATM allocation problem: obstacle & desired clusters



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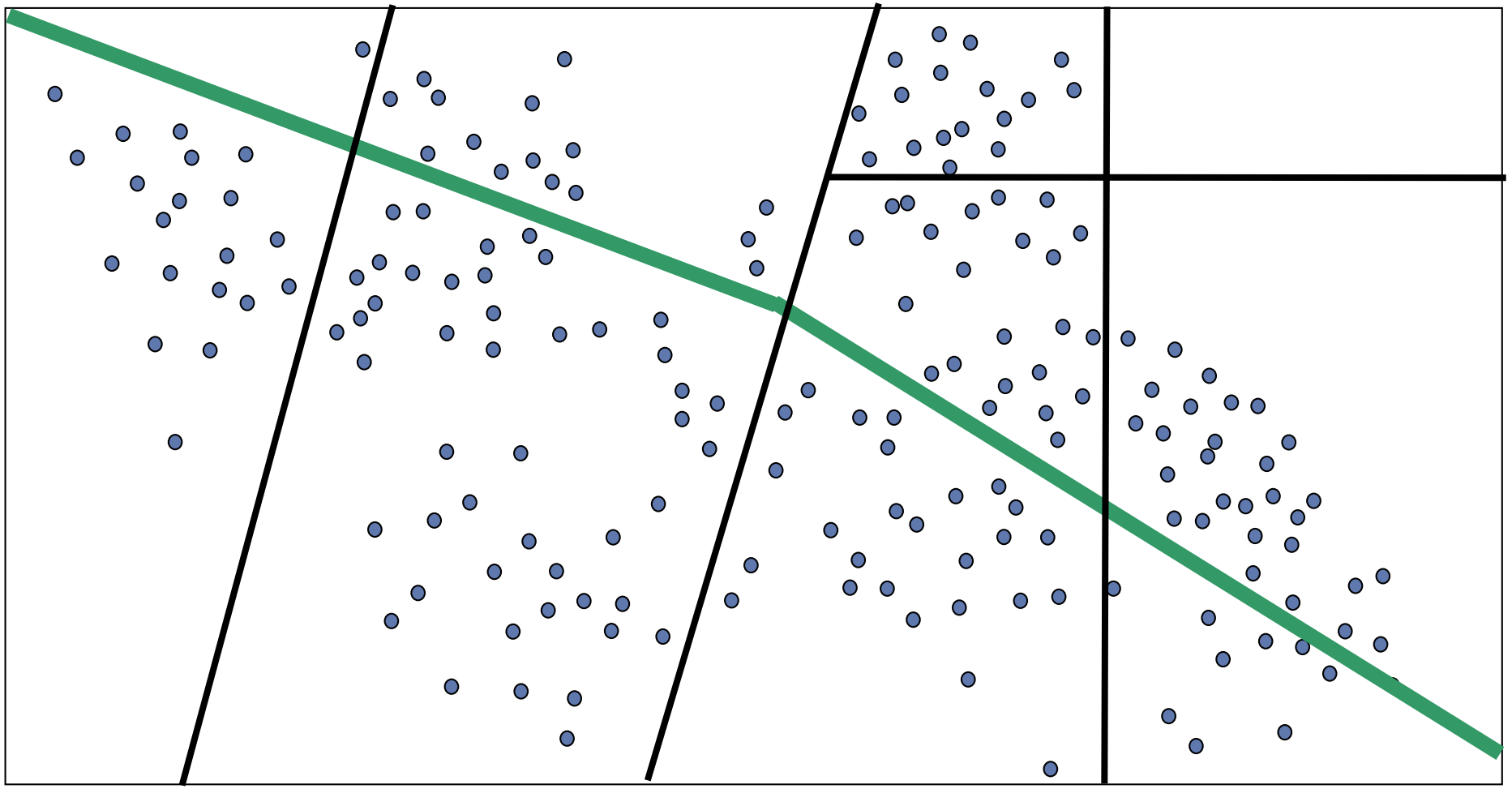

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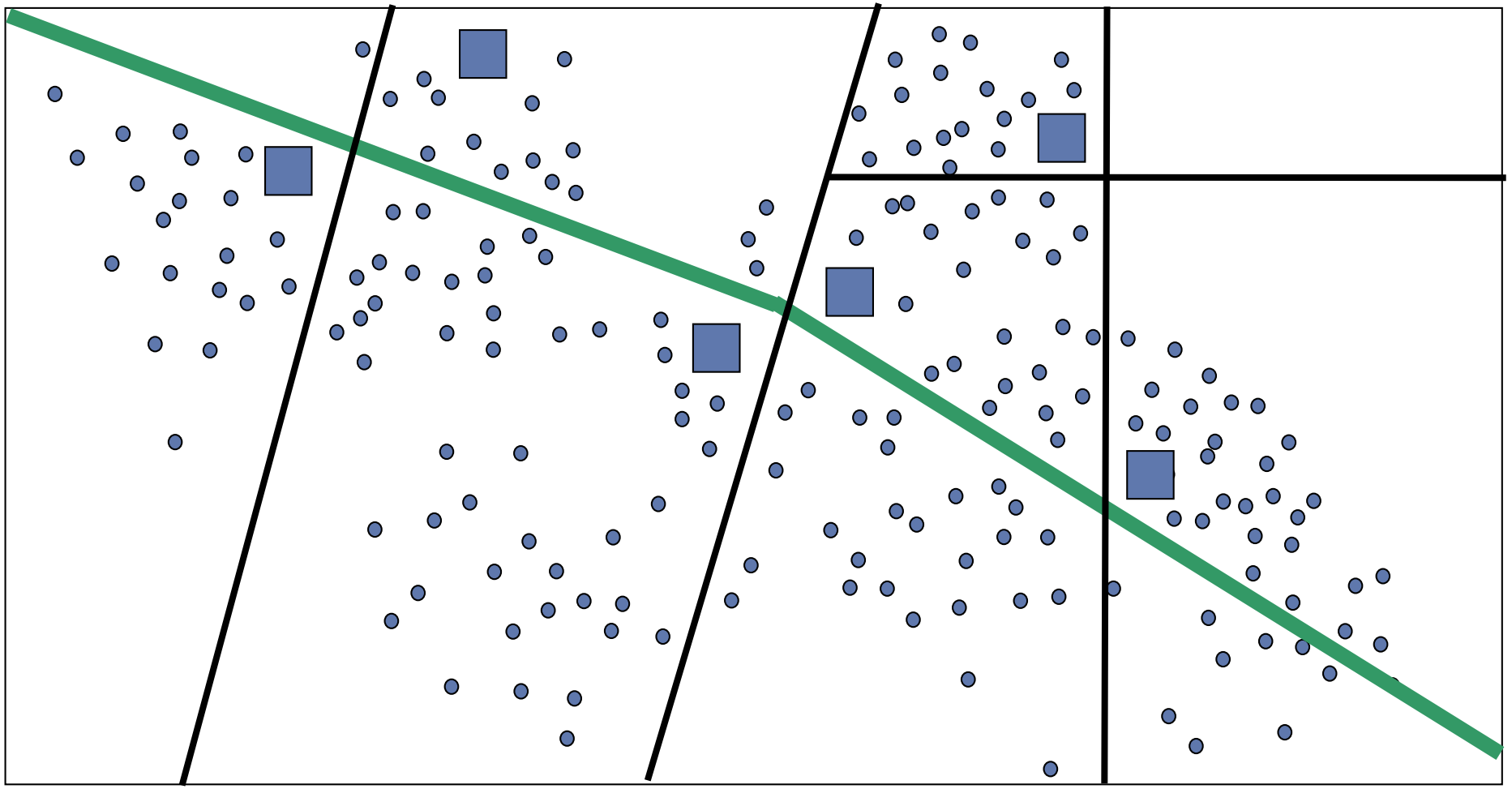
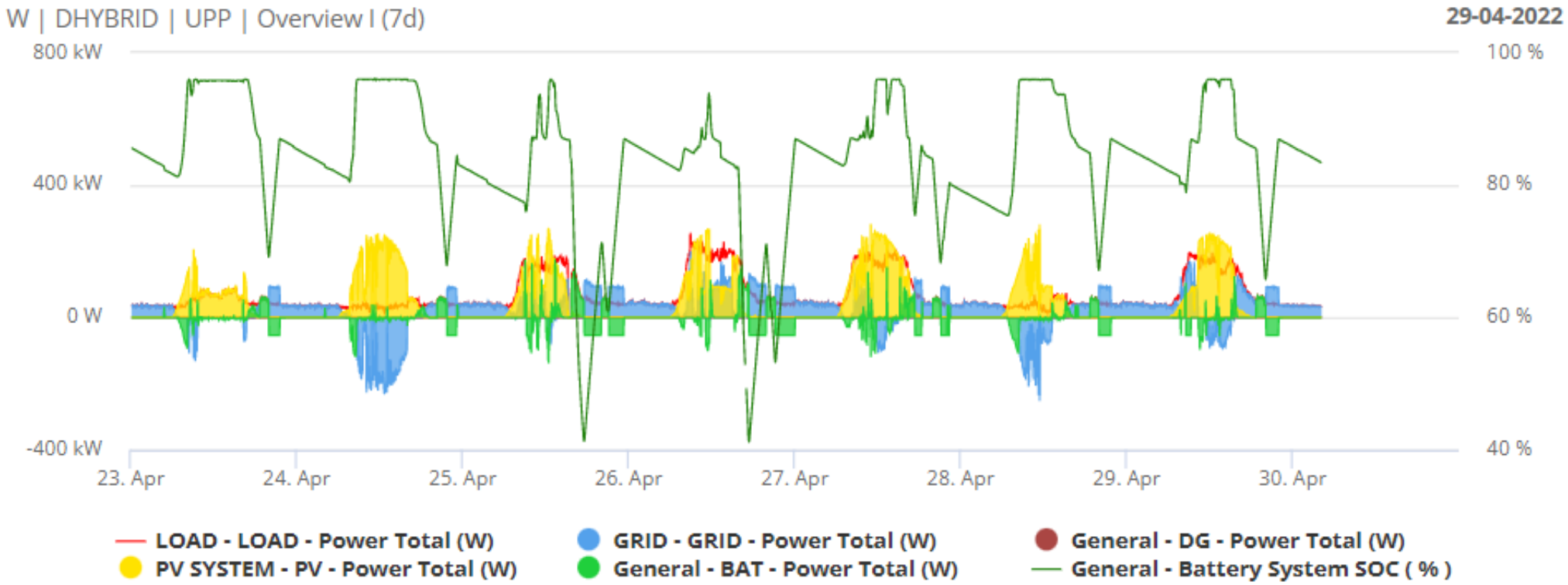


Prescriptive Analytics: Energy Mix

When should you charge/not charge the Grid?



Source: LECO/DIMO/UoM Grid

References

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- What Is Prescriptive Analytics? Your 5-Minute Overview by Shannon Kearns
- Word Power | Prometheus and Epimetheus by Danny Ballan
- What is Prescriptive Analytics? by talend
- Do Algorithms Make Better — and Fairer — Investments Than Angel Investors? by Torben Antretter, Ivo Blohm, Charlotta Siren, Dietmar Grichnik, Malin Malmstrom, and Joakim Wincent
- What Is Prescriptive Analytics? 6 Examples by Catherine Cote
- Prescriptive Analytics by Eileen Robinson