Towards the autonomous machine learning fueled supply chain

2020-06-26

Malte Tichy, Sr Data Science Consultant @ Blue Yonder

MCnet machine learning school

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Who is Blue Yonder?

A Neural Bayesian Estimator for Conditional Probability Densities

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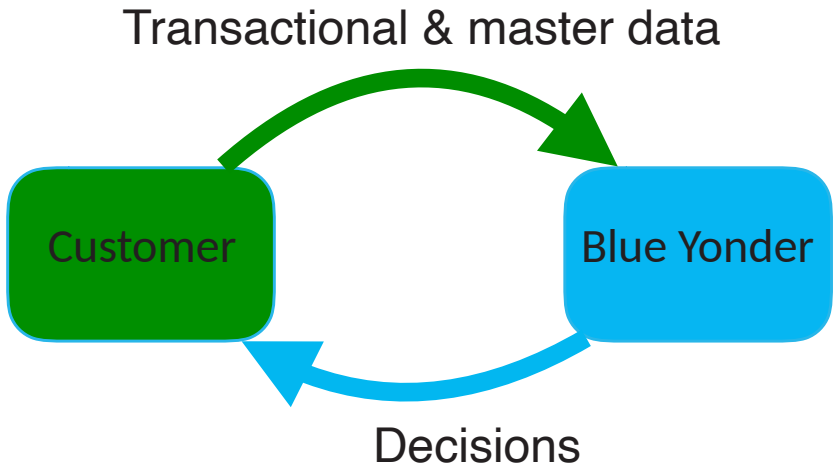

2002
<phi-t> physics information technology, Karlsruhe

2007
Joint venture with Otto group, office in Hamburg

2011
Re-naming

2014
Warburg Pincus invest
Focus on retail
Office in UK/US

2018
Acquisition by jda. software

2020
Rebranding

blueyonder

"Forward looking, forward thinking"

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jda.
Plan to deliver™

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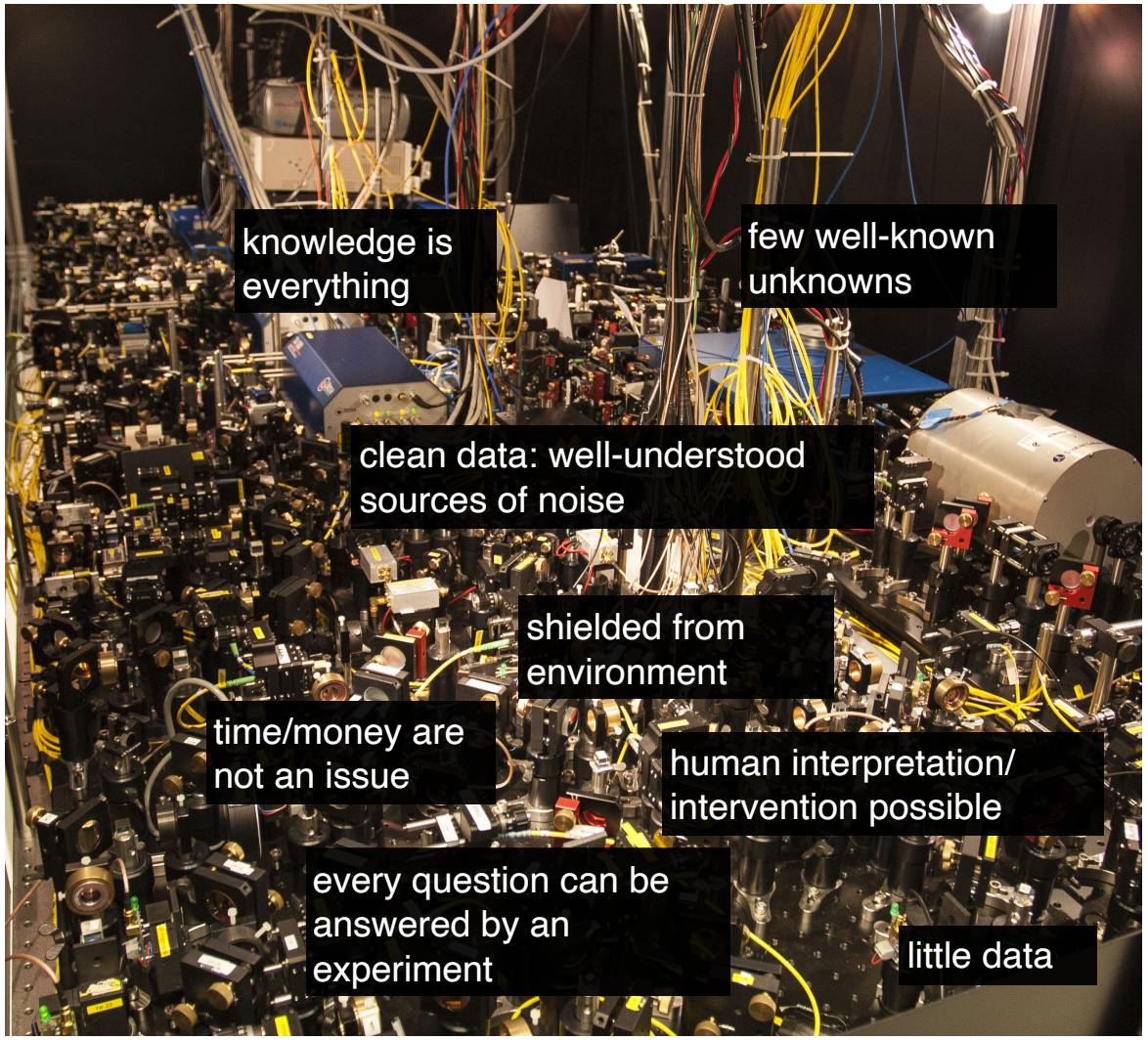
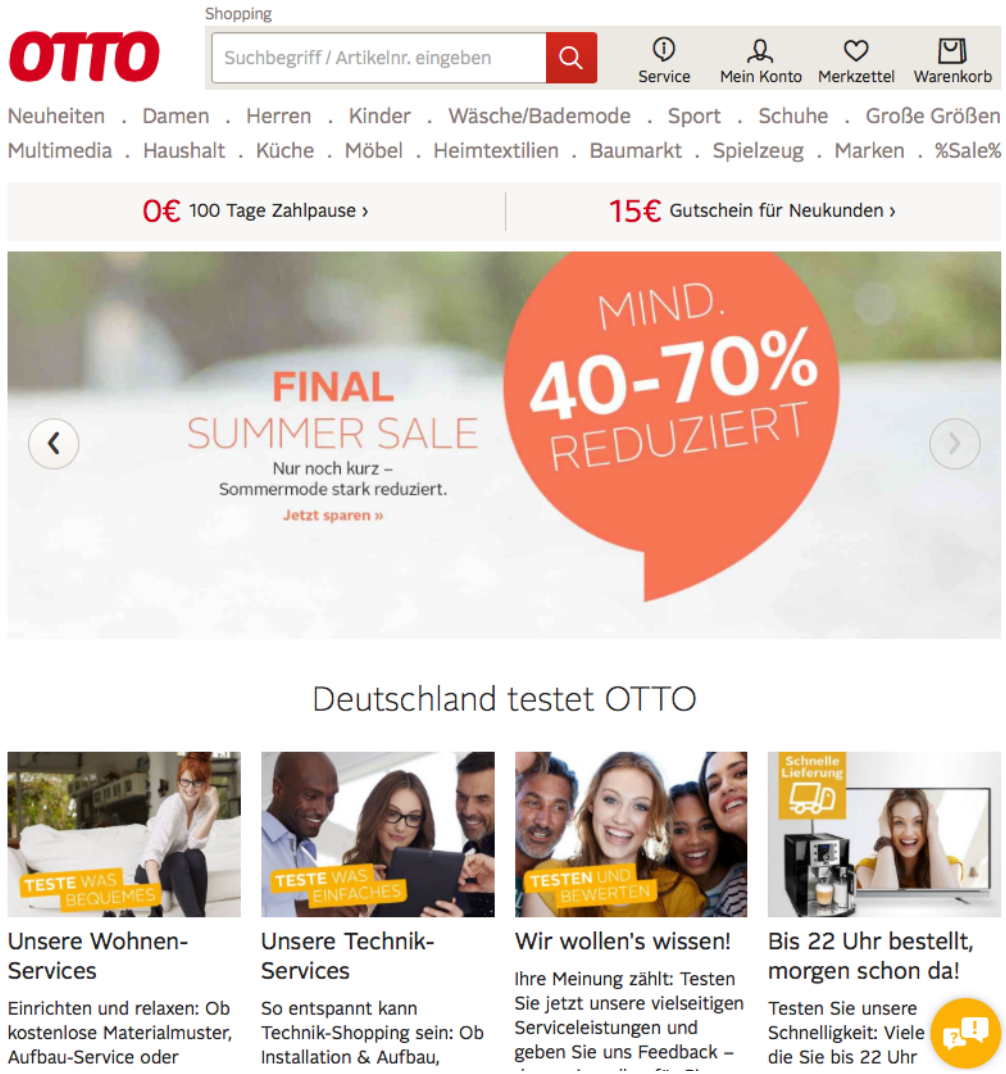
From the ivory-tower lab to the “real world”





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1) What is a good decision?

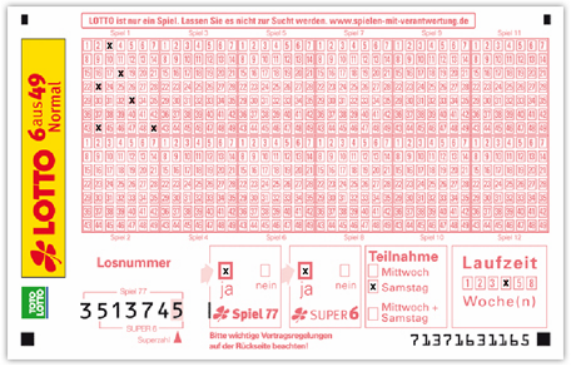
2) How do we ensure good decisions?

3) What's a good pricing decision?

4) What about customer returns?

5) What's happening now with COVID19?

Outcome bias in decision evaluation



€20'000'000

"A choice of action that has lead to a desirable outcome."

really bad definition!

we are subject to the outcome bias

we intuitively judge decisions by outcome, not by intention

Outcome bias in decision evaluation

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45 years old, heart problems, expectance(life)=55 years
Surgery?
P(deathlsurgery)=0.08, expectance(lifelpatient survives, surgery)=65 years
Decision: Let's do surgery!

End of story 1:
he dies -> "it was a bad decision"

End of story 2:
he survives -> "it was a good decision"

J. Baron, J. C. Hershey: Outcome bias in decision evaluation. *J Personality & Social Psych.*, ***54***, 569-579 (1988).

we are subject to the outcome bias
we intuitively judge decisions by outcome, not by intention

What is a good decision?

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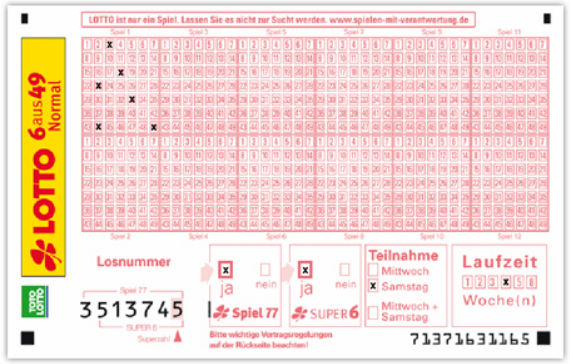
The judgement of a decision
- must only depend on information available **at the time the decision was made**
- in particular, it must be **independent of the outcome**

*Judge **how well the decision was taken**, not how lucky the decision-taker has been.*

F. Gino, What We Miss When We Judge a Decision by the Outcome, Harvard Business Review, https://hbr.org/2016/09/what-we-miss-when-we-judge-a-decision-by-the-outcome

What is a good decision? Values & facts



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How does the world behave? (objective)

What do we value? (subjective)

What is a good decision?

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An action that maximizes a well-defined (subjective) goal, accounting for the environment's (objective) behavior.

Good decision

the objective facts, our responsability (micro-decision)

A bad decision is based on an unrealistic, bad decision model or aims at the wrong reward.

the subjective values, customer responsability (macro-decision)

Reinforcement learning paradigm

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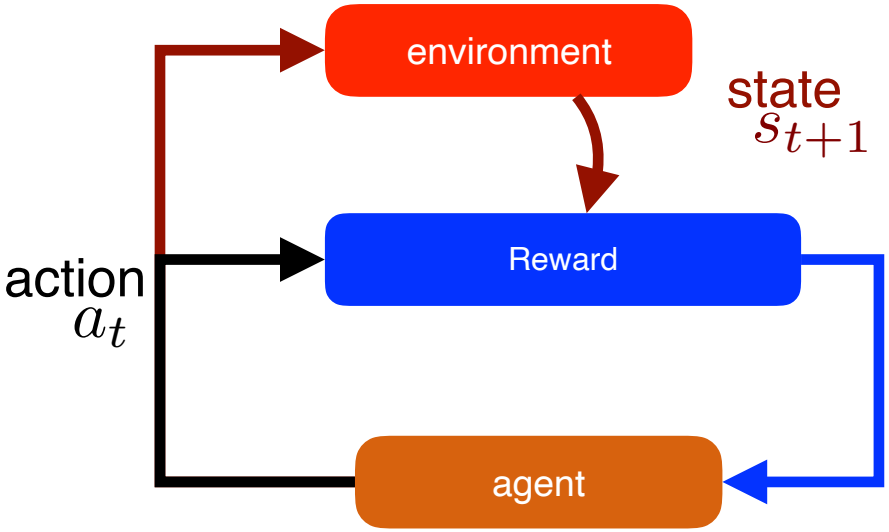
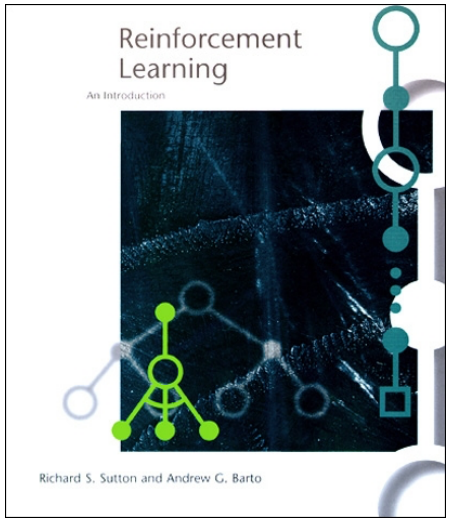
Good decision



$P(\text{state}|\text{action})$

"An agent chooses a policy of actions in an environment and receives a reward."



www.incompleteideas.net

Decisions in practice

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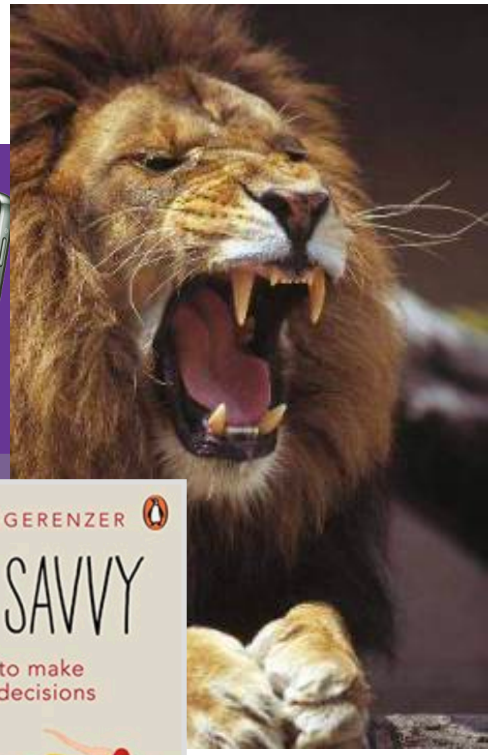
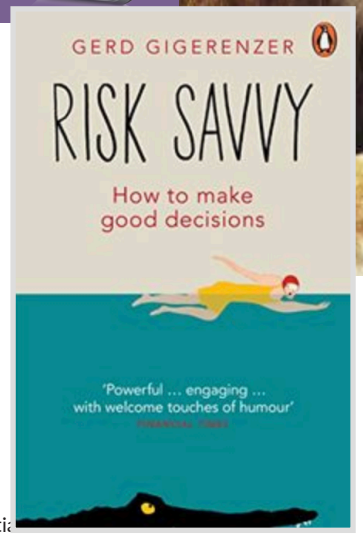
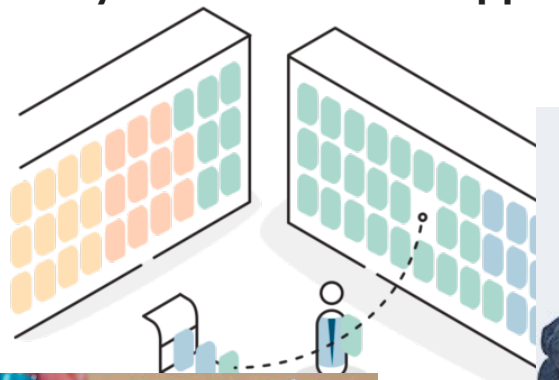
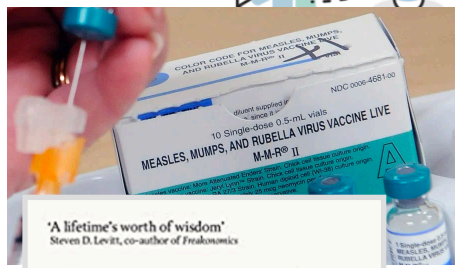
Little data or unclear "objective function"
Analytical data-driven approach unfeasible
-> Use Heuristics

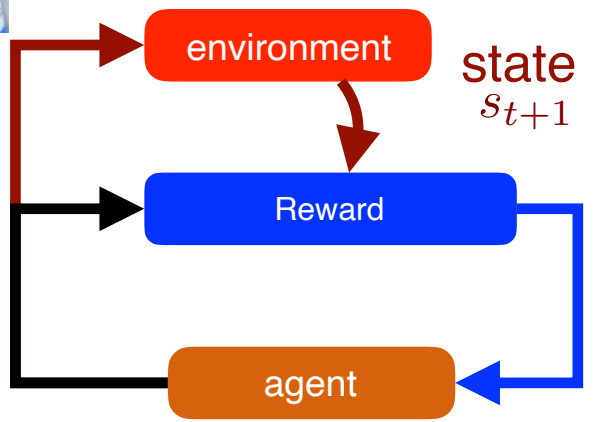




Analytical data-driven approach beats heuristics







$P(\text{state}|\text{action})$

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Modularization of decision-making

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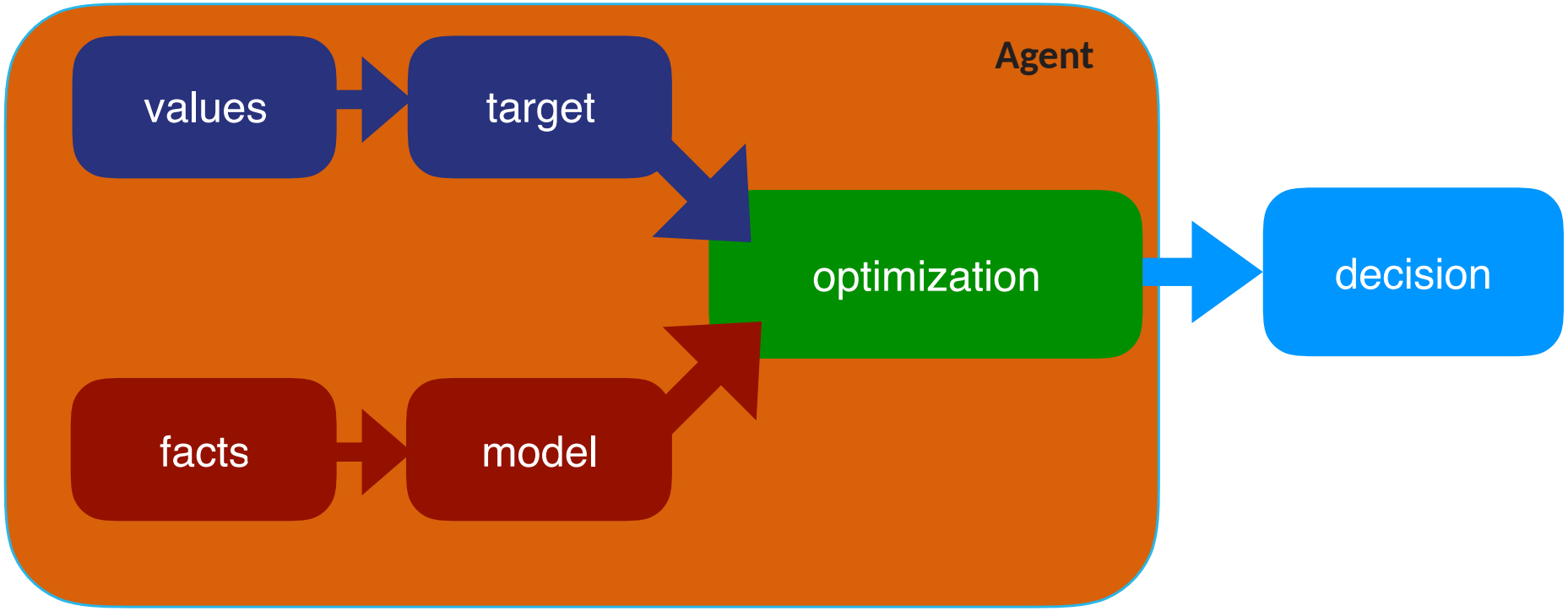
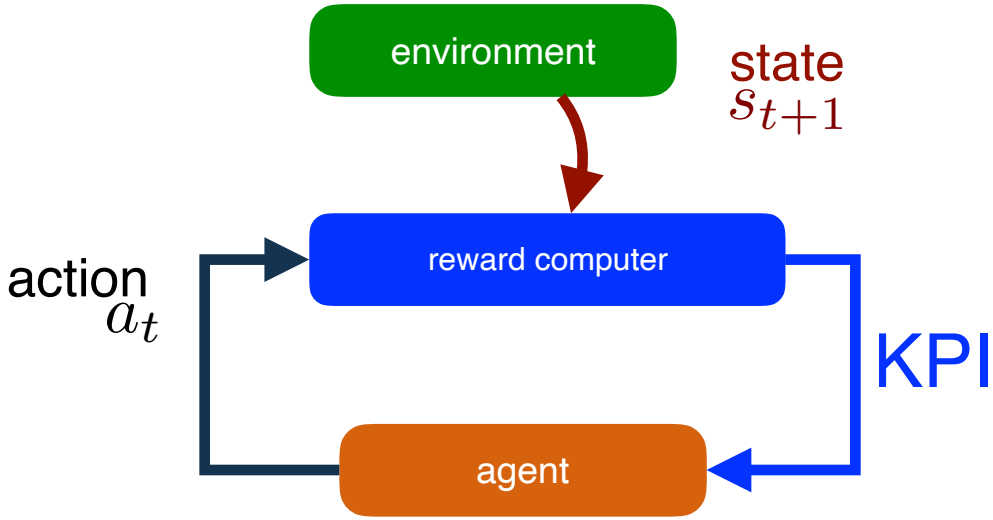


Decisions in action-independent environments

- Low-volume trading
- Gambling against the bank: Lottery, roulette
- KPI depends on e.g. weather



$$\mathrm{KPI} = \mathrm{KPI}(\mathrm{state}, \mathrm{action})$$

$$P(\mathrm{state})$$

Decision validation ~ prediction model validation

Decisions in action-dependent environments

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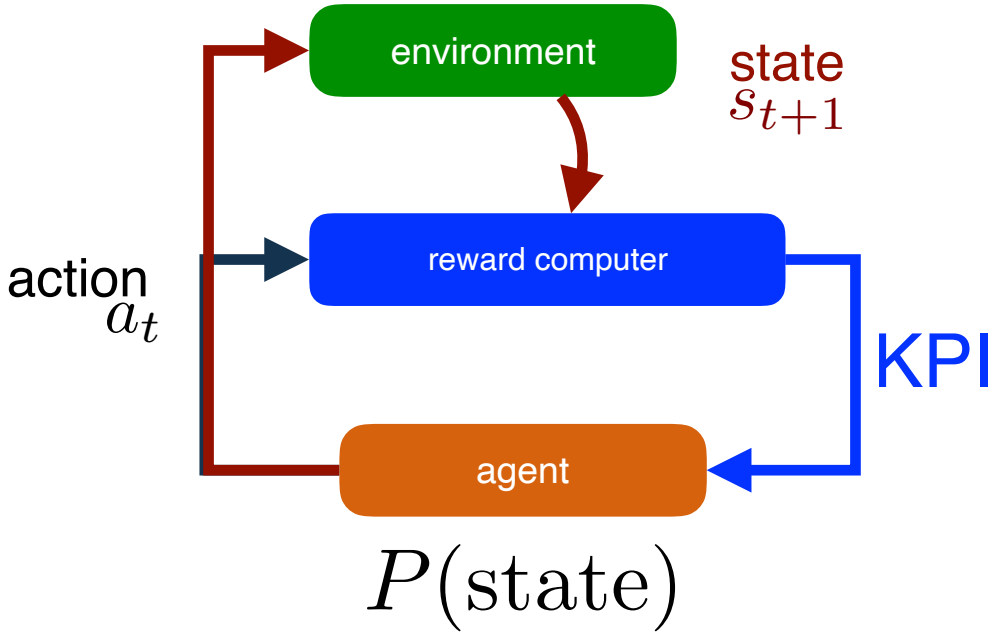
- High-volume trading
- Playing against an opponent: Poker, Chess
- State depends on our decision, e.g. climate
- Replenishment [demand depends on stock level]
- Pricing [demand depends on price]

$$\mathrm{KPI} = \mathrm{KPI}(\mathrm{state}(\mathrm{action}), \mathrm{action})$$



Evaluating decision-making

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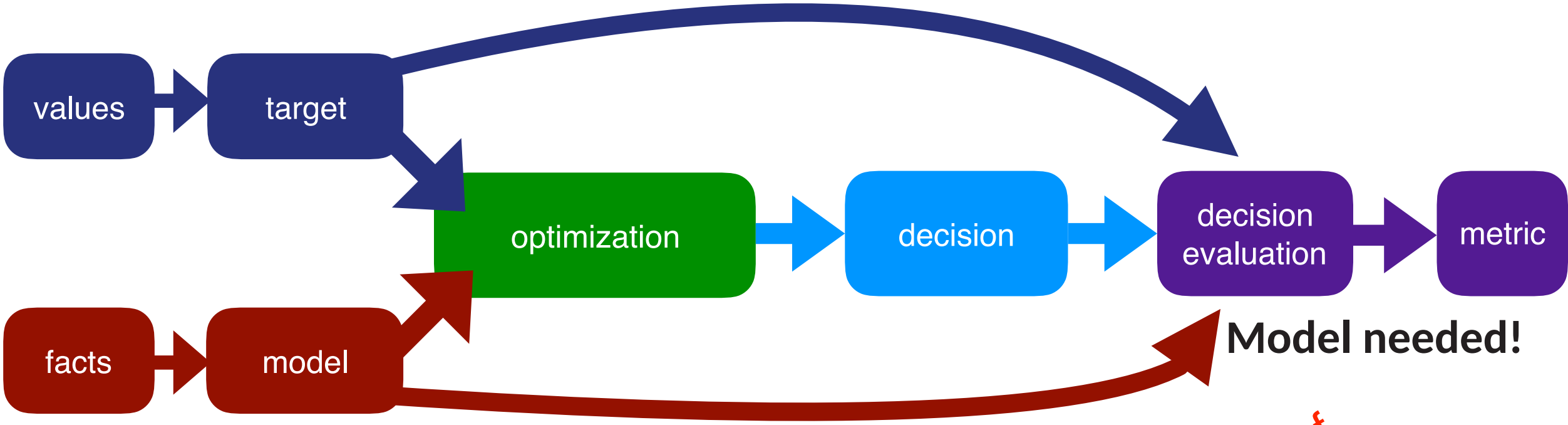

conflict of interests! "a student grades himself"

Decision-making cross validation

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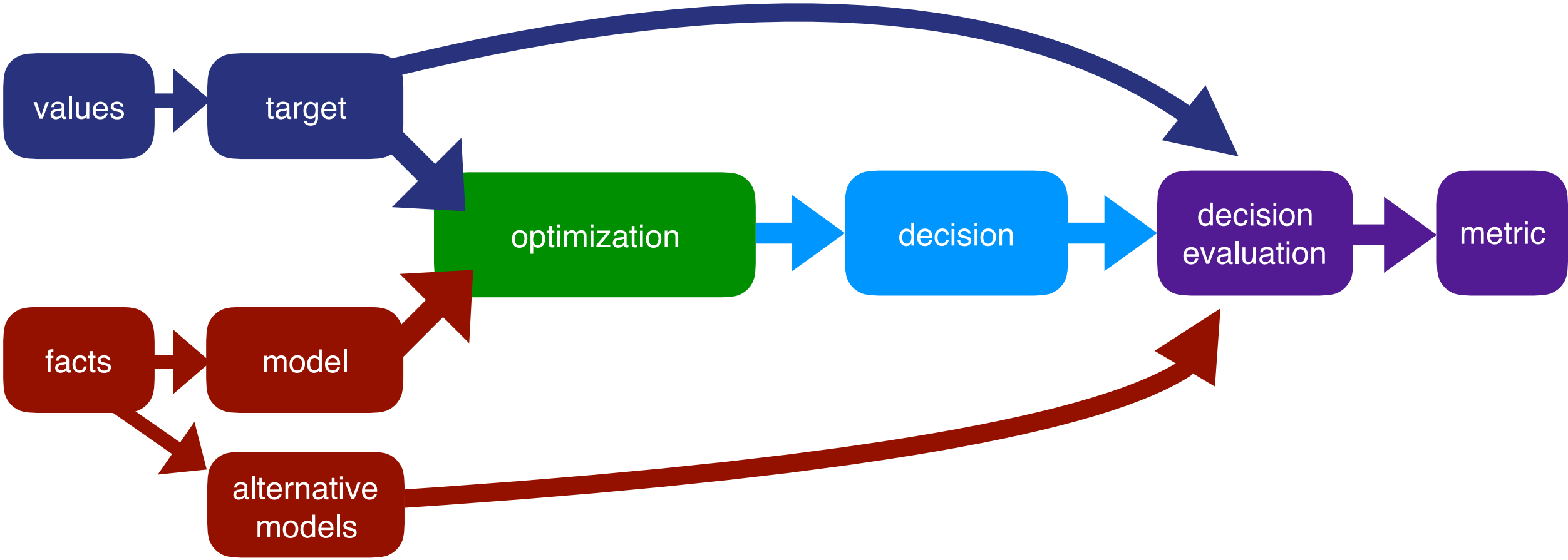

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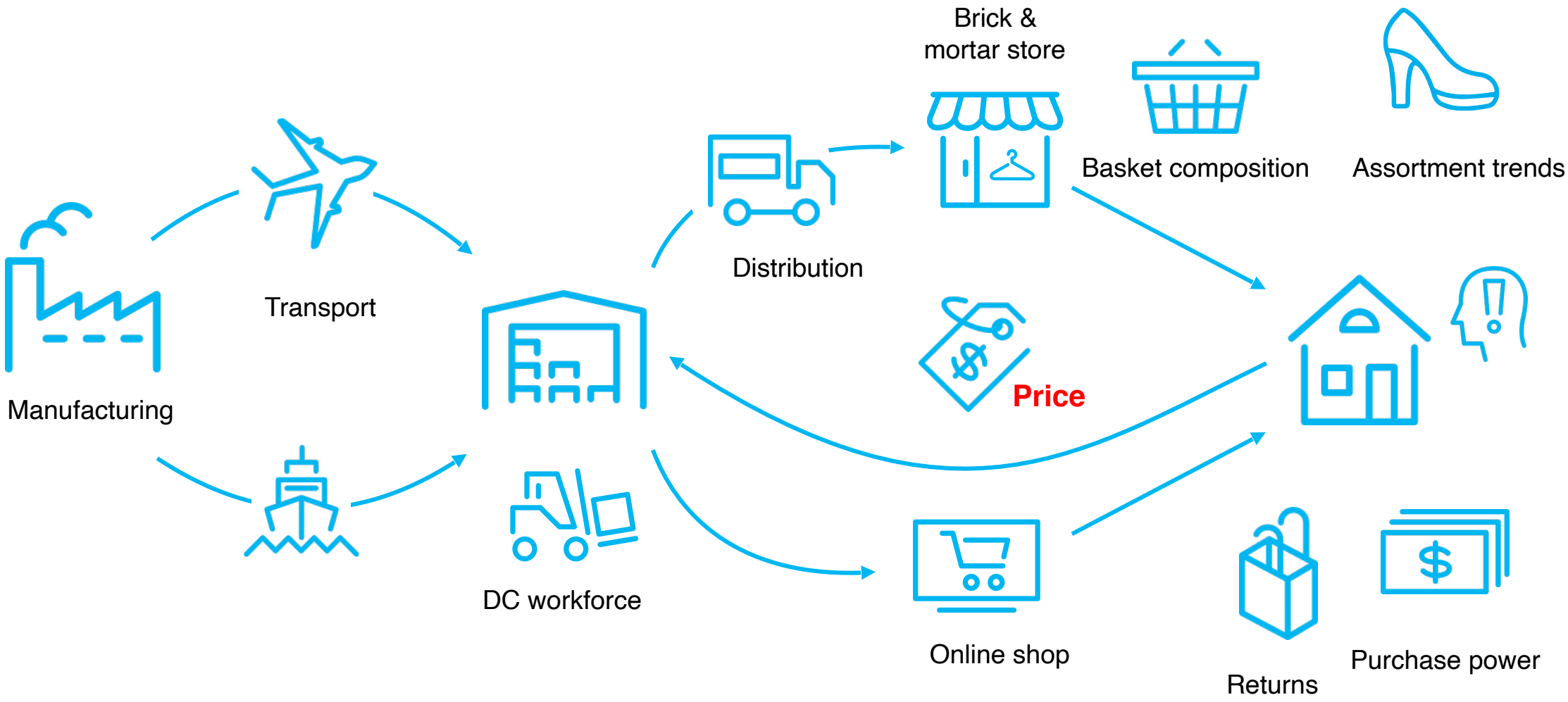
Let’s have a break!

The price in the supply chain



Markdown pricing

Price reductions in fashion retail towards the end of season in order to:

- maximize sell through rate (sold items / initial stocks)
- maximize profit
- respect price constraints
- respect boundary conditions

Markdown pricing: Classical approach

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Price reductions in fashion retail towards the end of season in order to:
- maximize sell through rate (sold items / initial stocks)
- maximize profit
- respect price constraints
- respect boundary conditions

Implicitly contained & entangled:

- Boundary conditions (Rules)
- Business goal
- Absolute sales model
- Price-sales-model
- Optimization

Heuristic solution:

	10 weeks left	8 weeks left	6 weeks left	4 weeks left
<30% sell through rate	-20 %	-30 %	-40 %	-50 %
<40% sell through rate			-30 %	-40 %
<50% sell through rate			-20 %	-30 %
>50% sell through rate				

Modularized approach to markdown pricing

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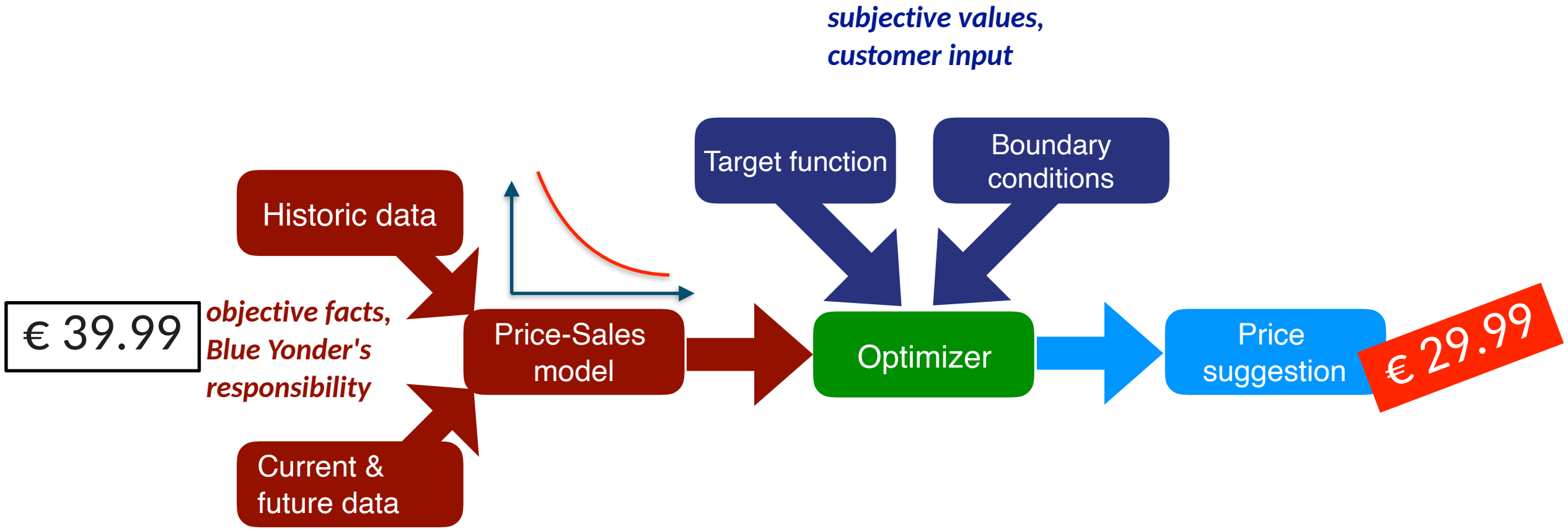
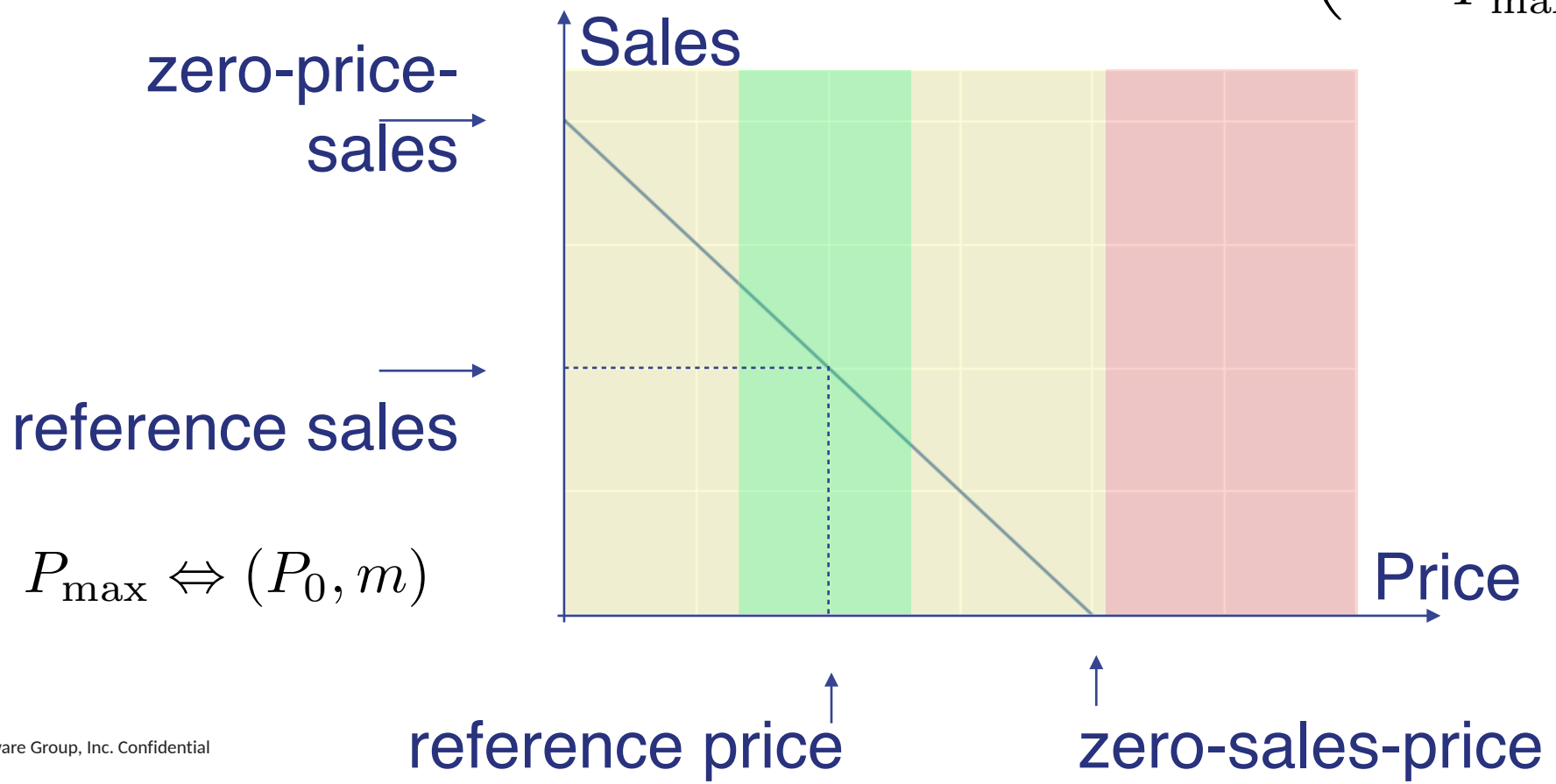


Price-sales relation

- Depending on context: exponential, power-law
- This talk: intuition + illustration > precision

$$S(P) = S_{\max}\left(1 - \frac{P}{P_{\max}}\right)$$



Good, better and optimal prices

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Sales $S(P) = S_0 \left(1 + m\frac{P - P_0}{P_0}\right)$

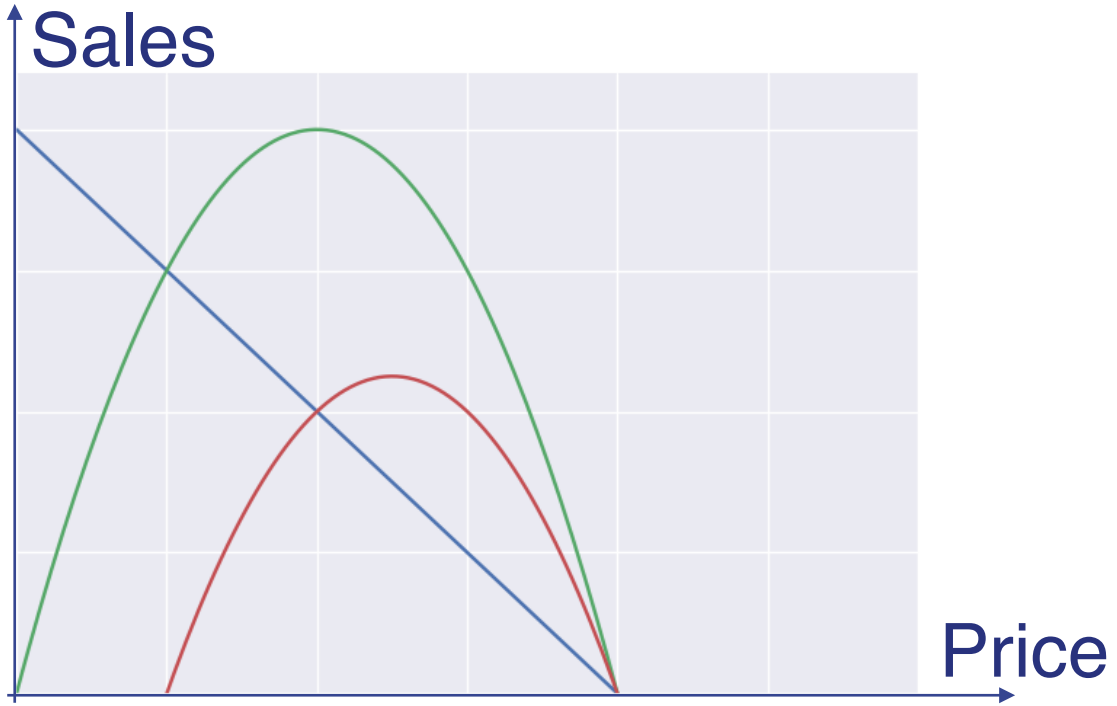
Revenue $R(P) = PS(P)$

Profit $M(P) = (P - C)S(P)$

$$P^* = \frac{1}{2}C + \frac{1}{2}\left(1 - \frac{1}{m}\right)P_0$$

Costs

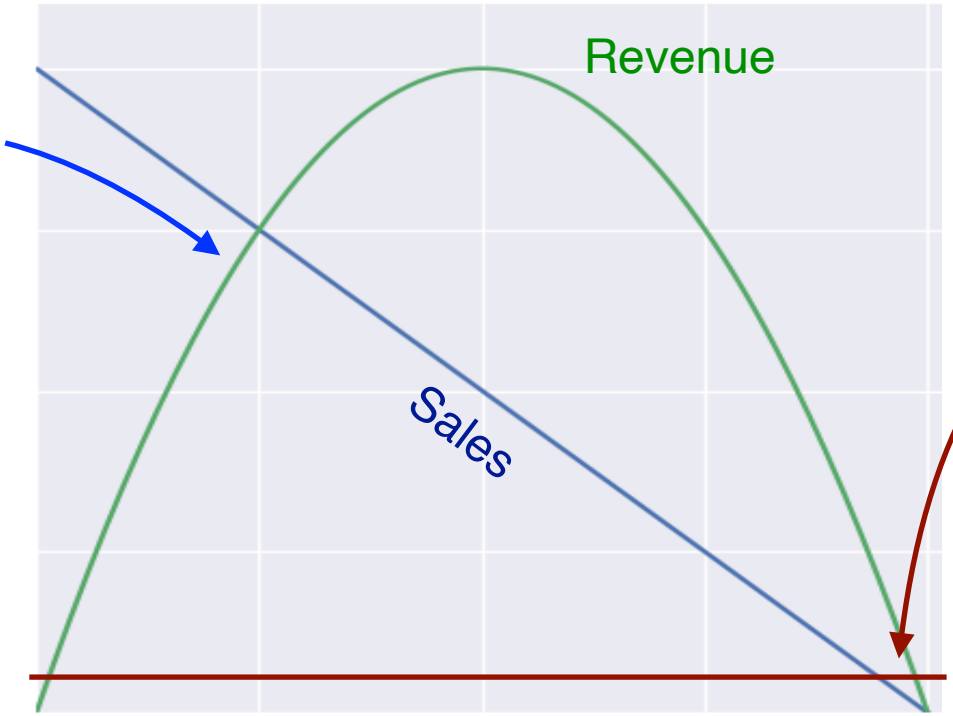
Elasticity



What about stocks?

Stocks don't matter at all ⟷ Stocks are all that matter

- **Video streaming:**
- Unlimited "stocks", infinitely scaleable, no scarcity
- Low marginal costs (?)
- Maximize profit/revenue/ market share…

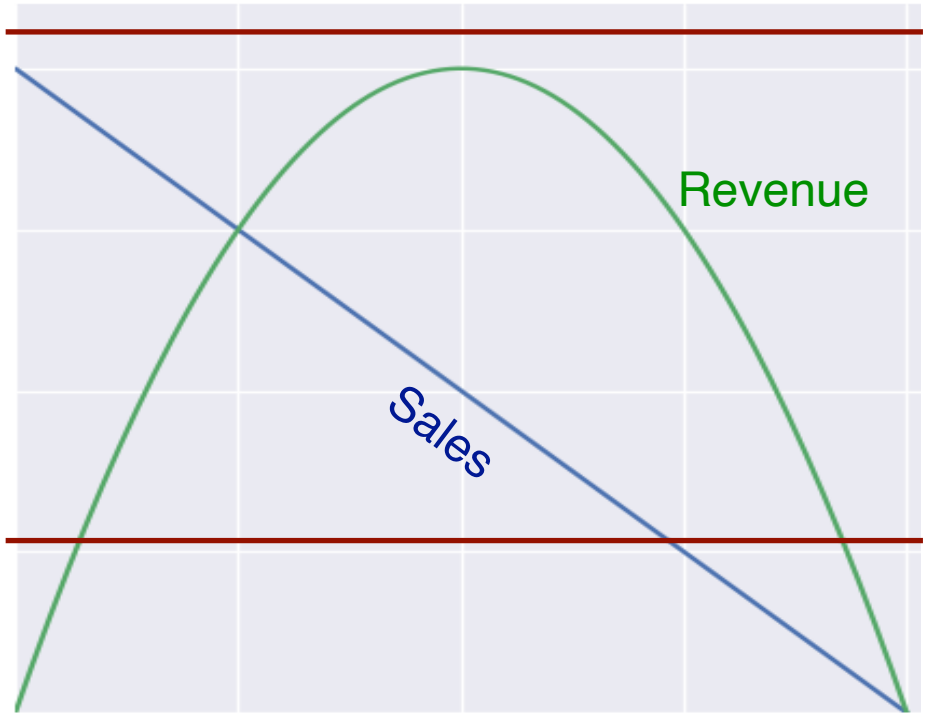


- **Real estate:**
- Very limited "stocks"
- Price points certainly not revenue-optimal
- Can sell a flat/house only once, to the highest bidder

What about stocks?

Stocks don't matter at all ⟷ Stocks are all that matter

Stock level of major flop



Stock level of surprise best seller

Increase price, obtain sub-optimal profit/revenue due to scarcity

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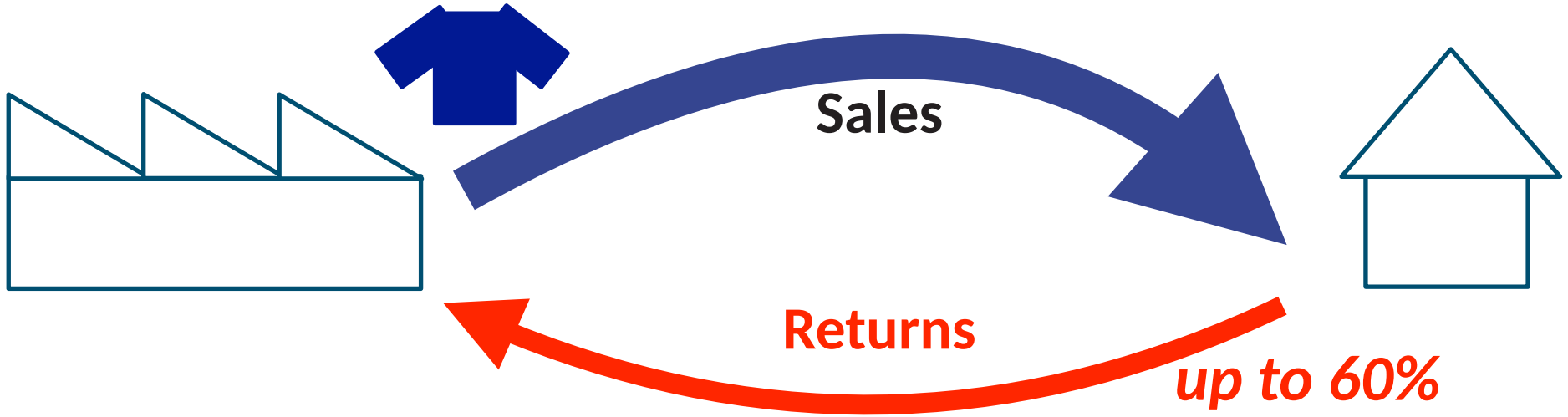
Impact of returns

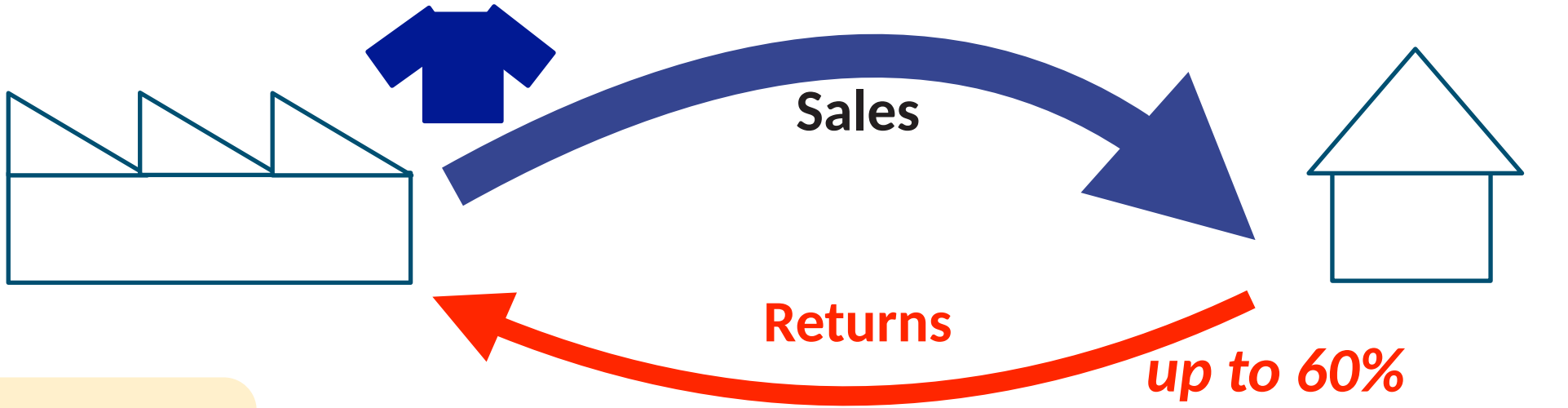


Return expenses threaten profitability

Returns lead to over- and underestimated availability

➡Pricing (and any other solution..) needs to account for returns

Impact of returns



1) Impact of returns on profitability

Objective function

Rules, processes

2) Account for returns in available stocks

3) Impact of price, basket size, size, day of the week... on return probability

Models

Optimization

Pricing decision

The most important and most underestimated jeopardy to profit in online retail

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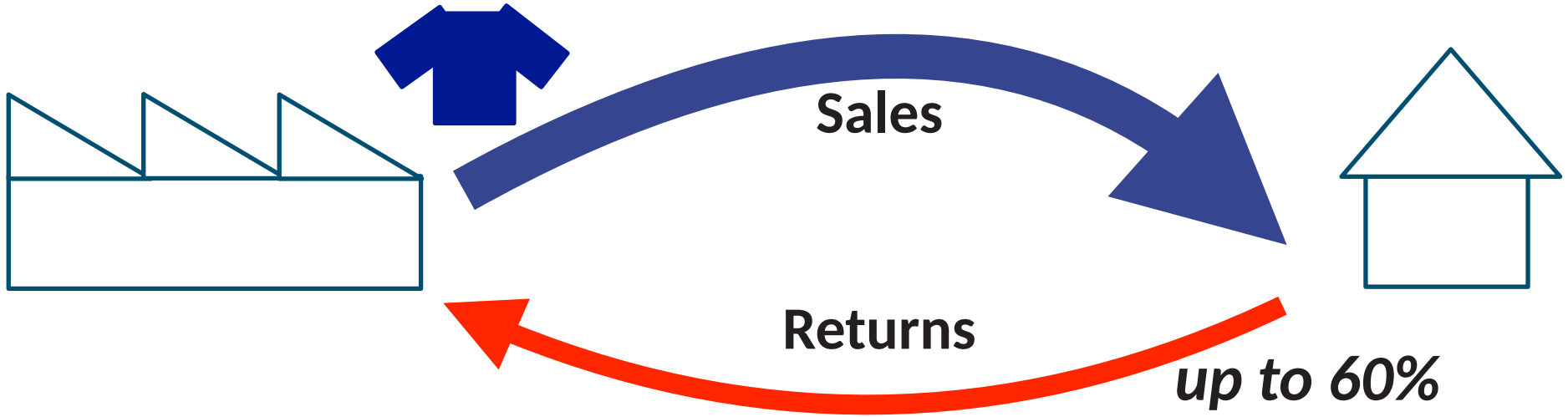


Profit = How much x How profitable

= Volume x Margin

$$= \text{Sales}(\text{SellingPrice}) \left(\left(\frac{\text{SellingPrice}}{1 + \text{VAT}} - \text{PurchasePrice} \right) (1 - \text{ReturnR}) - \text{cost}_{\text{ship}} - \text{ReturnR} \cdot \text{cost}_{\text{return}} \right)$$

Break-even to profitability:

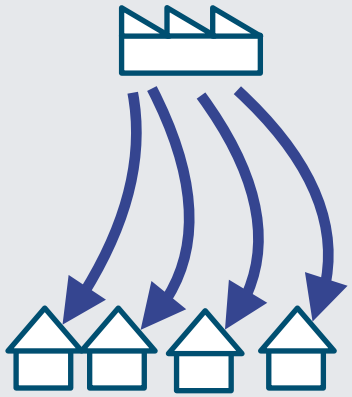
$$\text{effective costs} = (1 + \text{VAT}) \cdot \left(\text{PurchasePrice} + \frac{\text{costs}_{\text{shipping}} + \text{ReturnRate} \cdot \text{costs}_{\text{return}}}{1 - \text{ReturnRate}} \right)$$

non-linearity!

Impact of return rate on profit

$$\text{effective costs} = (1 + \text{VAT}) \cdot \left(\text{PurchasePrice} + \frac{\text{costs}_{\text{shipping}} + \text{ReturnRate} \cdot \text{costs}_{\text{return}}}{1 - \text{ReturnRate}} \right)$$

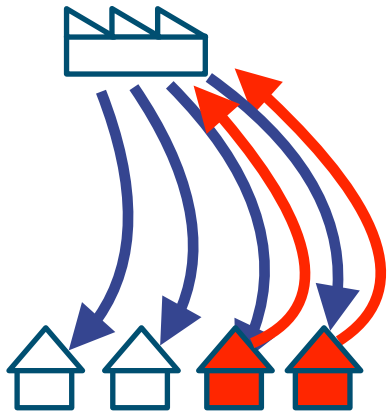
Example with selling price 29.99 €

Return rate	0 %
Effective costs	8,69 €
	

Cost-based approach

Traditional cost-based heuristics: $P^* = P^*_{\text{revenue}} + \frac{1}{2}\text{effective cost}$

Effect on situation with returns:

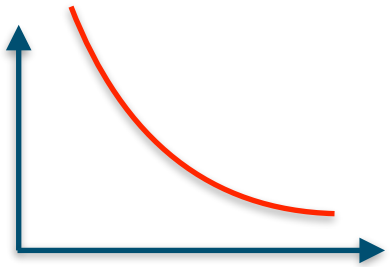


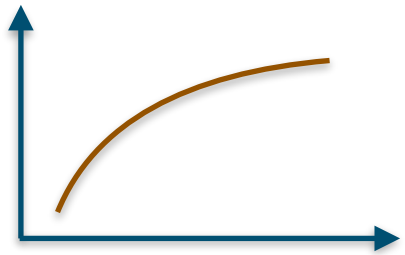
High returns → Low profitability → Increase price → High returns

Cost-based approach leads to vicious circle!

Price-return-relation

Price-Sales model



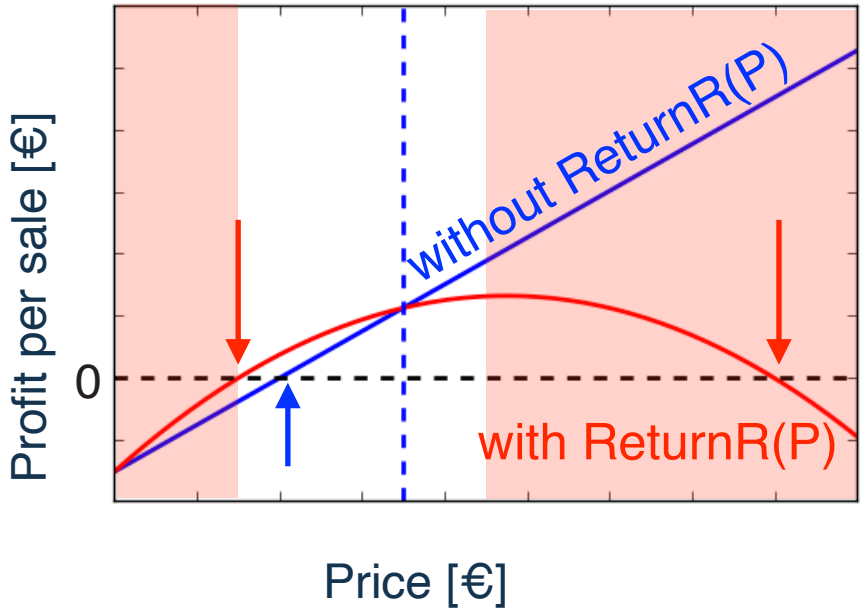


Price-Return model

$$\text{Sales}(\text{Price})\left(\left(\frac{\text{Price}}{1+\text{VAT}}-\text{PurchasePr}\right)(1-\text{ReturnR}(\text{Price}))-\text{cost}_{\text{ship}}-\text{ReturnR}(\text{Price})\cdot\text{cost}_{\text{return}}\right)$$

including price-return-effect yields:

- lower effective costs
- increasing price can lower profitability



Architecture for return-conscious pricing

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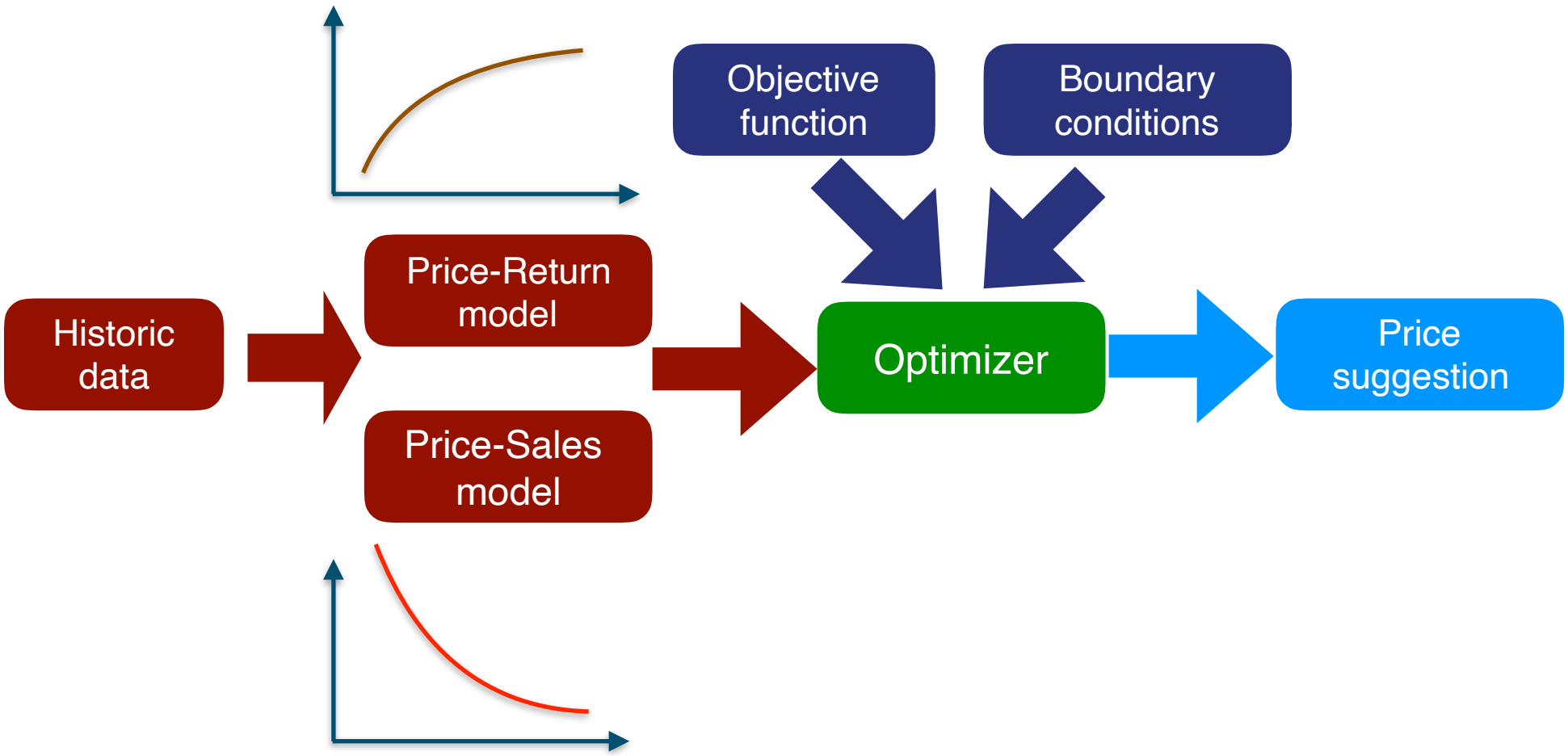
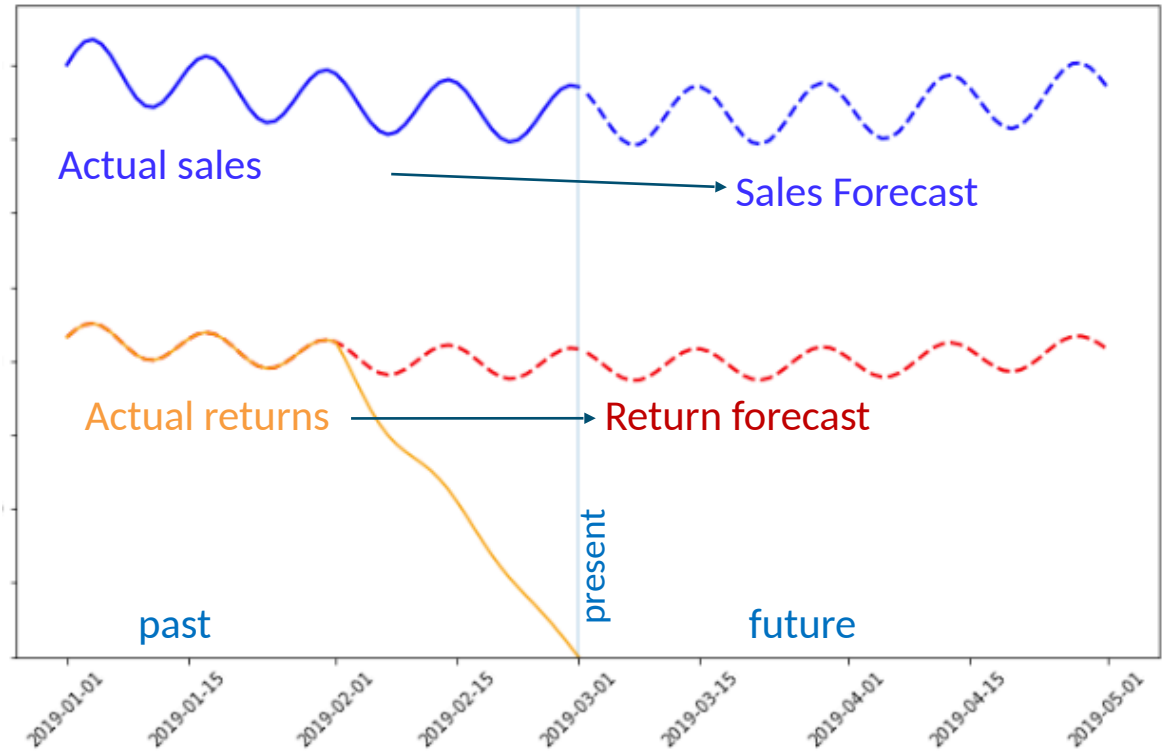


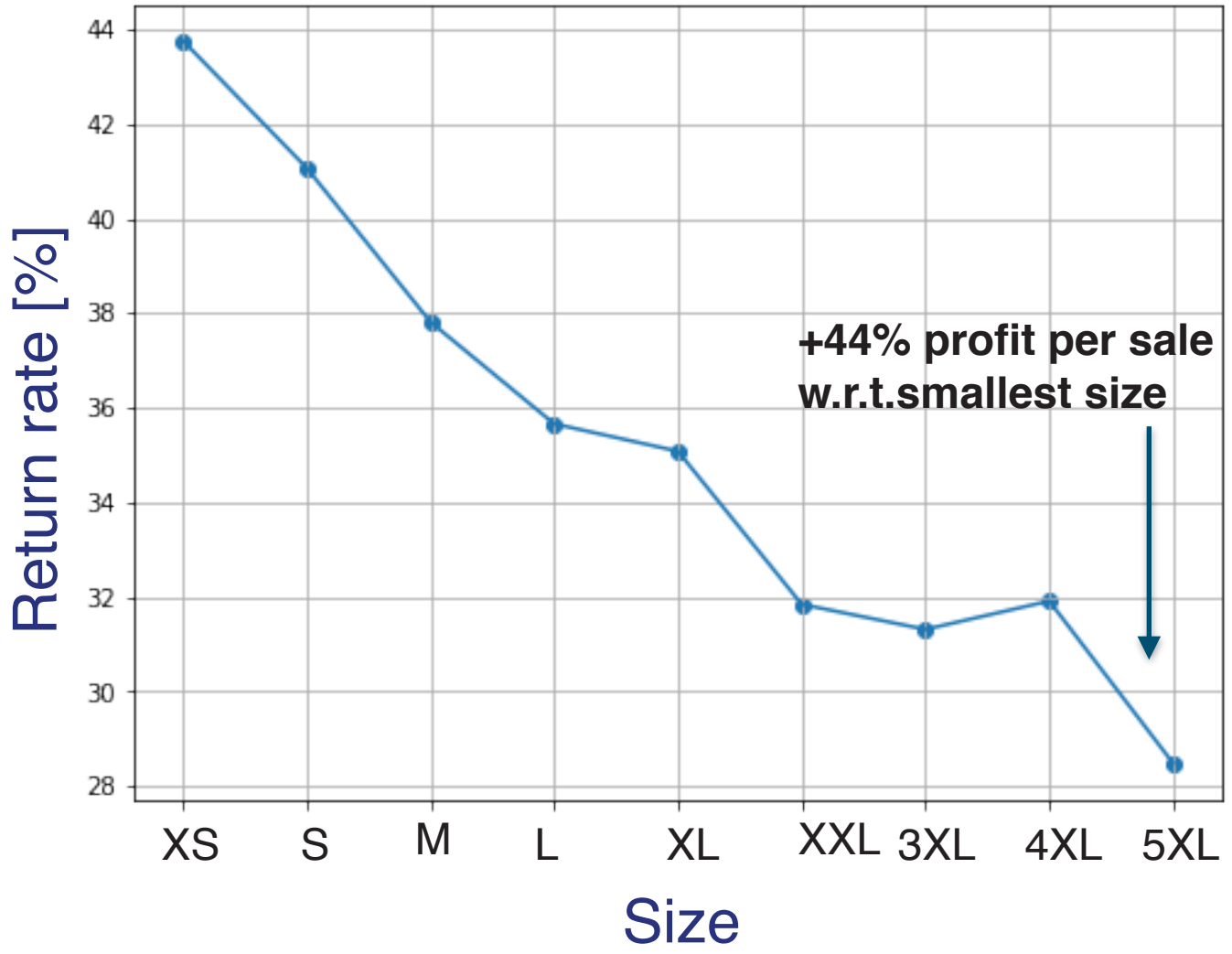
Returns and stocks availability

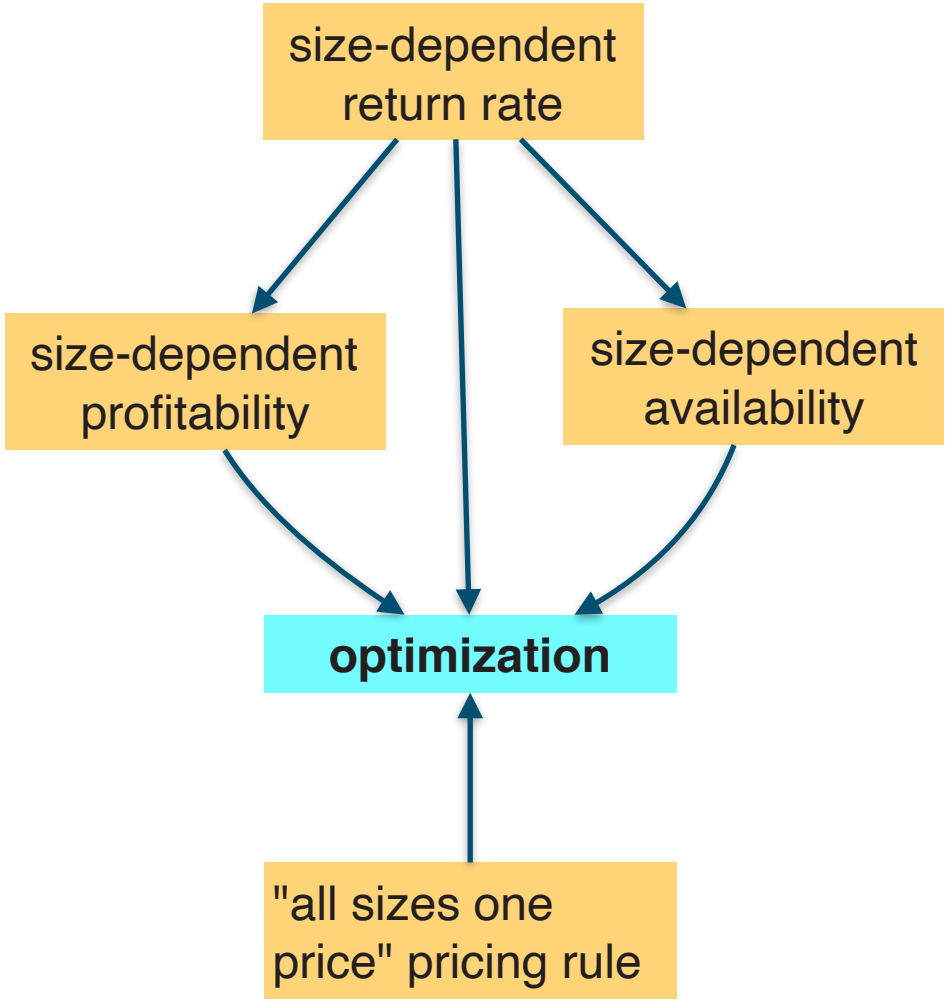


Available inventory in future =

Today's inventory
– forecasted sales
+ forecasted returns of actual sales in the past
+ forecasted returns of forecasted sales
+ future incoming/distributed stocks

Example: Size & return rates





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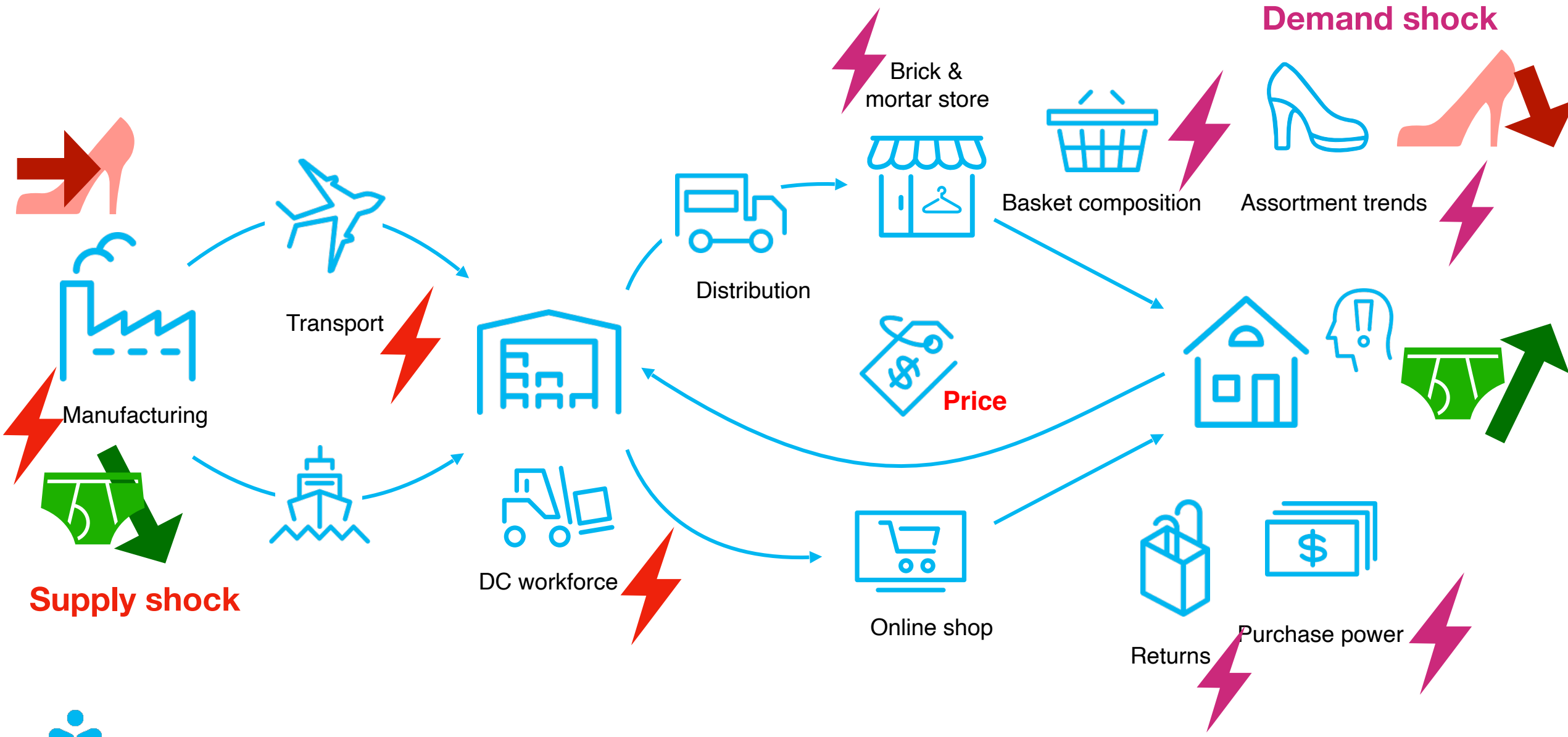
Holistic treatment of pricing-problem,
account for price-sale & price-return-relation.

5) What's happening now with COVID19?

Covid 19 and the supply chain



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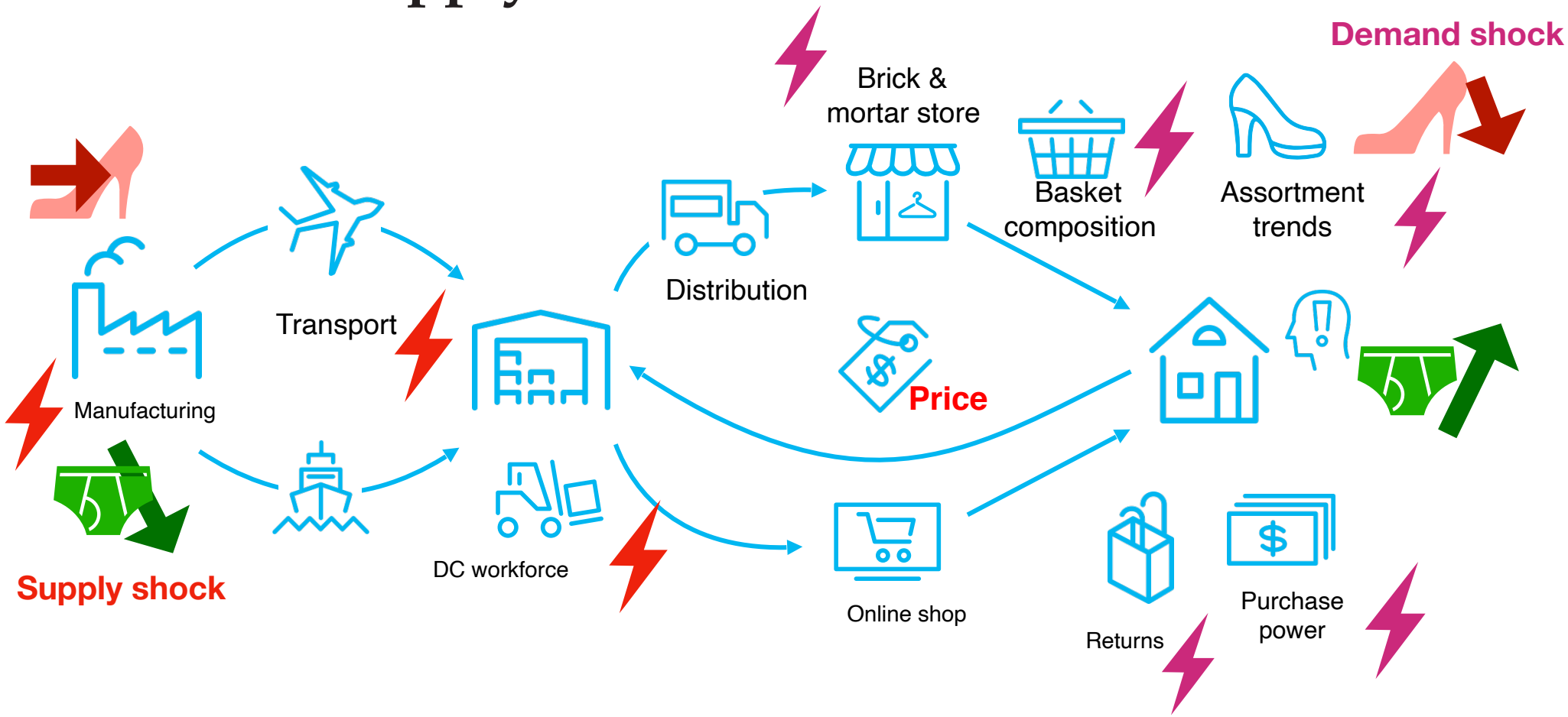

Normal times:

- Supply matches well-predictable demand, supply chain balanced out
- Price corrects for any misbalancing as a last line of defence and thereby maximises KPIs

COVID-19:

- Entire supply chain disrupted
- Supply and demand shocked, but shocks are not aligned and amplify each other: heavy over- & under-stock simultaneously on different articles
- Pricing accounts for all incoming and outgoing stocks
- Immediate optimal reaction for each individual article

1) What is a good decision?

An action that maximizes a well-defined (subjective) goal,
accounting for the environment's (objective) behavior.

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2) How do we ensure good decisions?

Modularize subjective & objective components, cross-validate
against independent models.

3) What's a good pricing decision?

A meaningful business target function is optimized on the basis of
a realistic price-sales-model & price rules & stock levels.

4) What about customer returns?

Holistic treatment of pricing-problem,
account for price-sale & price-return-relation.

5) What's happening now with COVID19?

Modularization, full optimisation & fast adaptation beat
price rule sets and manual interventions

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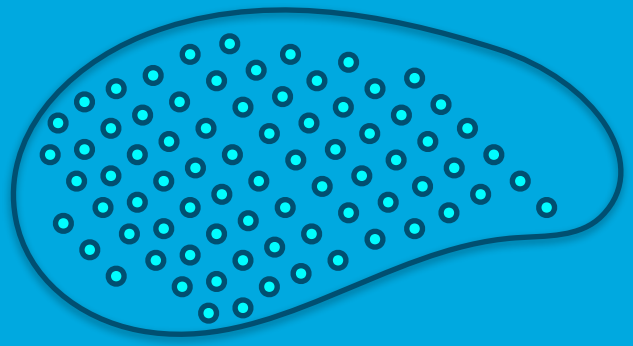
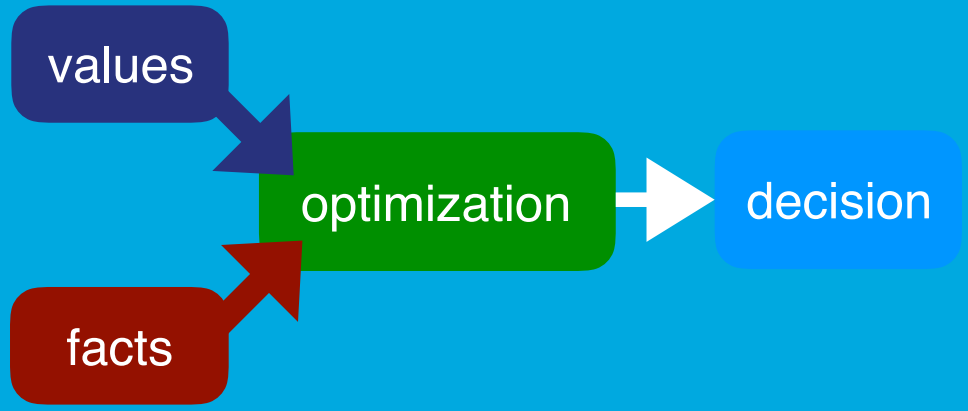


- Artificial Intelligence takes the granular tedious **micro-decisions** so we focus on strategic **macro-decisions.**



- Modularized architecture mirrors **systematic decision making**, allowing scalable, reliable, verifiable micro-decisions.

- Modeling all aspects of an individual **sales process** including **returns** yields great benefits to online retailers.