SHEET METAL ASSORTMENT OPTIMIZATION WITH K-MEANS

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Agenda

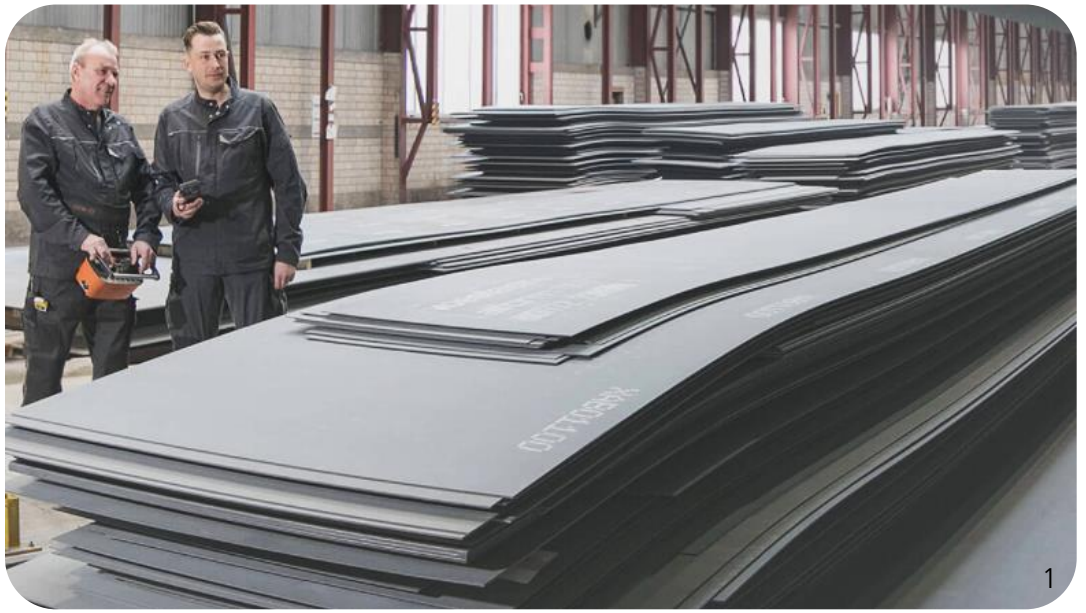
1. Introduction
2. State of the art and related research
3. Optimization approach for simulating inventory scenarios
4. Architecture of the developed software tool
5. Results and application experience
6. Outlook and further research acitivities

Introduction

Inventory optimization in the procurement of sheet metal for small series and contract manufacturer

Challenges

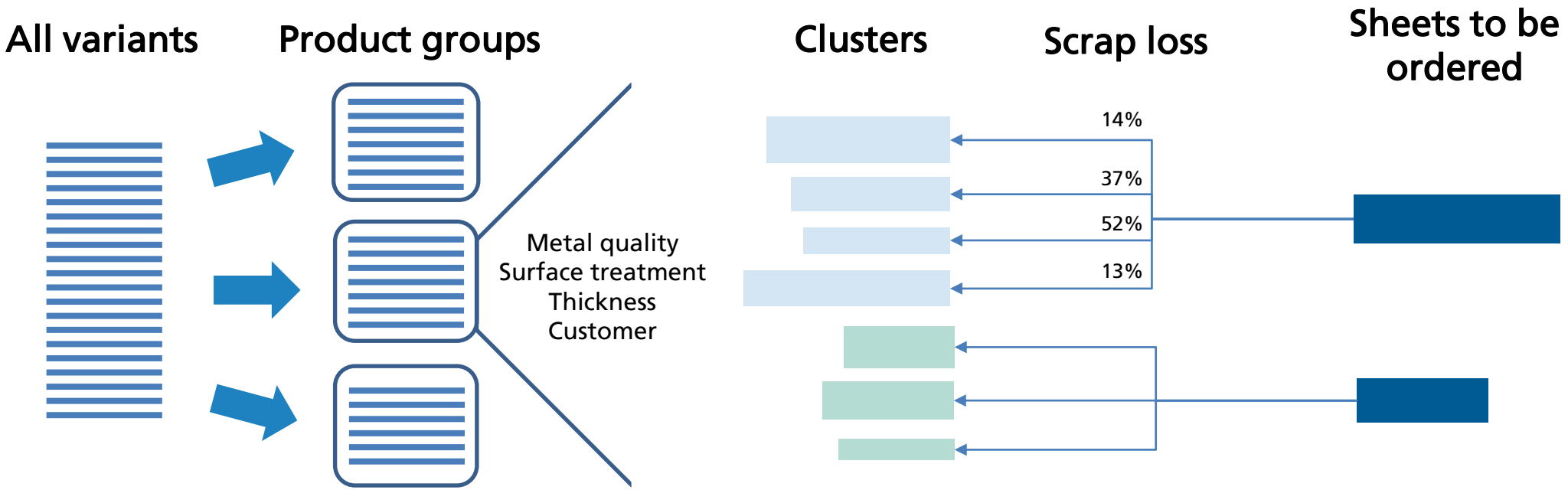
- Much inventory binds capital
- Low inventory reduces customer service
- High number of variants for projects or small batch sizes
- Large minimal order lot sizes
- Handling effort due to mixed stacks



Reducing the number of the variants to be ordered
by using the opportunity to substitute sheets by a larger sheet

Sources: [1]Ferro Umformtechnik

Inventory optimization through reduction of variants



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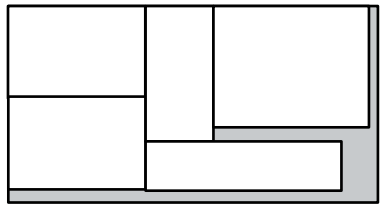
State of the art and related research

Industry:

Companies apply established methods for inventory management from ERP software and can be found in literature (e.g. ABC-Analysis)

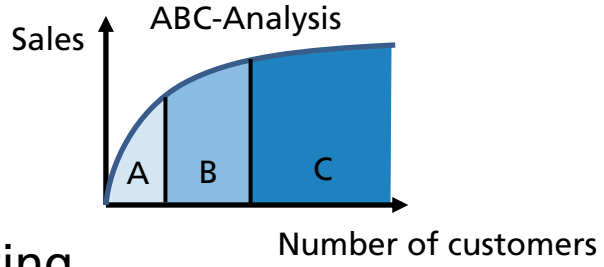
Cutting stock problem (CSP)

- Cutting standard-sized pieces into pieces of required size while minizing waste[1]
- Similarities with knapsack / bin packing problem[2]
- Difference: Cut several sheets from a single sourced sheet



Assortment problem[3,4]

- When company is unable to store all materials, they must choose what to store and what not.
- ABC-Analysis[5]
- Inventory Pooling with DES[6]
- Simulation of operation concepts with DES[7]



➡ Much in common with both problems but no exact fitting

Sources: [1]Wäscher et al., 2007; [2]Horowitz & Sahni, 1974; [3]Pentico, 2008; [4]Sachs, 2015; [5]Chen et al., 2008; [6]Hafner et al., 2019; [7]Teter et al., 2019

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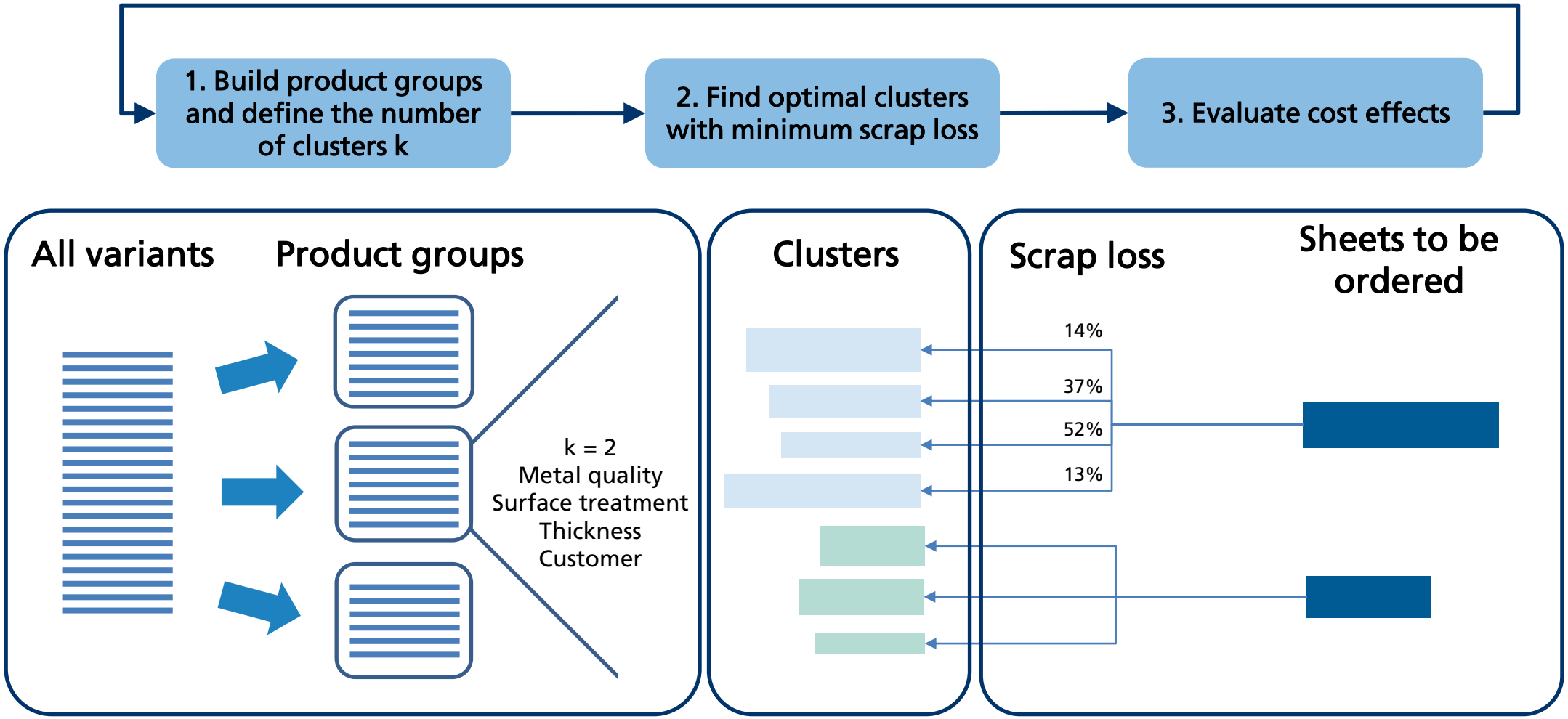
Optimization approach for simulating inventory scenarios



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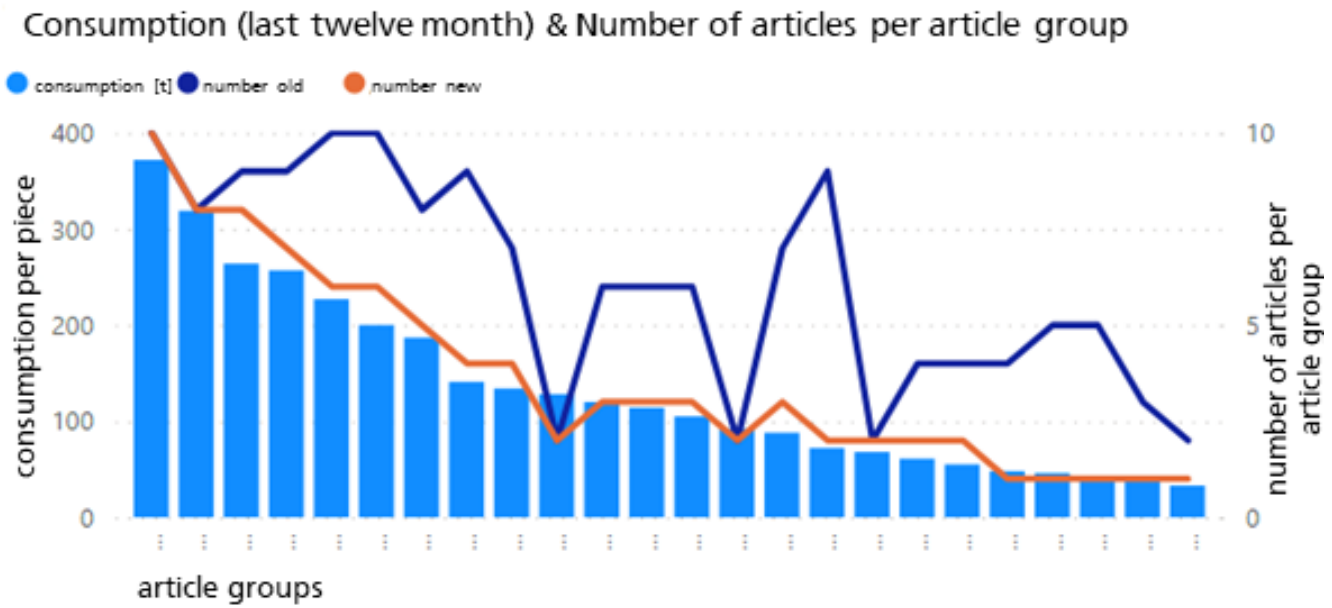
1. Define the number of clusters k for each product group

- Define target number of variants for all articles
- Build product groups (e.g. metal quality, surface treatment and thickness)
- Distribute available clusters to all product groups with a heuristic approach depending on the consumption
  - Product group with large consumption gets more clusters
  - Product group with small consumption gets less clusters



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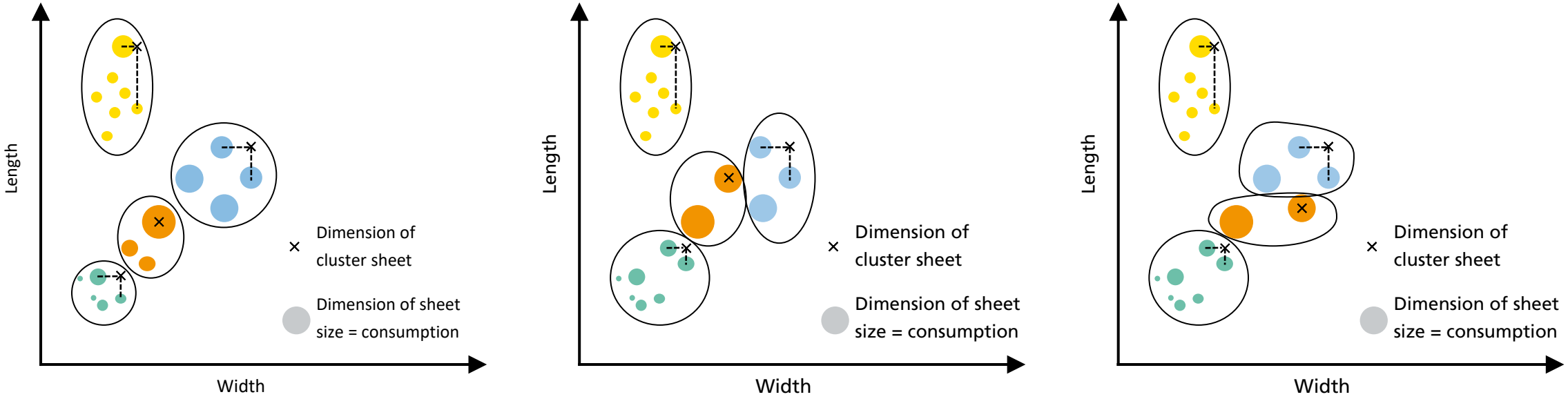
2. Find optimal clusters with minimum scrap loss



- Optimization problem can be described as an integer linear program[1]
- Number of allocations: k^n
- NP-complete problem ⟶ not computable for practial applications[2]
- k-Means algorithm as heuristic approach[3]

Cluster

Scrap loss per sheet

$$min \sum_{i=1}^{n} \sum_{j=1}^{k} r_{i,j}(l_j \times w_j - l_i \times w_i)$$

Sheet

Allocation $r_{i,j} \in \{0,1\}$

Sources: [1]Schrijver, 1998; [2]Karp, 1972; [3]Pedregosa et al. 2011

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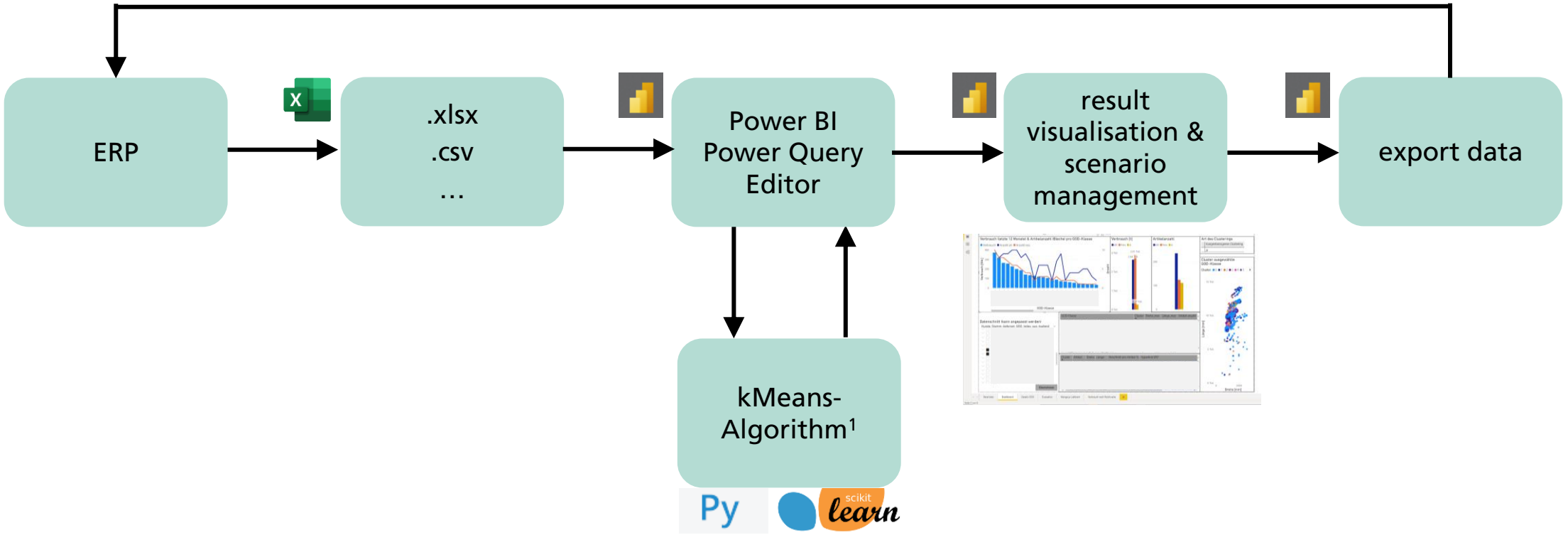
3. Evaluate cost effects

- Calculate effects of different simulation scenarios
- Economic-Order-Quantity (EOQ)[1] policy was used to calculate effects of ordering costs and inventory level

Scenario parameter	Effects
Target number of clusters	Scrap loss
Consumption forecast	Number of clusters per product group & scrap loss
Customer specific material costs	Same clustering decisions for different customers can generate different costs
Administrative ordering costs	Decreases in connection with number of clusters
Scrap price	Positive effect on costs
Safety stock	Large effect on average bound capital
Storage fix costs	Dependency on bound capital and average inventory levels

Source: [1]Schwarz, 2008

Architecture of the developed software tool



Source: [1]Pedregosa et al. 2011

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Results and application experience

Results

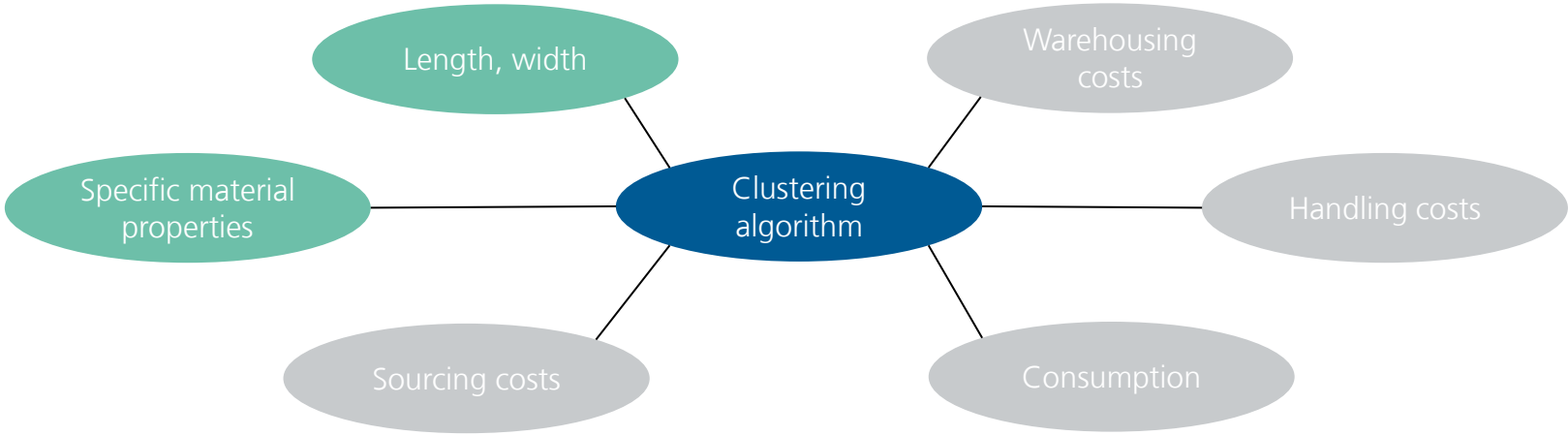
- Developed and evaluated an application-specific AI-model for inventory optimization
- This toolset enables customers to simulate and evaluate different inventory scenarios (e.g. future demand scenarios)
- Company used the solution to reduce number of its sourced sheets

What we've learned

- Tools like Power BI with the algorithmic of open-source AI-libraries like scit-kit learn enable a rapid implementation of the solution
- Toolset supports better and faster decision making regarding variant reduction for future demand scenarios
- API of Power BI with python is difficult to debug and consumes considerable time

Outlook and further research activities

- Extending the modelling approach by considering further costs and performance attributes.



- Implement algorithm which calculates the optimal number of clusters k (not only optimal allocation)
- Benchmarking the approach with exact solution (regarding quality and runtime)
- Effects on customer service and handling costs
- Using other clustering algorithms and other operations research approaches not based on clustering

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Thank you for your attention!

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