SYSTEMS ENGINEERING RESEARCH CENTER

AUBURN UNIVERSITY

Manufacturing Cost Prediction in the Presence of Categorical and Numeric Design Attributes

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Introduction

MANUFACTURER'S COST ESTIMATION STRATEGY

Critical Questions:

- What is the negotiation power over the underlying product price? Is the expected cost accurate?
- Is it possible to know the cost of a new and unique design before it is actually manufactured?

Introduction

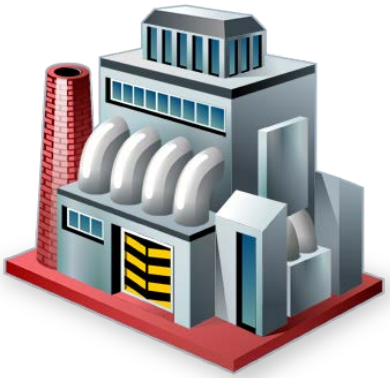
- When manufacturing a new unique design, the focal point is to establish a price which maximizes customer value while being profitable.
- Since an irreversible and large amount of capital is tied up in production elements, estimating manufacturing costs accurately is critical.
- Final decisions about the product price should be based on analytical approaches, instead of intuitive expectations.

Introduction

- "Cost plus pricing" or "Cost based pricing"

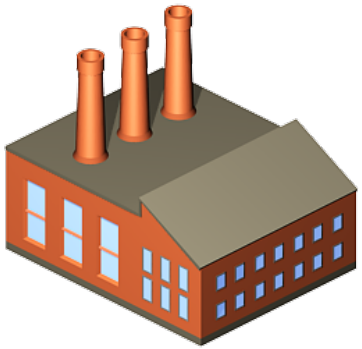
- Poorly established product prices that are a function of product cost may cause two unfavorable consequences:
  - (1) A potential loss of profit due to the gap between the expected cost and the actual cost
  - (2) A loss of customers and goodwill due to higher prices than necessary

Cost Estimation Challenge vs. Competitive Pricing



Manufacturer A

$5 /piece

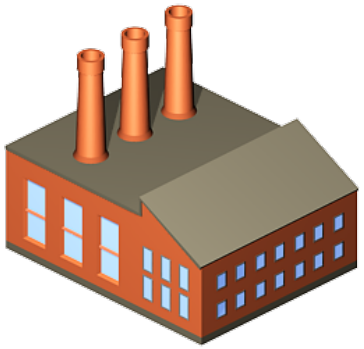


Manufacturer B

$4.50 /piece

Tubular Cable Lugs

Customer



Manufacturer C

$4 /piece

Motivations

- Many cases, costs are estimated based on primitive intuitive approaches that are far from reality and accuracy.
- Making parametrical distribution assumptions for design attributes can be arbitrary.
- Over a diverse product family, establishing only a single accurate estimation model is challenging and doubtful.

Our Approach

- We would like to predict the manufacturing cost of a product quickly and accurately.

- We investigate ways of using clustering methods to predict the manufacturing cost of products in the presence of complex numeric and categorical design attributes.

- The accuracy of the methodology is assessed in comparison to a traditional approach, a polynomial regression model in absence of a clustering approach.

Objectives

- To accurately and quickly predict the cost of a particular product before it is manufactured
- To deploy clustering techniques to achieve improved accuracy in the prediction
- To find appropriate number of clusters for a given case and series of products

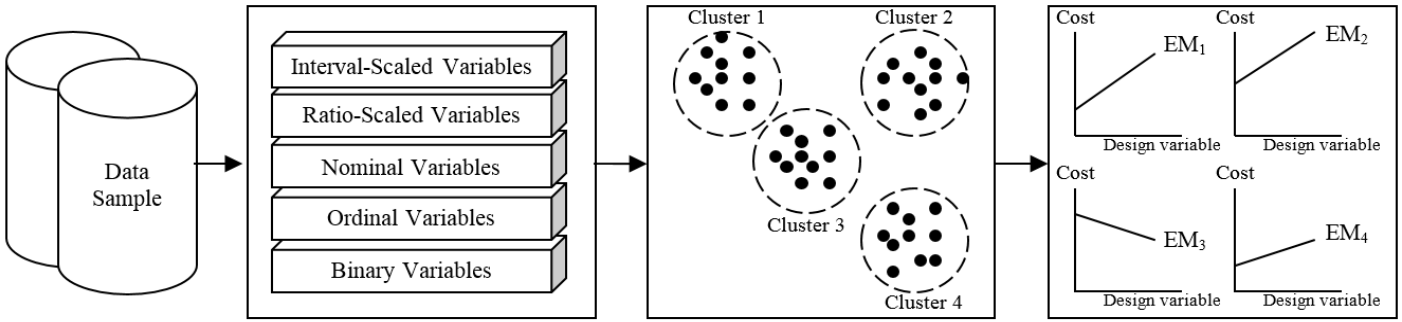
Contributions

- First to introduce a manufacturing costs estimation approach for mixed categorical and numeric variables using clustering methods

- Implemented a simple heuristic to determine the appropriate number of clusters for mixed data when there is no prior knowledge about the number of product groups

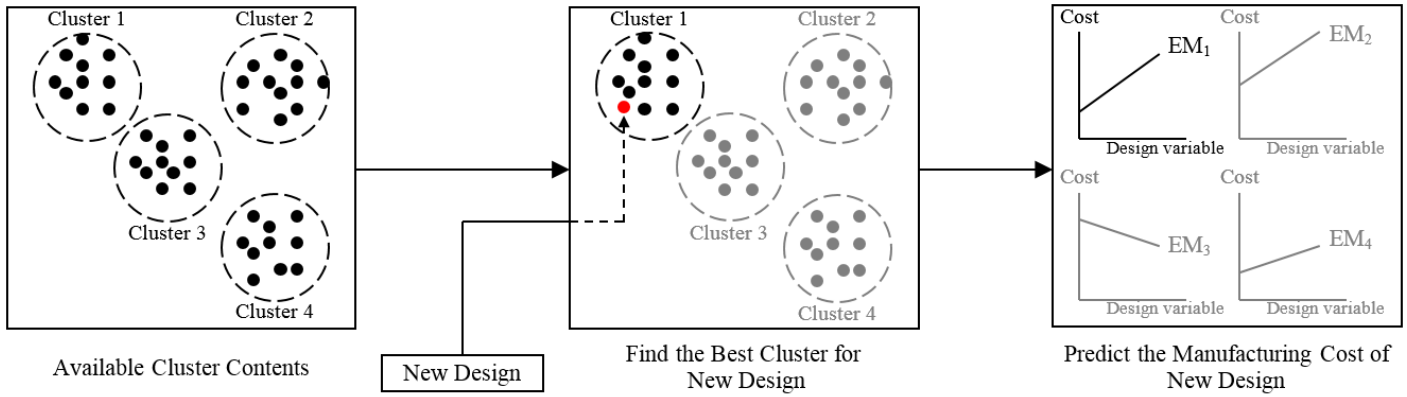
Suggested Methodology

1



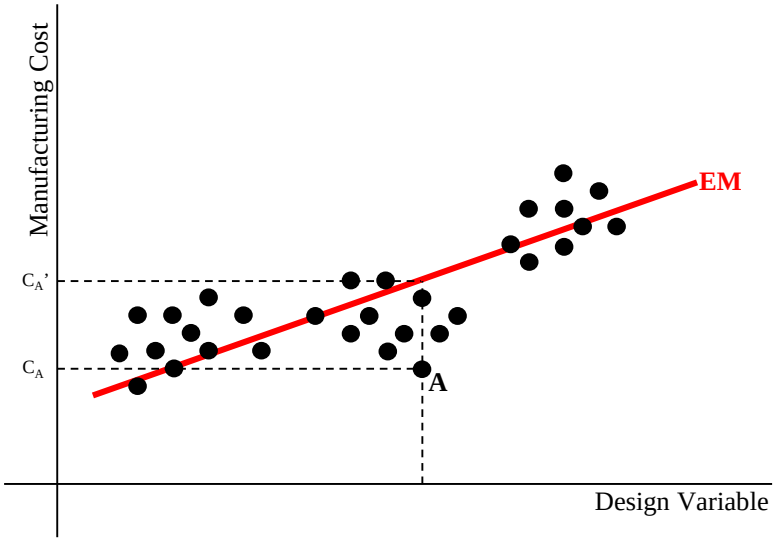
Data Collection | Variable Pre-processing and Determining Number of Clusters | Clustering Analysis | Building Cost Estimation Models

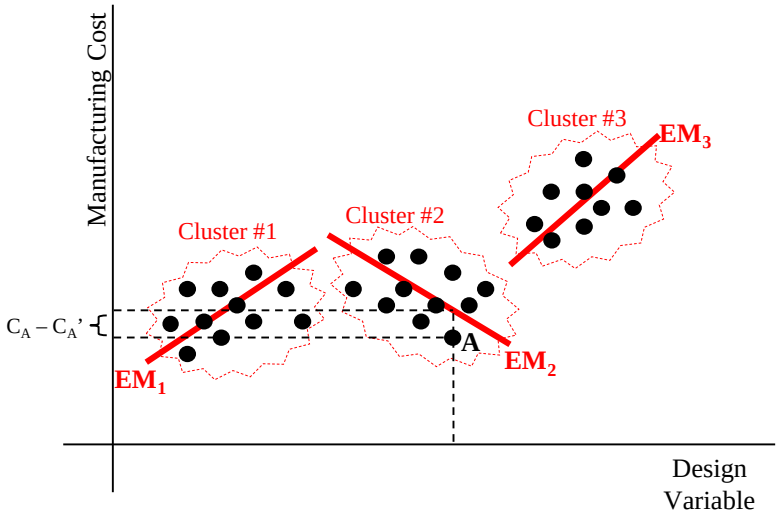
2



Available Cluster Contents | Find the Best Cluster for New Design | Predict the Manufacturing Cost of New Design

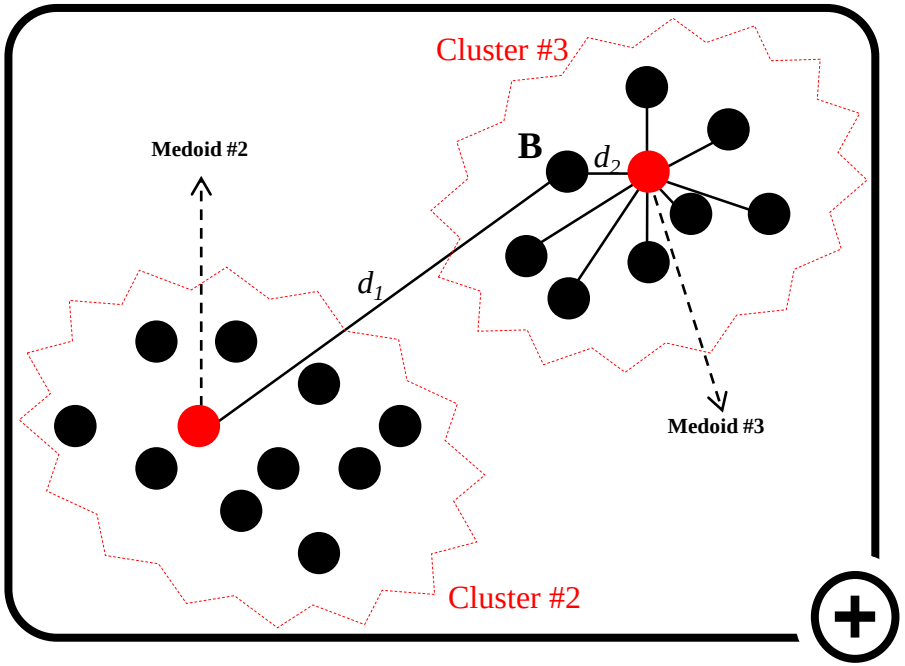
Suggested Methodology





Choice of Clustering Algorithm

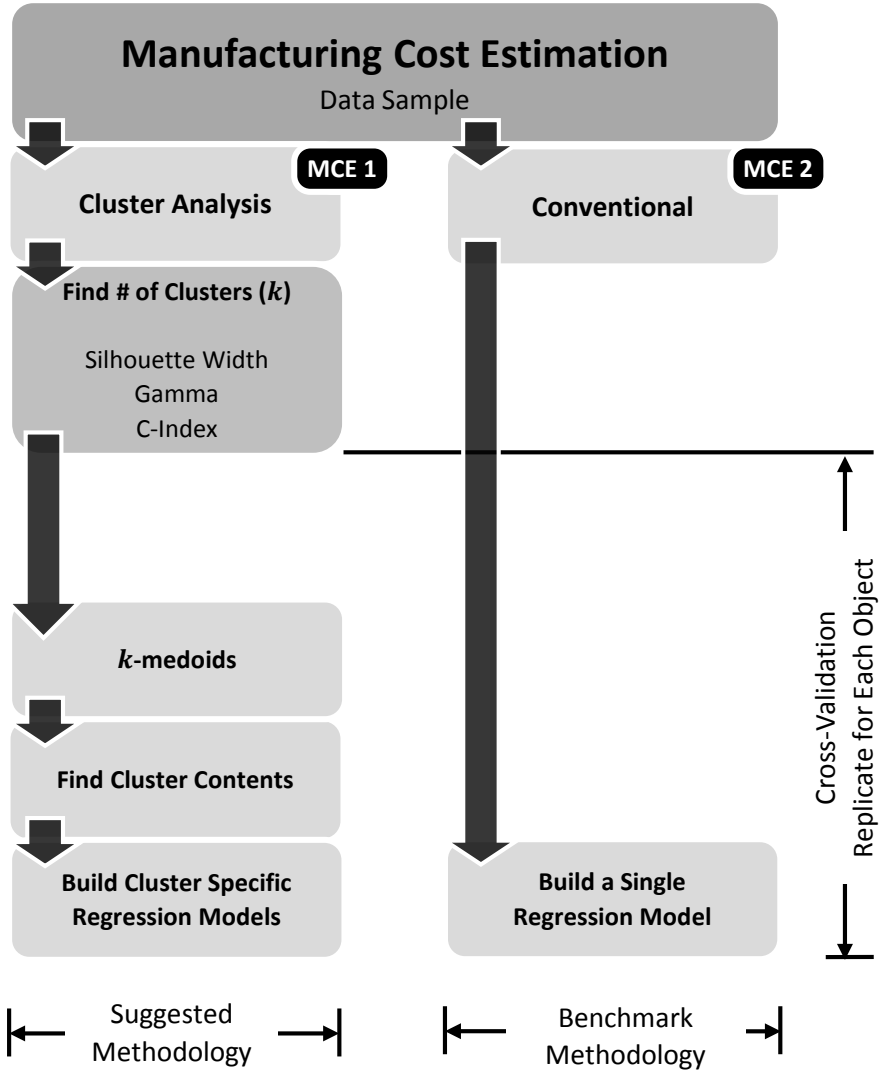
- k-medoids
  - —Operates on a dissimilarity matrix
  - —No randomness: Initial solution (BUILD), Moves (SWAP)
  - —Handles outliers



Choice of Number of Clusters

- Top 6 performing indices (Milligan and Cooper):
  - —Calinski and Harabasz's PSF
  - —Duda and Hart's $J_e(2)/J_e(1)$ or PST2
  - —*Dalrymple-Alford's C-index
  - —*Baker and Hubert's Gamma
  - —Beale's F-ratio
  - —Sarle's CCC
- *Rousseeuw's average silhouette width
- Consensus among Gamma (local peaks), silhouette width (local peaks & > 0.5), C-index (local troughs)

Summary of the Methodology

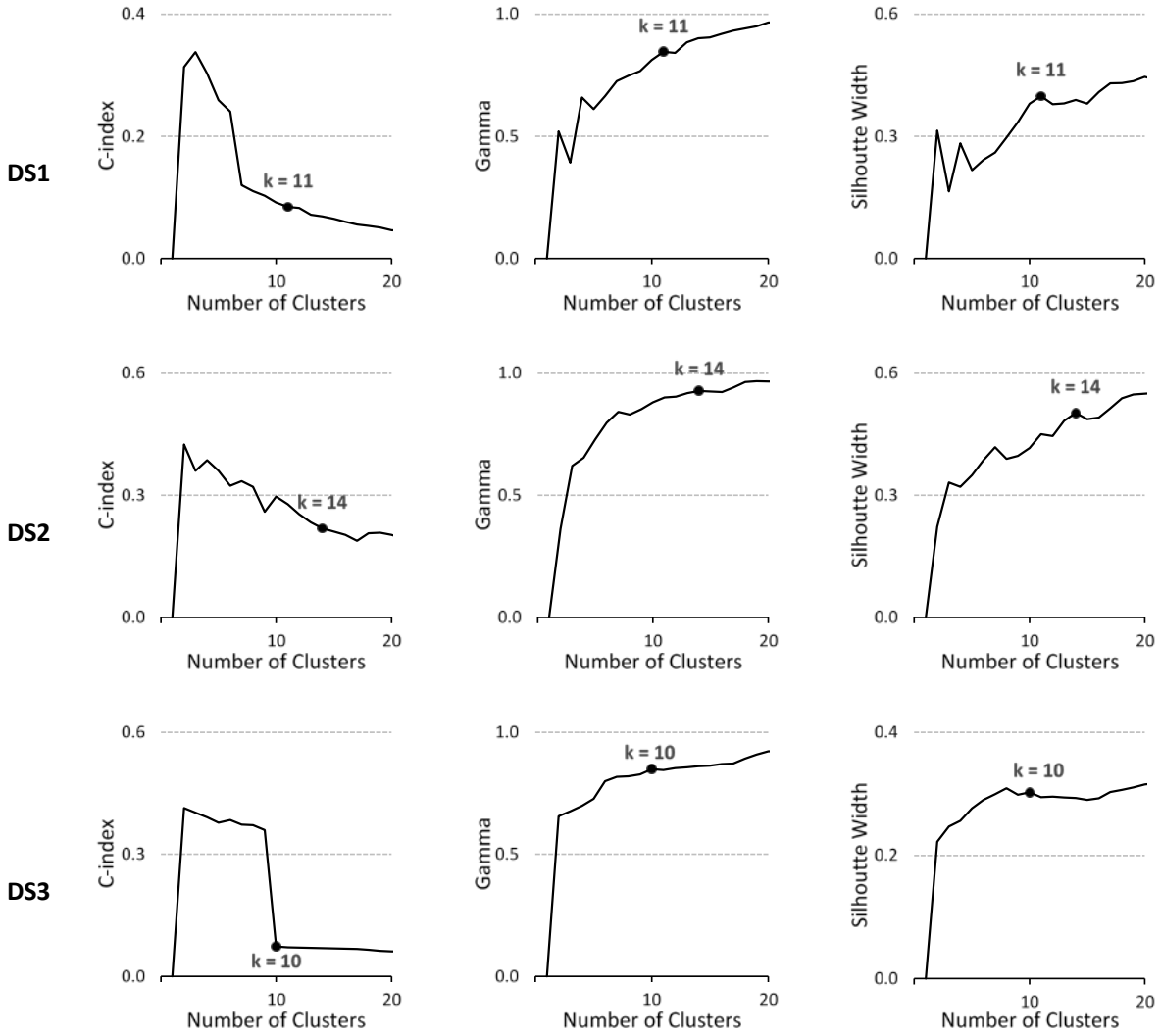


Real World Applications

- Electromagnetic and lightening protection parts manufacturer
  - **DS1** Tubular cable lugs: 12 variables
  - **DS2** Air rods: 10 variables

- Plastic kitchen and household products manufacturer
  - **DS3** Plastic parts: 51 variables

Determining the Number of Clusters



Results – Performance Metrics

MARE

	MCE 1	MCE 2
DS 1	**4.98%**	49.82%
DS 2	**5.81%**	15.42%
DS 3	**12.39%**	33.83%

Min ARE

	MCE 1	MCE 2
DS 1	0.00%	0.00%
DS 2	0.00%	0.00%
DS 3	0.00%	0.00%

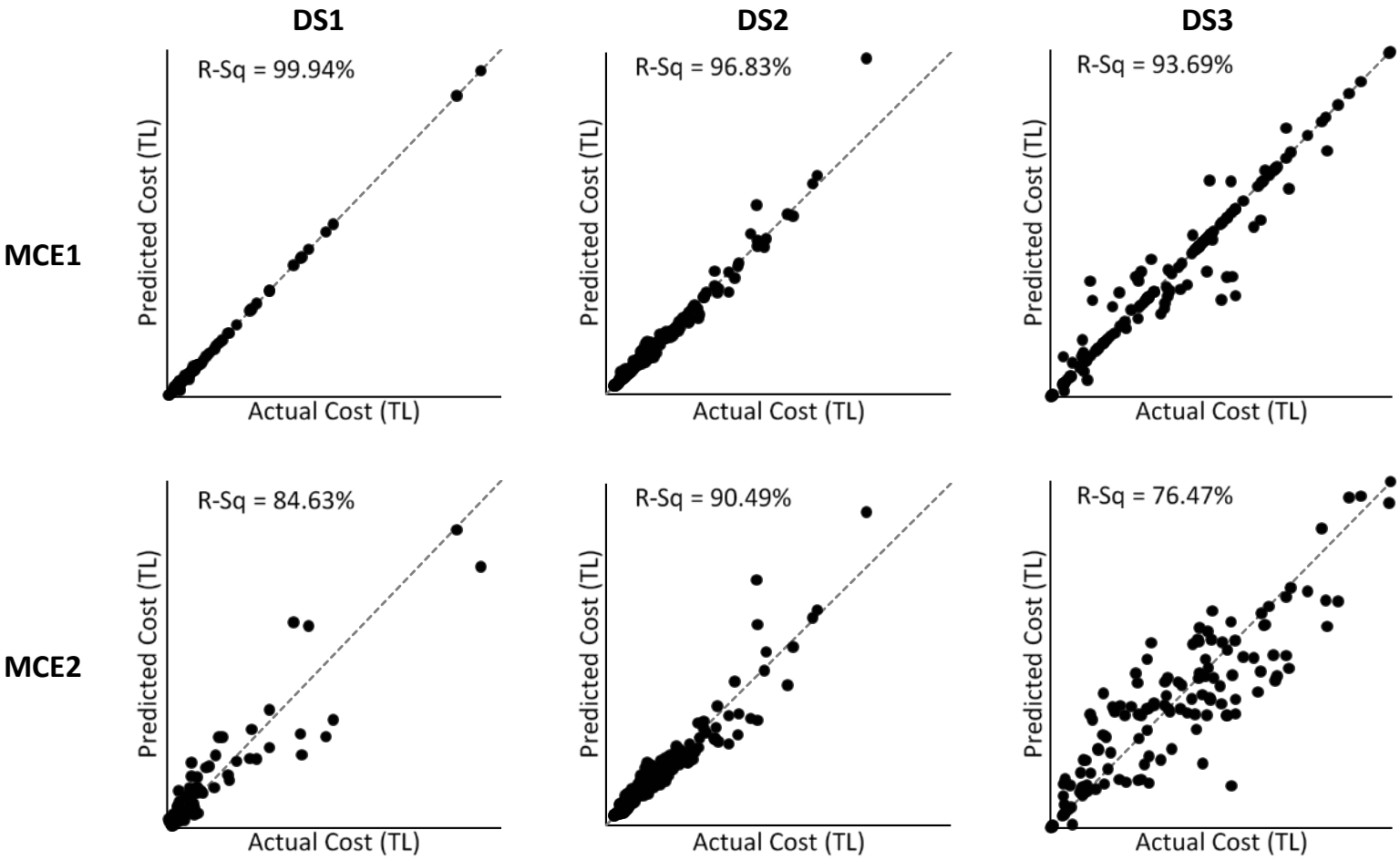
RMSE

	MCE 1	MCE 2
DS 1	**8.86%**	140.26%
DS 2	**355.72%**	615.92%
DS 3	**17.71%**	34.20%

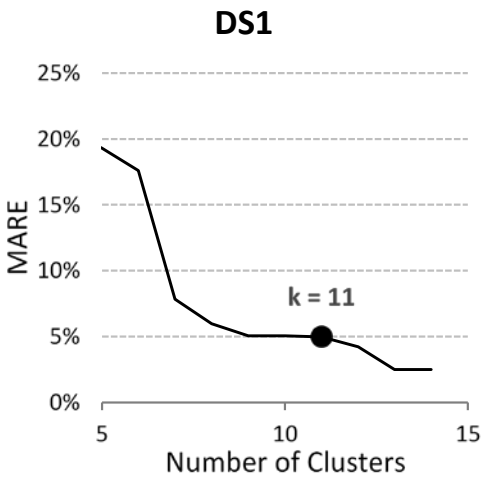
Max ARE

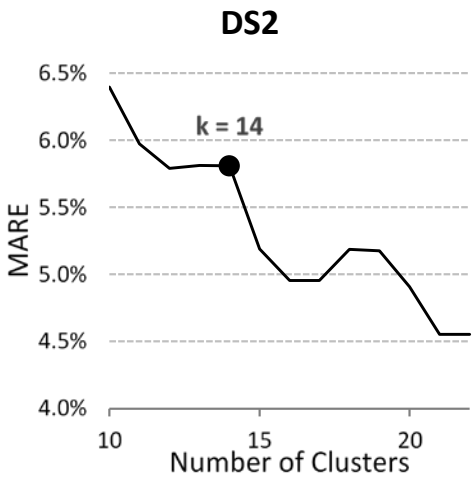
	MCE 1	MCE 2
DS 1	**46.67%**	429.52%
DS 2	**56.04%**	64.36%
DS 3	**203.54%**	233.79%

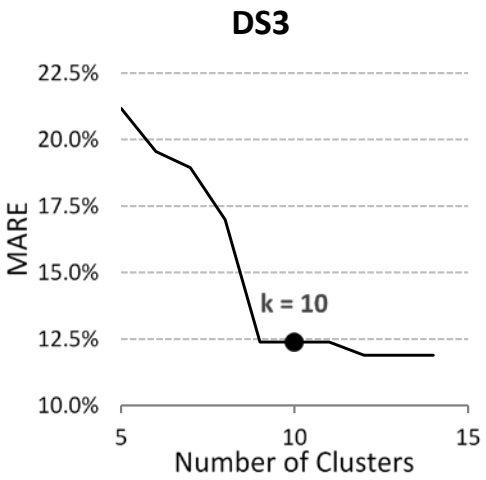
Results – Model Fit



Results – Sensitivity of Number of Clusters







Conclusions I

- We investigated ways of using clustering methods to predict the manufacturing cost of a product without actually manufacturing it.
- The accuracy of the methodology is assessed in comparison to a simple regression model with the absence of clustering approaches.
- The main concern is to predict the manufacturing cost of a product without dealing with arbitrary assignments of statistical distributions to cost related attributes.

Conclusions II

- In real production systems often a variety of products are being manufactured under a single facility roof.
- Over a diverse product family, establishing only a simple accurate estimation model is challenging and even questionable.
- This motivated us grouping products according to their design features, common manufacturing operations or some other factors by dividing the whole database of products into neighborhoods.
- Then for each group of products (clusters), a cost estimation model is developed to predict the manufacturing cost of a new product with using the cluster specific model.

Direction of Future Research

- Developing a comprehensive similarity measure that demonstrates high inter-cluster variability while being able to handle mixed categorical and numeric design attributes.
- A deterministic model such as a mixed integer programming model can be implemented to obtain the optimal cluster results.
- Information gain criterion can be considered when deciding on the inclusion of a candidate predictor (design attribute) in the cost estimation model.

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