Selecting suitable spare parts for additive manufacturing

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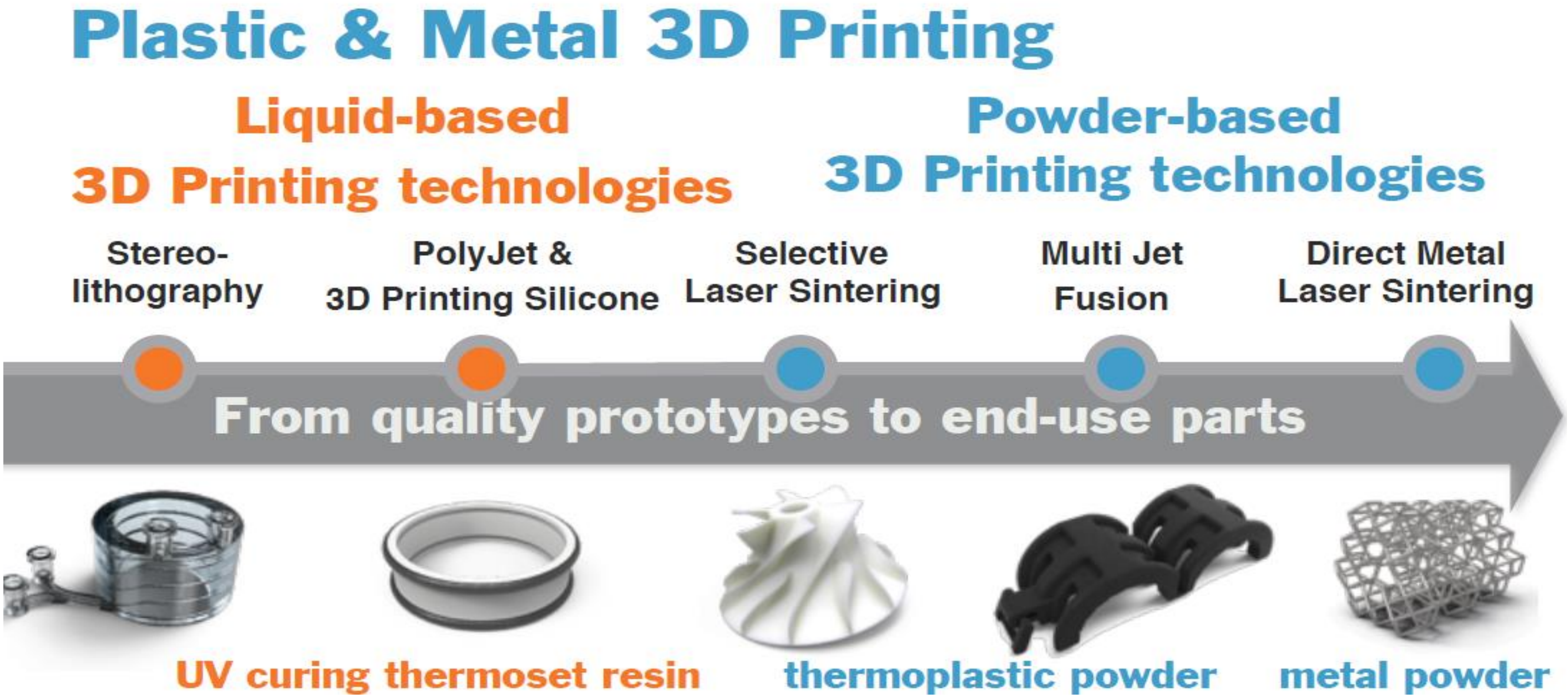
Agenda

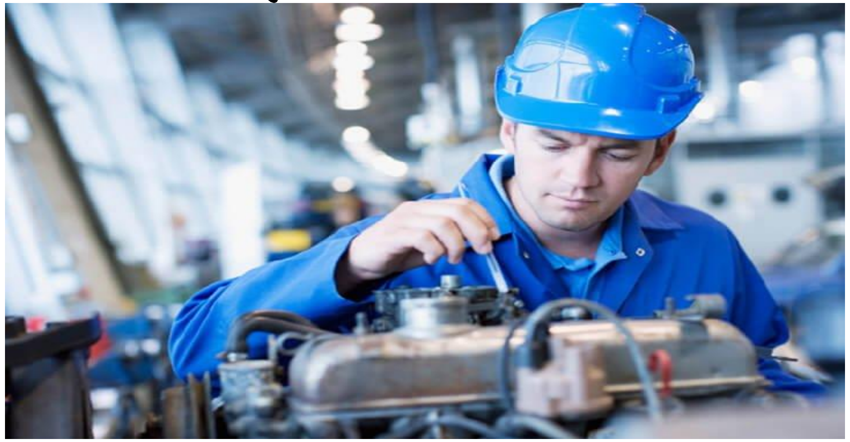
- Introduction to additive manufacturing
- Why additive manufacturing for spare parts ?
- Have real industrial parts been printed?
- Part selection- the big challenge in adopting additive manufacturing
- Two case studies
- Criteria for screning and assessment
- Pre-assessment workshop
- Criteria thresholds
- Logic Decision Diagrams and Fuzzy Inference Systems
- Results and next steps
- An alternate approach
- Which approach to use in what context
- Key take aways

Overview of Additive manufacturing technologies



Source: Protolabs

Why additive manufacturing for spare parts?



High inventory of spare parts

Volume of some spare parts are too low

Suppliers no longer want to deliver

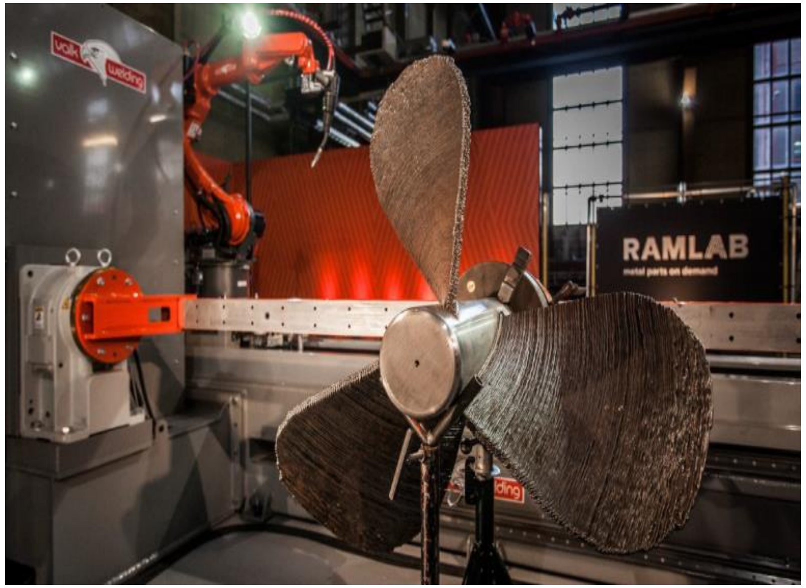
No CAD files exist for the spare parts

Long lead times for spare parts manufacturing

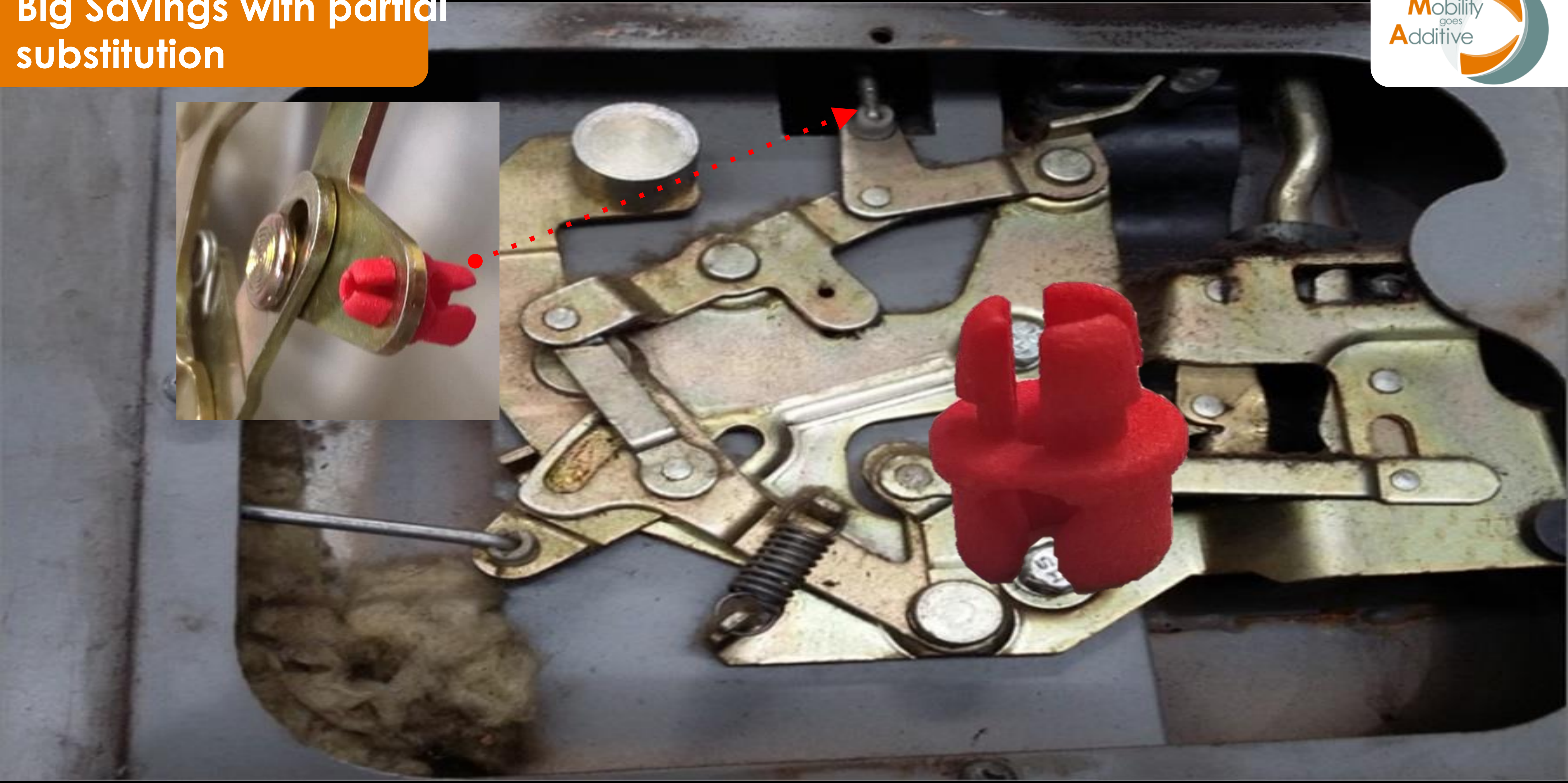
Locked up in last-time buy purchases

Lifetime service contracts

Have real industrial parts been printed?

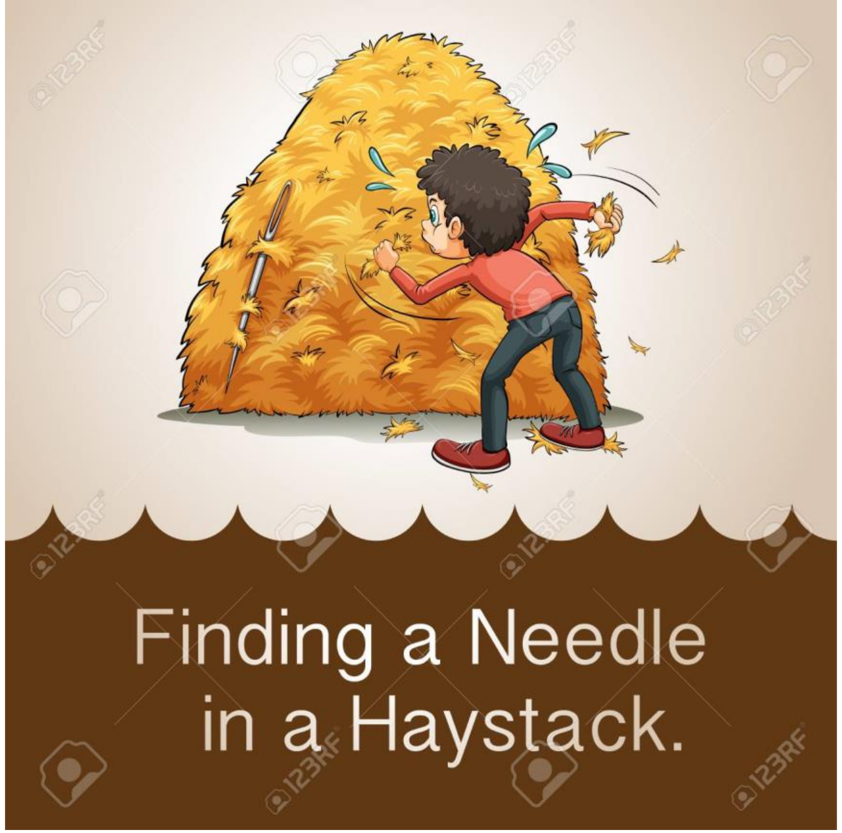


Big Savings with partial substitution



Prevention of downtime

Part selection- the big challenge in adopting additive manufacturing



- You have a large portfolio of spare parts (> 50,000)
- How do you figure out which of these spare parts can be manufactured using AM ?
- What are your objectives ?
- Which factors to consider ?
- Which method to follow to process the data ?

TWO CASE STUDIES

Criteria for assessing spare parts

Technical

1. Size
2. Materials
3. Surface finish requirements
4. Tolerance requirements
5. UV resistance
6. Chemical resistance
7. Corrosion resistance

Supply chain

1. Lead time
2. Demand and demand uncertainty
3. Unit cost
4. Supply risk
5. Inventory
6. Criticality
7. Repairability

Six Step Spare Part Selection Method

Step 1 - Information Sharing

Step 2 - Define Objectives

Step 3 - Technological Attributes

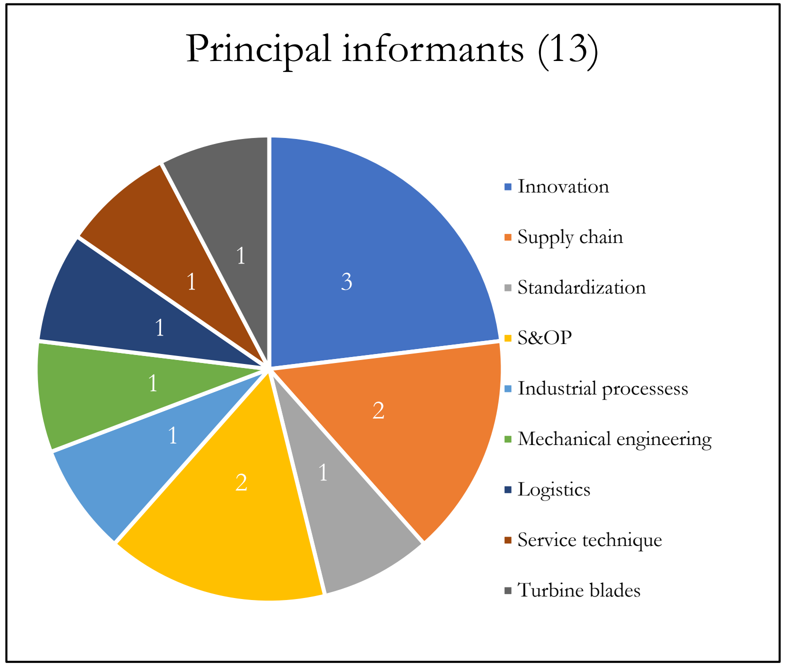
Step 4 - Strategic Attributes

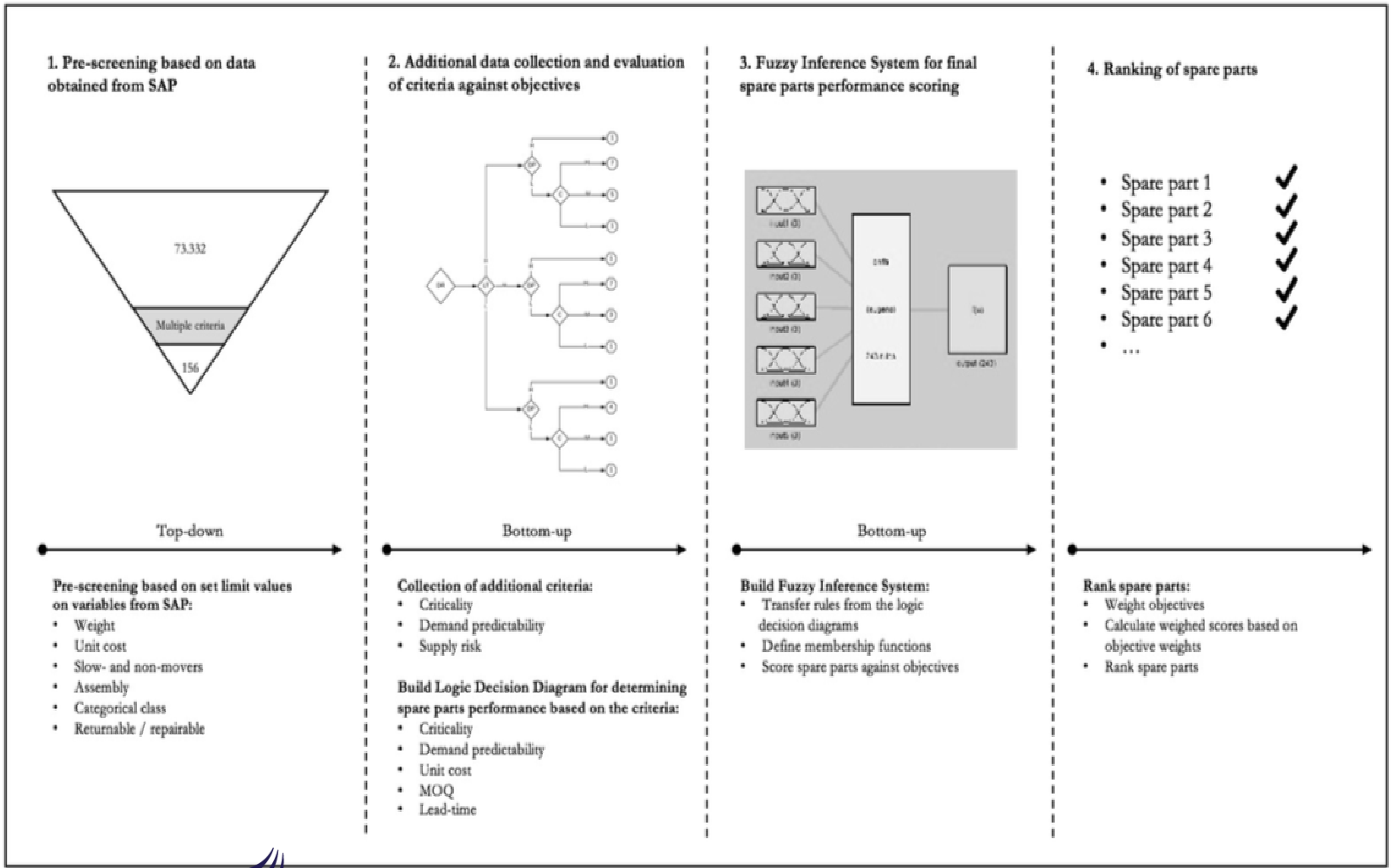
Step 5 - Selection of Spare Parts

Methodology

Objectives

- Inventory cost reduction
- Downtime reduction

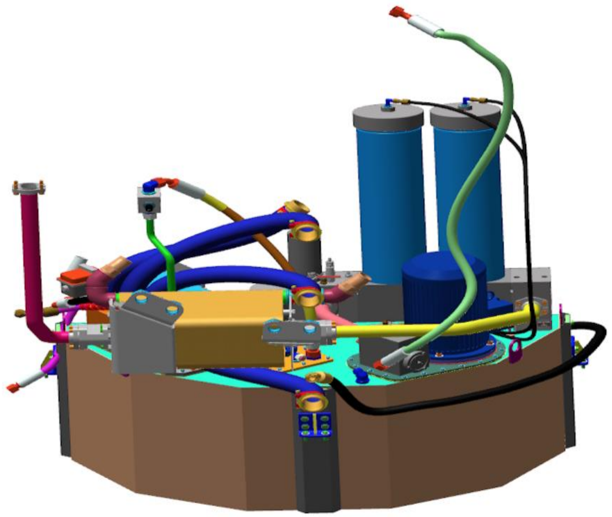


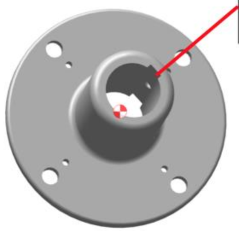


Criteria for screening and screening process

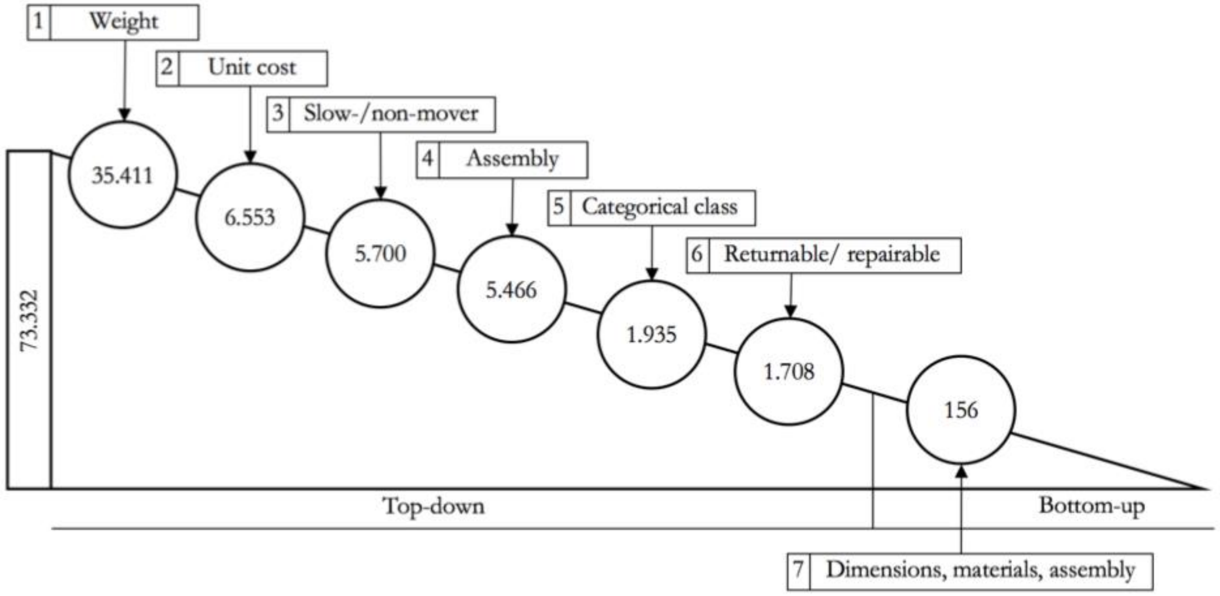
Criteria for screening

- ✓ **Weight**
- ✓ **Unit cost**
- ✓ **Demand volume / rate (Slow, non-mover)**
- ✓ **Part of assembly or not**
- ✓ **Categorical class**
- ✓ **Returnable-repairable**
- ❑ Durability
- ❑ Lifecycle stage
- ✓ Repairability
- ✓ Technical spec. availability
- ❑ Obsolescence
- ✓ Size (to fit the build envelope)
- ✓ Material type





Summary	
Name	743051.prt Gear Flange LG, Hansen
Area	177044 mm²
Volume	1.000000e+006 mm³
Mass	9 kg
Center of Gravity	(39.62, 0.00, 0.40) mm
Envelope	~(140.00, 260.00, 260.00) mm



Preparing for assessment- workshop

- Preparation for workshop
  - Criteria for assessment
  - Data analysis
  - Clustering

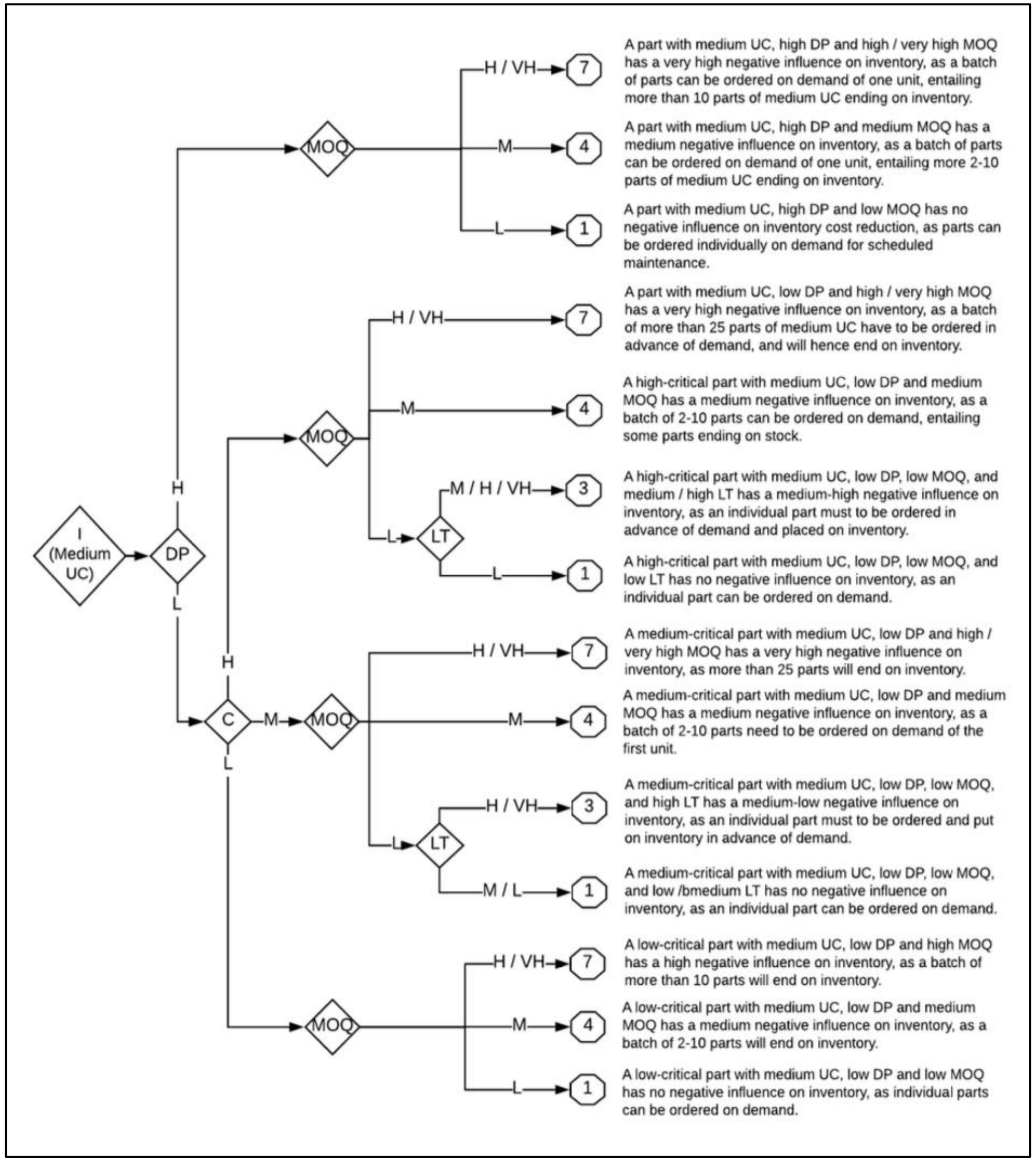
Criteria for assessment
✓ Lead-time
✓ Unit cost
✓ Criticality
✓ Demand predictability
✓ Supply risk
✓ Minimum order quantity
✓ Material

Order	SAS ID	Cluster	Material
1	30	1.1	29050648
2	119	2	VT730098
3	21	3	29005348
4	109	4	788507
5	83	5	764849
6	3	6	10204229
7	55	1.2	702670
8	DEF		
9	40	3	60065484
10	18	4	112095

Criteria thresholds

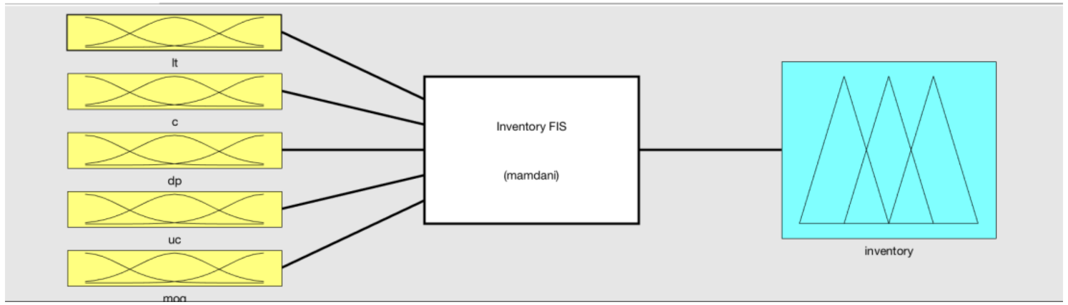
	Criteria value classes			
Criteria	**Low**	**Medium**	**High**	**Very high**
LT (in days)	LT ≤ 7	7 < LT ≤ 21	21 < LT ≤ 42	LT > 42
UC (in €)	500 ≤ UC ≤ 1.000	1.000 < UC ≤ 2.000	2.000 < UC ≤ 4.000	UC > 4.000
C	Part failure has no influence on breakdown	Part failure leads to breakdown after 21 days	Part failure causes immediate breakdown	-
DP	Corrective maintenance	-	Preventive maintenance	-
SR	No. of suppliers ≥ 3 ∧ no LT variation	No. of suppliers = 2 ∨ LT variation	No. of suppliers = 1 ∧ LT variation	-
MOQ	MOQ = 1	2 ≤ MOQ ≤ 10	10 < MOQ ≤ 25	MOQ > 25

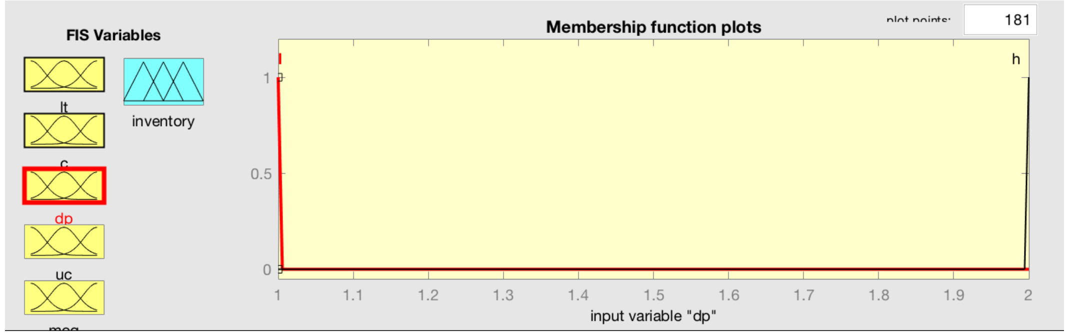
Logic decision diagrams

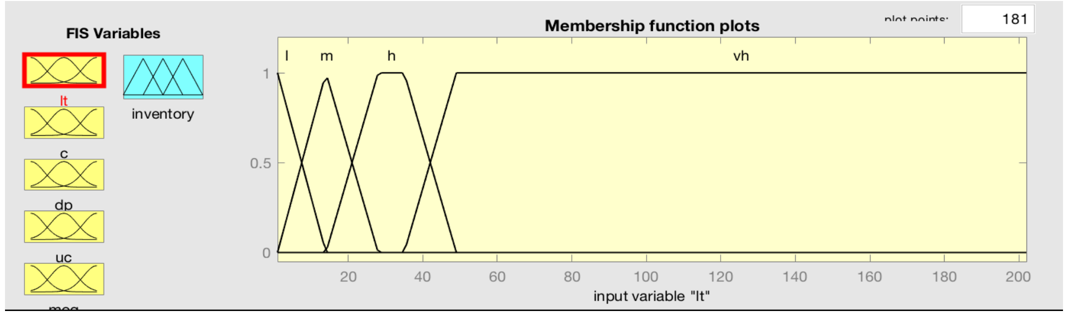


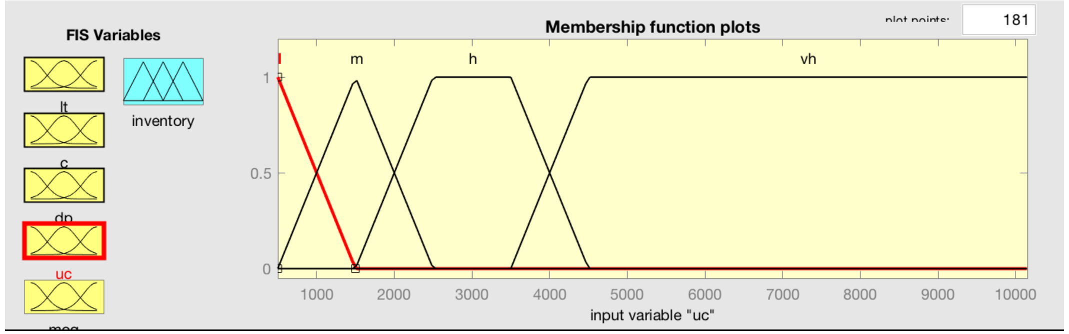
	Criteria value classes					Performance scores	
Material	C	DP	LT	UC	MOQ	D	I
29050648	High	Low	Very high	Low	Medium	7	3
29005348	High	High	Very high	Medium	Medium	1	4
788507	High	Low	Very high	Very high	Low	7	4
10204229	High	Low	Medium	Low	Very high	7	7
702670	High	Low	Very high	Low	Low	7	1
112095	High	Low	Very high	Very high	Medium	7	6
29031017	High	Low	Very high	Low	Medium	7	3
773042	High	Low	Very high	High	Low	7	3
61325	High	Low	Very high	Low	Low	7	1
61326	High	Low	Very high	Low	Medium	7	3
763147	High	Low	Very high	Low	Low	7	1
29052797	High	Low	Very high	Low	Medium	7	3
60099884	High	Low	Very high	Low	Low	7	1
753432	High	Low	Very high	Low	Low	7	1
60046071	High	High	Very high	Low	Low	1	1
29052798	High	Low	Very high	Low	Medium	7	3
779210	High	Low	Low	Low	Low	4	1

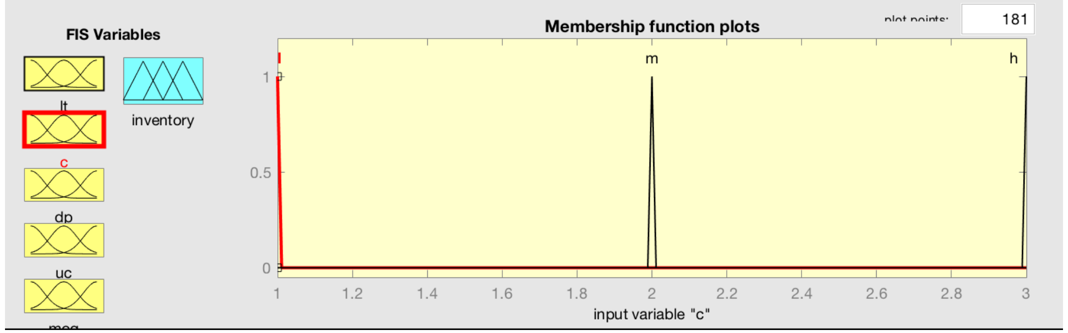
Fuzzy Inference System- Inventory

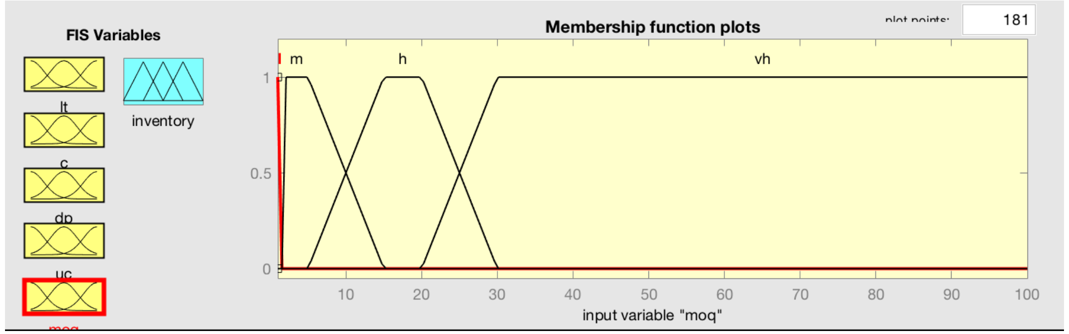












Results based on logic diagrams and FIS

Rank	Material	Description	Weight (kg)	3y consumption	Stock	Inventory value (€)	Make/buy
1	10204229	STUD M30 X 430 10.9 FLZNLNC	2.14	0	5	2,598.5	Buy
2	112095	PITCH BLOCK STD/LT	61	0	0	0	Buy
3	29031017	PINION Z11 M20	88.8	0	0	0	Buy
4	788507	VALVE BLOCK FOR 3MW PU	150	1	1	4,643.53	Buy
5	29052797	FLANGE DE LS	40.8	0	0	0	Buy
6	29052798	FLANGE NDE LS	41.7	0	0	0	Buy
7	61326	ENDSH NDE DA560 EN-GJS 400	120	0	10	9,031.3	N/A
8	29050648	FILTER BLOCK	27	0	0	0	Buy
9	773042	FRON.LEFT/REAR RIGHT CLAW BEAM	95	0	0	0	Buy
10	60099884	PINION FOR YAW-GEAR, NM72/2000	21.4	0	0	0	N/A
11	61325	ENDSH DE DA560 EN-GJS 400	105	0	1	678	N/A
12	702670	PLATE FOR CRANK ARM	37	4	7	4,513.39	Buy
13	763147	REINF. V66 TORQUE ARM, MACH. L	99.5	0	0	0	N/A
14	753432	HOUSE F.ROTATING CONTACT	17,6	0	0	0	Buy
15	779210	FLANGE FOR CYLINDER	22.5	3	1	528.9	N/A
16	29005348	PAWL FOR BLADE LOCK	0.993	0	0	0	Buy
17	60046071	BRAKE DISC Ø870	98.5	0	0	0	Buy

Practical implications and future actions

- A step in the right direction
- Identify those parts that are tricky to manage
- Validation of methodology
- AM experts for bottom-up assessment and selection of AM technology
- Business case development as next step

An Alternate Approach

1. INFORMATION SHARING

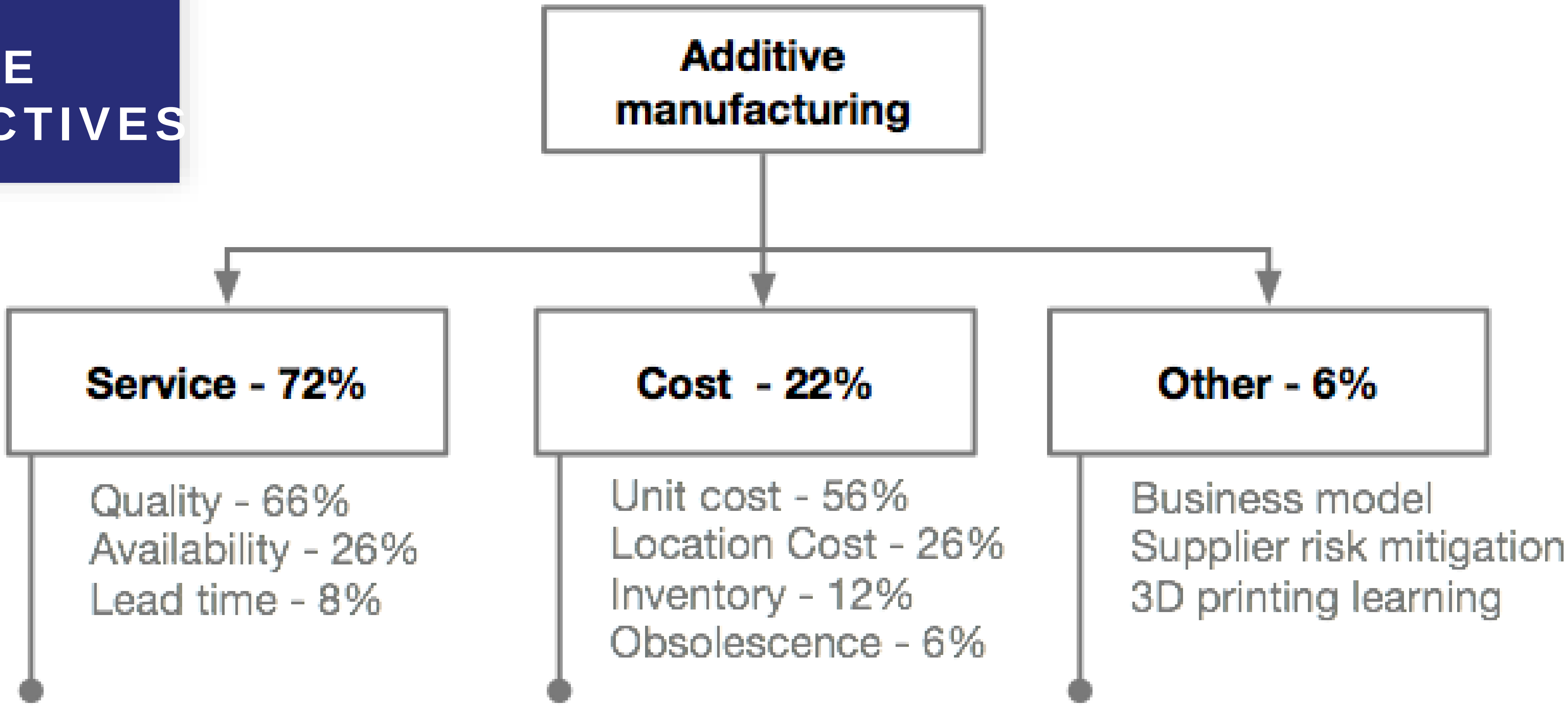
2. DEFINE OBJECTIVES

3.

4.

5.

6.



1.

2.

3. TECHNOLOGICAL ATTRIBUTES

4.

5.

6.

4 Attributes from the Literature

Basis for Technological Attributes Tool

	Material	Dimensions	Weight	Tolerances
ERP DATA	✗	✓	✓	✗
Printer Database	✓	✓	✗	✓

1.

2.

3. TECHNOLOGICAL ATTRIBUTES

4.

5.

6.

	Material	Dimensions	Weight	Tolerances
ERP DATA	✗	✓	✓	✗
Developed Printer Database	✓	✓	✗	✓

50,669

Spare Parts Discarded

1.

2.

3.

4. STRATEGIC ATTRIBUTES

5.

6.

- Screening
- Weighting of the Strategic Attributes
- Selecting the most Appropriate Method for Ranking the Spare Parts

Screening

	Time to Stock-out	Overhead Cost	Obsolete	Standard Cost
Problem	Having enough inventory of a spare part for more than 10 years service	Mismanagement of data: Materials of no standard cost, but high overhead cost	Spare parts are not in production and not being sold by Nilfisk	Spare parts with a standard cost is typically non-printable material
Action	Removing spare parts if: inventory / demand > 10	Removing spare parts with a overhead of more than 100% of the standard cost	Remove all spare parts classified as 'Obsolete'	Removing the spare parts which have a standard cost of more than 1000 DKK
Spare Parts Removed	271	4,101	1,464	528

6,364

Spare Parts Discarded

1.

2.

3.

4. STRATEGIC ATTRIBUTES

5.

6.

Selecting the most Appropriate Method for Ranking the Spare Parts

TOPSIS

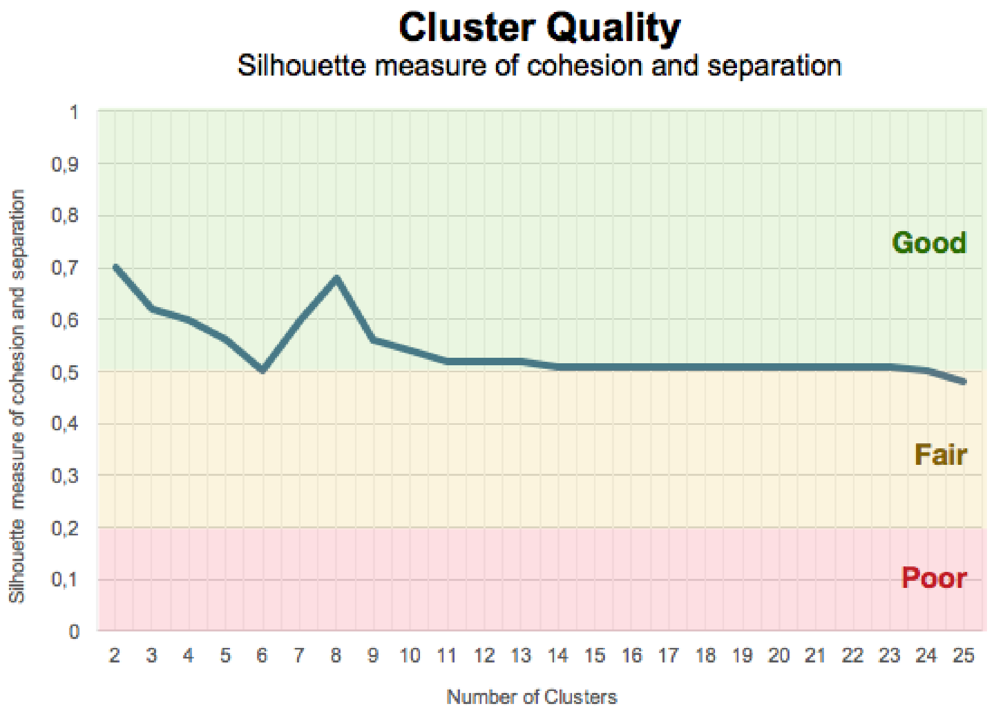
Material	Overhead Cost (DKK)	Lead Time (days)	Demand (12 months)	TOPSIS Score (Ci)	TOPSIS Ranking
56305665	364.74	85	1	0,972597613037653	1
53391A	311.50	99	1	0,971931770047372	2
56418987	321.29	68	6	0,96504184805561	3
56305436	428.82	50	1	0,964589392115614	4
8-51-05016	299.01	71	2	0,96433531665227	5
...	...	...	...	...	...
...	...	...	...	...	...
...	...	...	...	...	...
56304603	512,35	1	1	0,949103145137554	100

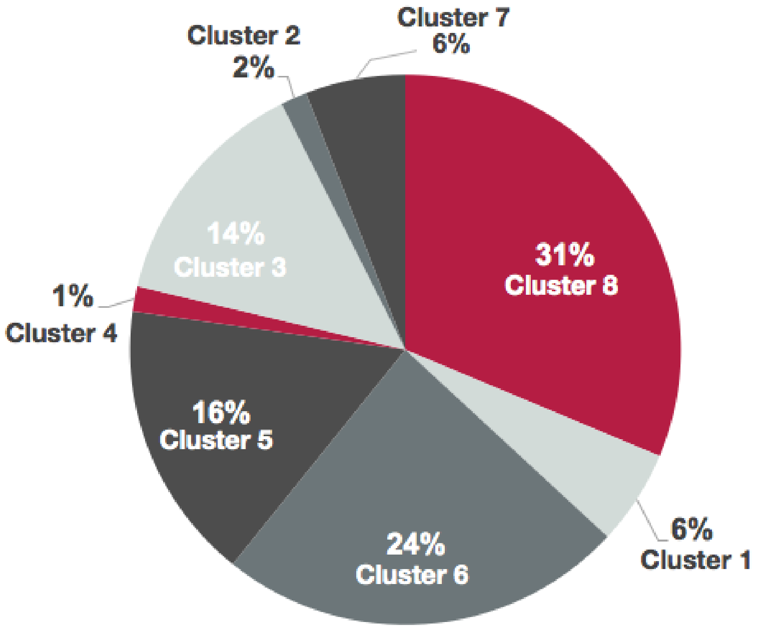
How can we obtain more valid rankings using MCDM?
How is the data actually positioned according to the 3 criterion?

1.
2.
3.
4. STRATEGIC ATTRIBUTES
5.
6.

Selecting the most Appropriate Method for Ranking the Spare Parts

Two Step Cluster Analysis



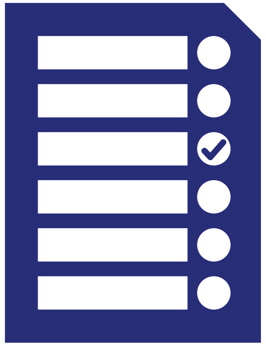


Size of Smallest Cluster	117 (1.5%)
Size of Largest Cluster	2470 (31.3%)

Ranking within Clusters using MCDM

Cluster No.	Input	TOPSIS Ideal (+/-)	
		Positive Ideal (+)	Negative Ideal (-)
1	LT	999.11 days	129.75 days
	D	6 units	982 units
	O	519.63 DKK	140.68 DKK
2	LT	907.29 days	0.07 days
	D	11 units	980 units
	O	428.82 DKK	0.00 DKK
3	LT	25.00 days	1.00 day
	D	1 unit	6,250 units
	O	141.65 DKK	30.59 DKK
4	LT	36.83 days	1.76 days
	D	12,142 units	28,6365 units
	O	48.81 DKK	0.00 DKK
5	LT	41.00 days	25.50 days
	D	1 unit	11,901 units
	O	89.11 DKK	0.00 DKK
6	LT	25.60 days	12.00 days
	D	1 units	12,092 units
	O	71.22 DKK	0.00 DKK
7	LT	78.00 days	42.00 days
	D	1 units	17,318 units
	O	79.76 DKK	0.00 DKK
8	LT	12.86 days	1.00 day
	D	1 unit	11,992 units
	O	39.13 DKK	0.00 DKK

LT: Lead time D: Demand O: Overhead Cost

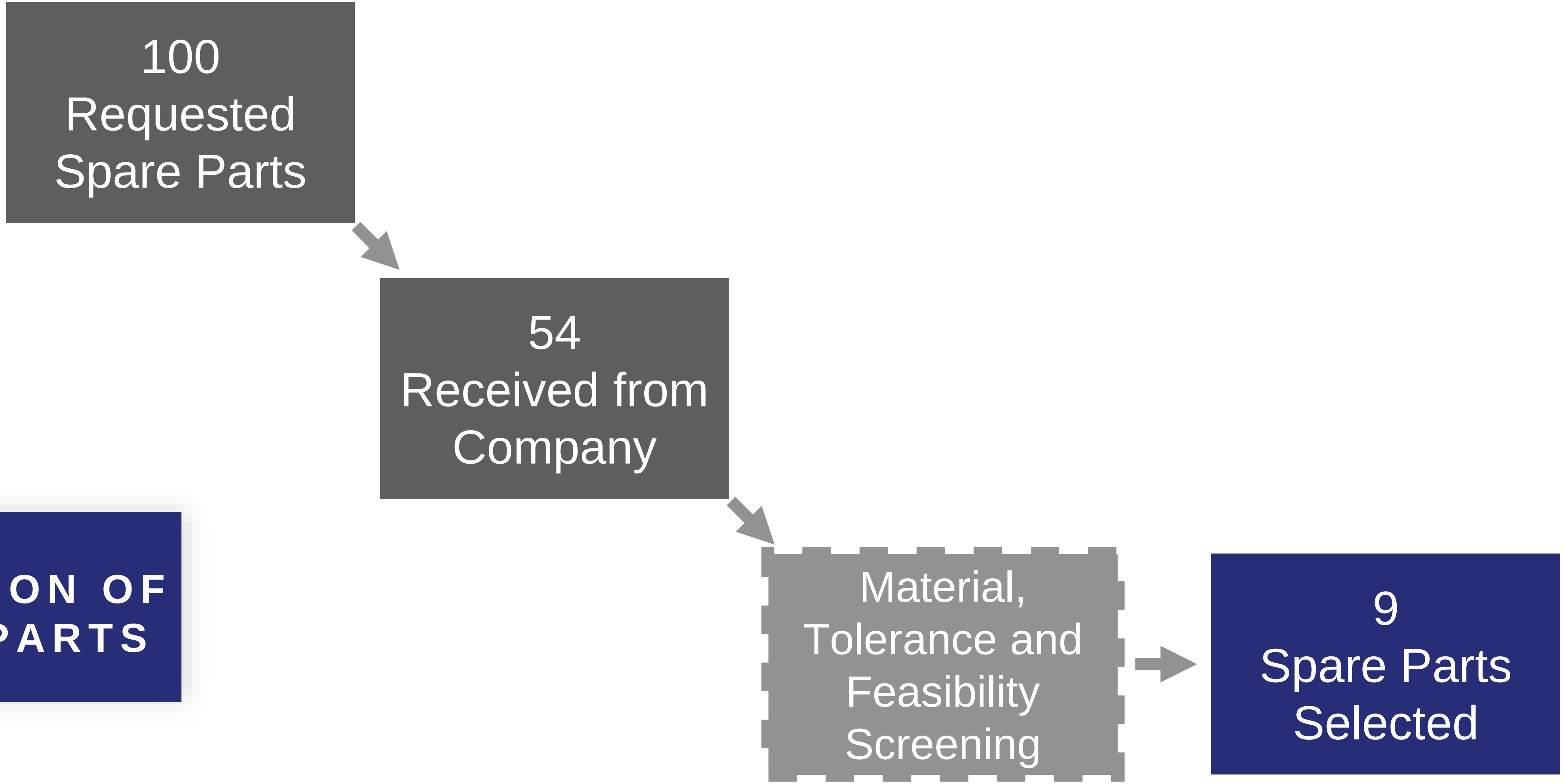


List of the most appropriate spare parts within each cluster

1.
2.
3.
4.
5. SELECTION OF SPARE PARTS
6.

Choosing Spare Parts

The Process Illustrated



Which approach to use in what context

1. **Multi-criteria decision making approach (MCDM)** –scoring parts on factors and linking factors to be objectives (suitable for less number of factors and less number of parts)
2. **Logic decison diagrams, cluster analysis and fuzzy inference system** (large number of parts, medium number of factors but strong interrelationships of factors and objectives)
3. **Cluster analysis and MCDM approach for ranking of part clusters and within cluster ranking of parts** (large number of parts, limited to medium number of factors and independence of factors)
4. **Bottom-up expert driven selection using a questionnaire or selection protocol** (no data available or not possible to do quantitative analysis)

Key take aways

- No ”one-size fit –all” approach
- Each company must choose the most appropriate approach based on multiple factors
    - Application area- spare parts, parts for new products,
    - whether redesign for AM is considered or not
    - Data availability etc
- Need to update the printer database to identify limits of AM technologies
- A group of cross-functional experts from the company should be involved through the entire process
- If there is no data- use bottom-up approach
- Use machine learning based feature recognition to automate part-identification process

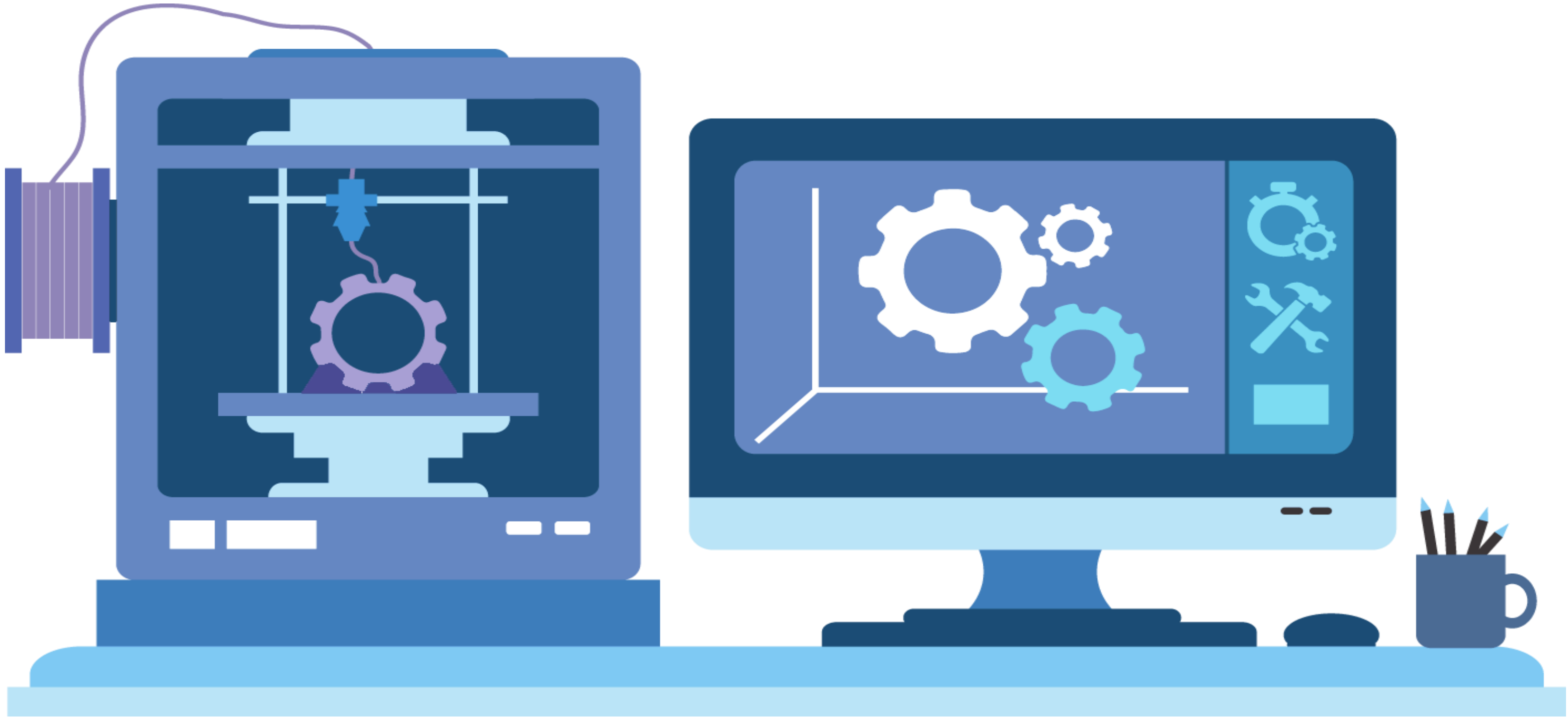
Commercial software to help you in part selection for additive manufacturing

3YOURMIND

CORETECHNOLOGIE

Questions

and Answers



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