Danfoss - Aftermarket Workflow and Process Creation and Implementation

Team:504

Team Introductions

David Bishop
Manufacturing Engineer

Alex Wilson
Process Engineer

Kyle Youmans
Control Engineer

Julian Villamil
Test Engineer

David Bishop

Sponsor and Advisor

Engineering Mentor
Shayne McConomy, Ph.D
Professor

Project Advisor
Yousuf Ali, Ph.D.
Professor

Engineering Mentor
Stephen Seymore
Operations Engineer Director

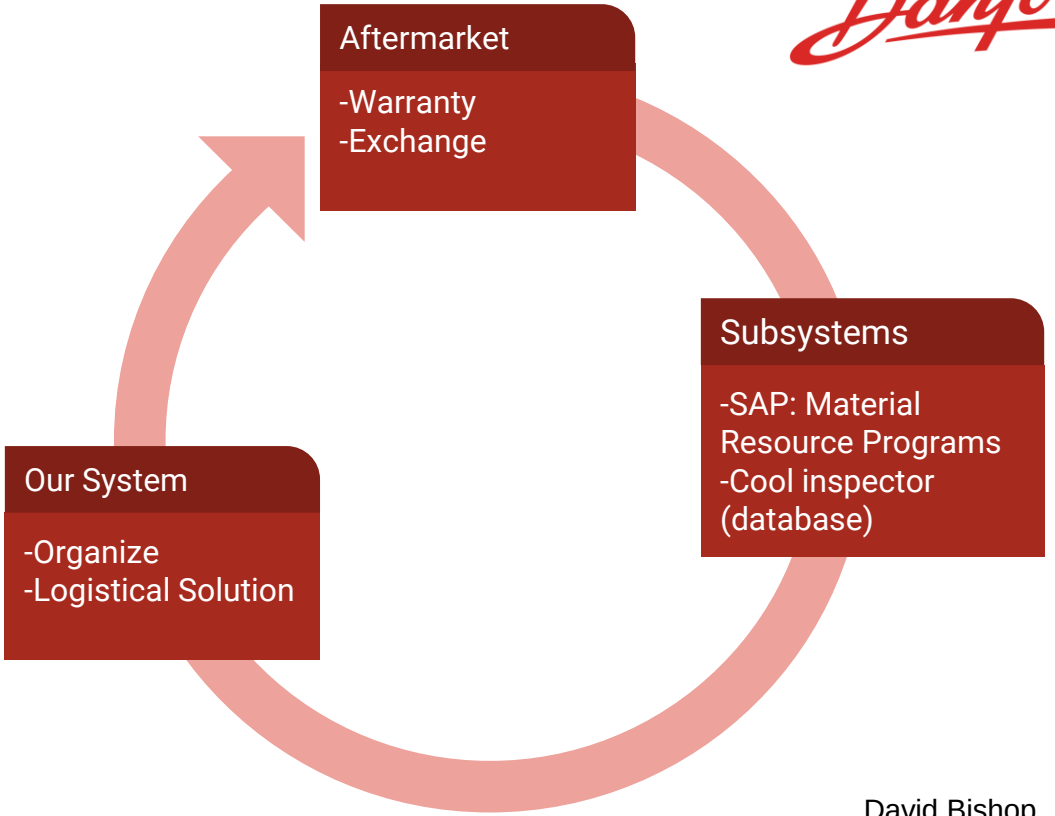
David Bishop

Previous Work Recap

David Bishop

Project Objective

"A system that coordinates existing record keeping subsystems to organize aftermarket production, preventing aftermarket parts from entering into new production. The system is automated and more effective than older subsystems."



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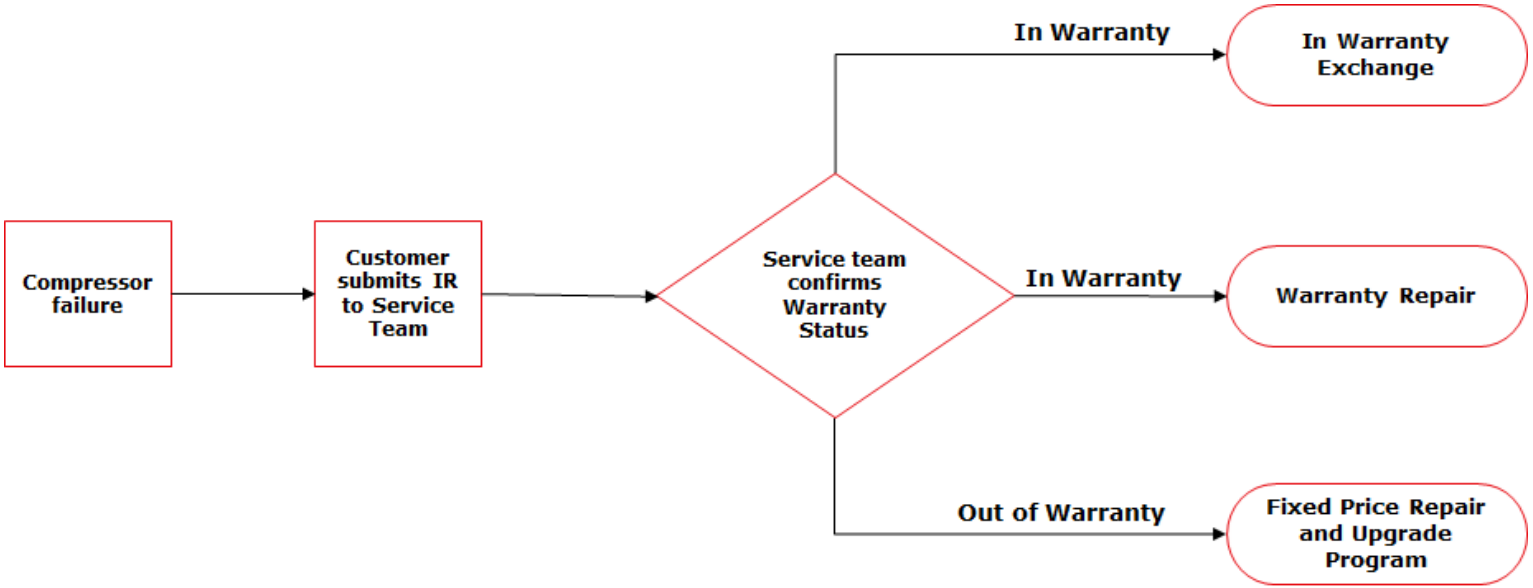
Future Aftermarket Repair Programs



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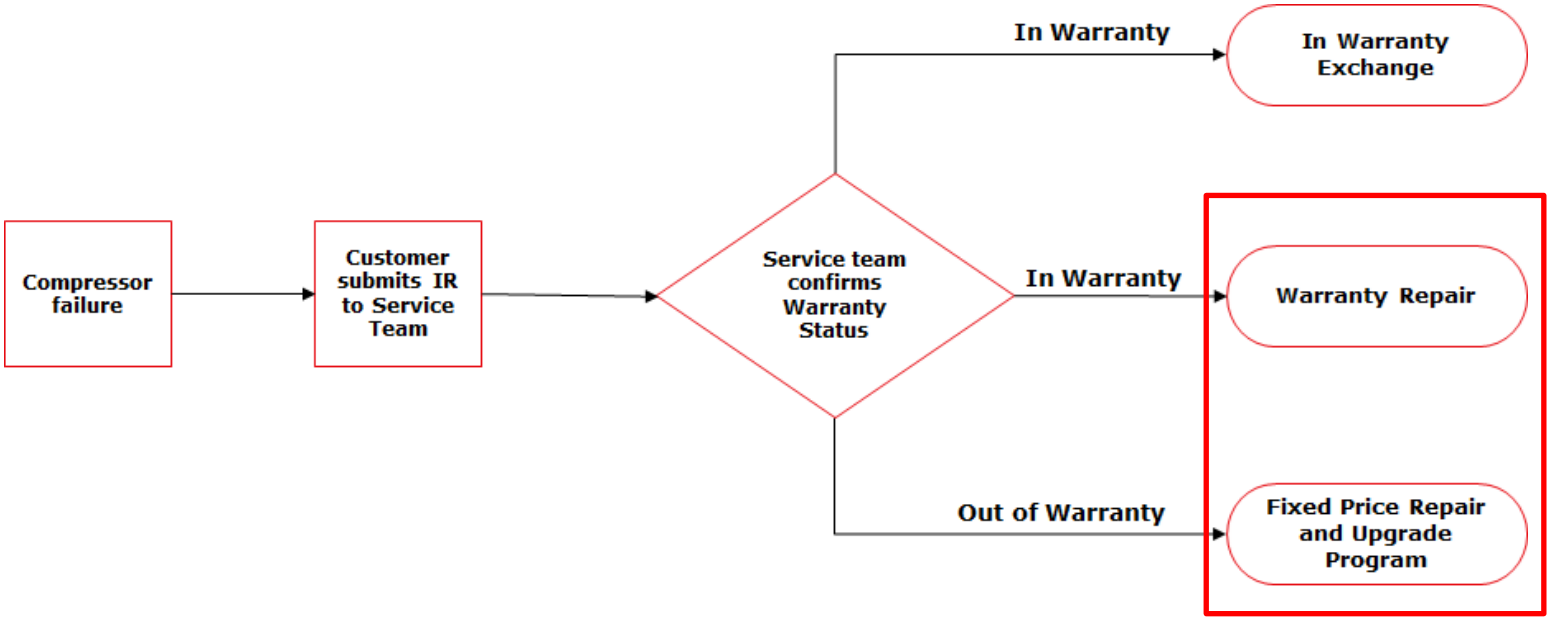
Future Aftermarket Repair Programs



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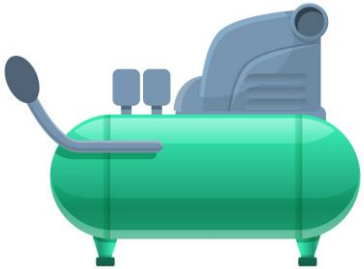
What's the Process?

Where we come in

Receive Compressor | Inspection | Planning | Production | Pack & Ship



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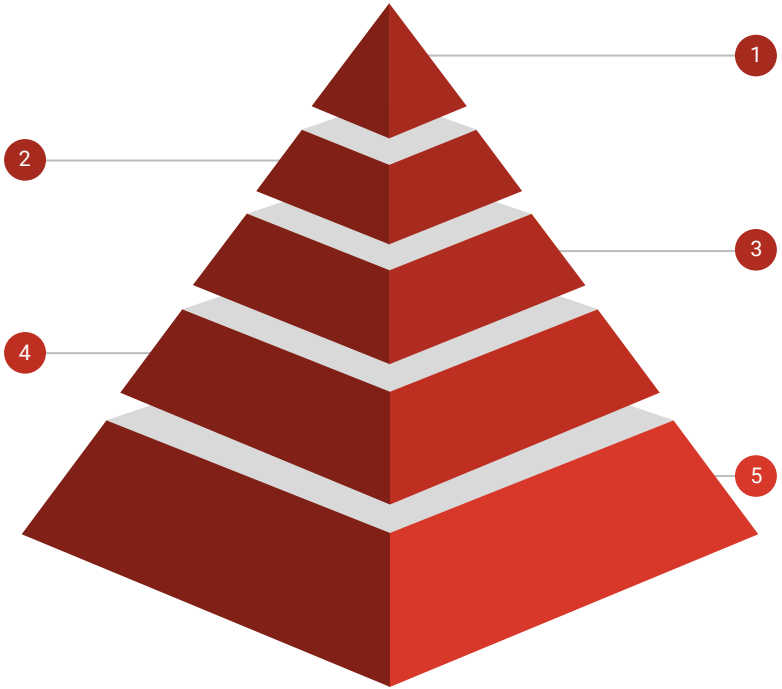
Interpreted Needs

Automation
The system is more robust than the current process with fewer human errors due to an automated design.

User Experience
System is capable of providing its outputs in a format that is accessible and easily understood by a common audience.



Organization
The system needs to catalog and store data in an organized way.

Quality
Aftermarket compressors are shipped back to their customers at the same level of performance or higher based on the bill of materials generated by the system

Adaptability
System is easily updated as software changes and input information changes

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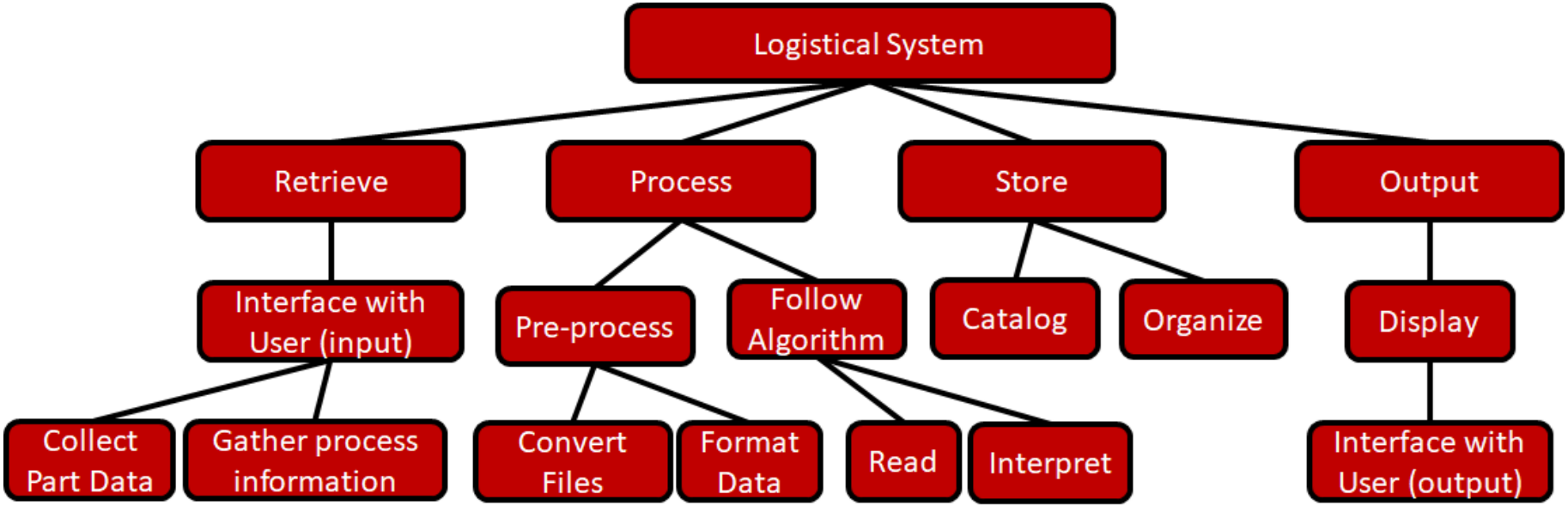
Functional Flow Chart



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Project Overview Following the “McConomy” Method

Targets and Metrics

How to validate functions?

- Analyzing subfunctions
- Relate subfunctions to a target and metric

Concept Generation

Creative thinking to produce possible concepts

- Concept generation tools
- High and medium fidelity concepts

Concept Selection

Determining the best fit solution

- Quality Function Deployment
- Pugh charts
- Analytical hierarchy process

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Targets and Metrics

Targets and Metrics

Binary : 1	Data Format Accuracy
100%	Part Conversion Efficiency
93%	Reliability
Customer Satisfaction Survey = 5	Code Complexity
Binary : 1	File Location Accuracy
Customer Satisfaction Survey = 5	Organization

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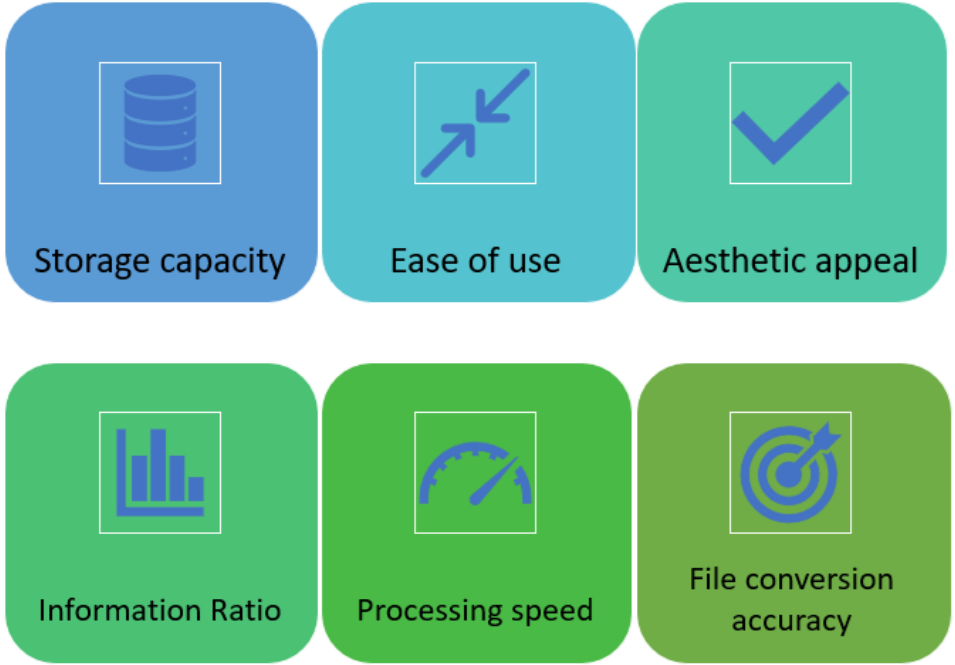
Targets and Metrics

- 10 Megabytes
- Number of Clicks = 1
- Customer Satisfaction Survey = 5
- 100%
- 2GHz – 4GHz in Task Manager
- 100%



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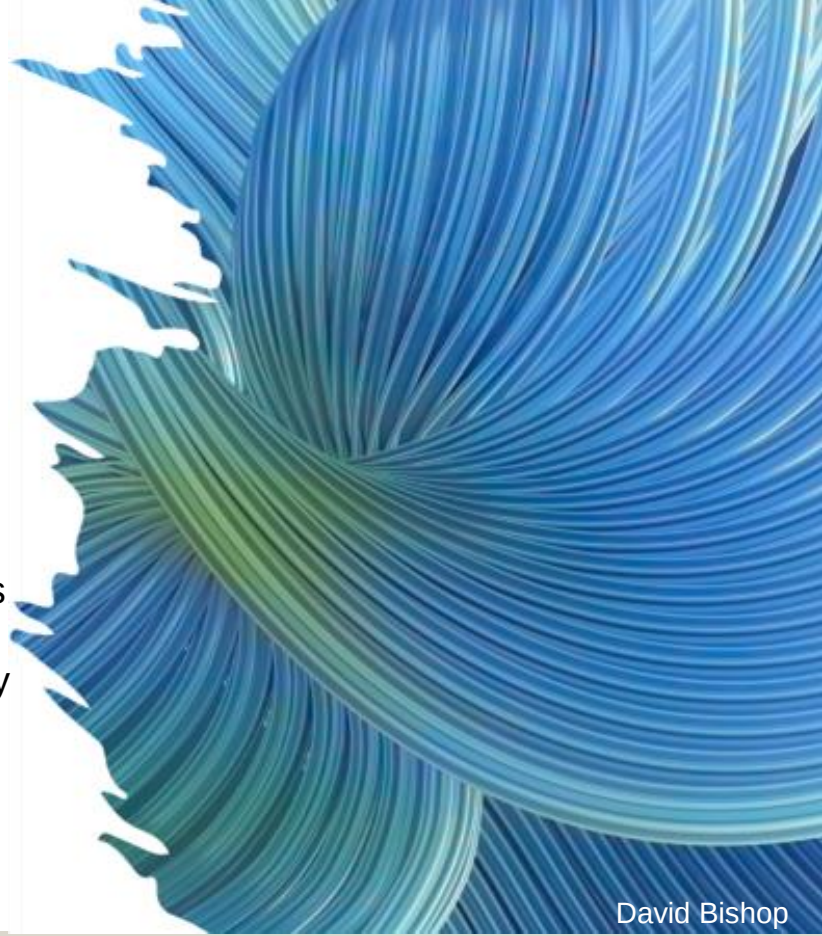
Critical Targets and Metrics

Storage

- Need enough storage space to:
  - Retrieve data
  - Run System
  - Store Data
- Target 10MB file I/O size

Reliability

- Needs to work better than current method:
  - Reduce human errors
  - Increase part replacement accuracy
- Target 93% reliability



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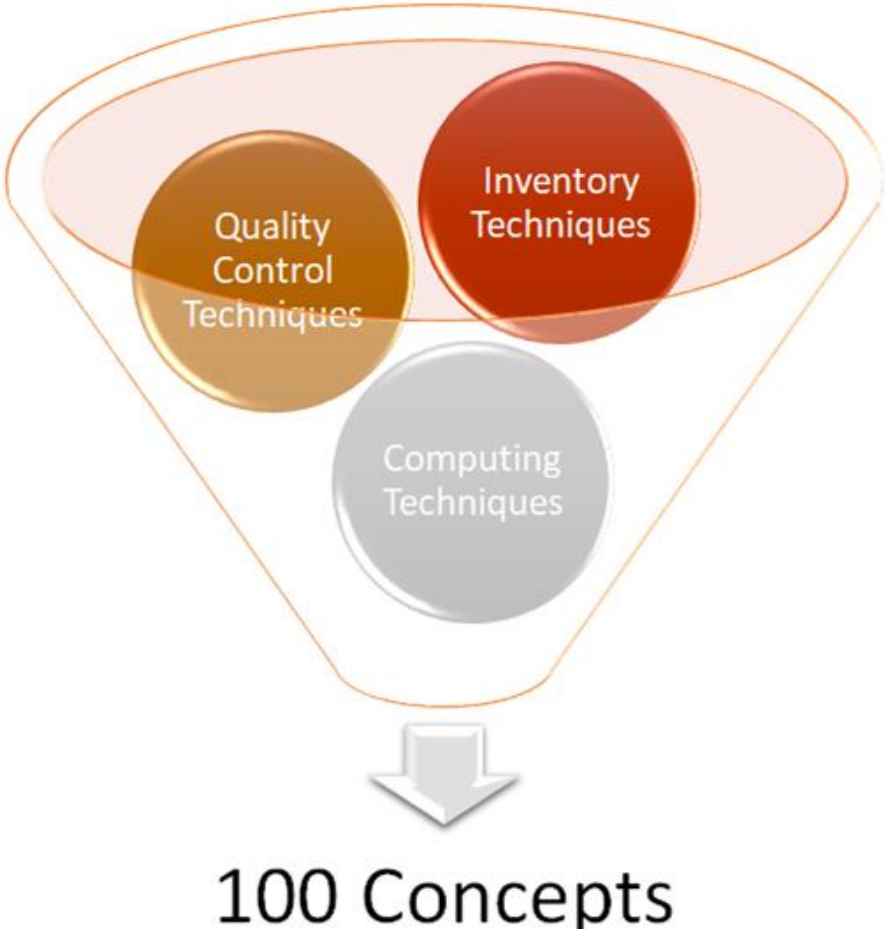
Concept Generation


Quality Control Techniques
Inventory Techniques
Computing Techniques
100 Concepts

100 concepts

Inventory Techniques

- Six Sigma
- Economic Order

Quality Control Techniques

- Controls Chart
- Statistical Sampling
- Histograms

Computing Techniques

- MATLAB
- Python
- C++

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High Fidelity Concepts

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Concept 1

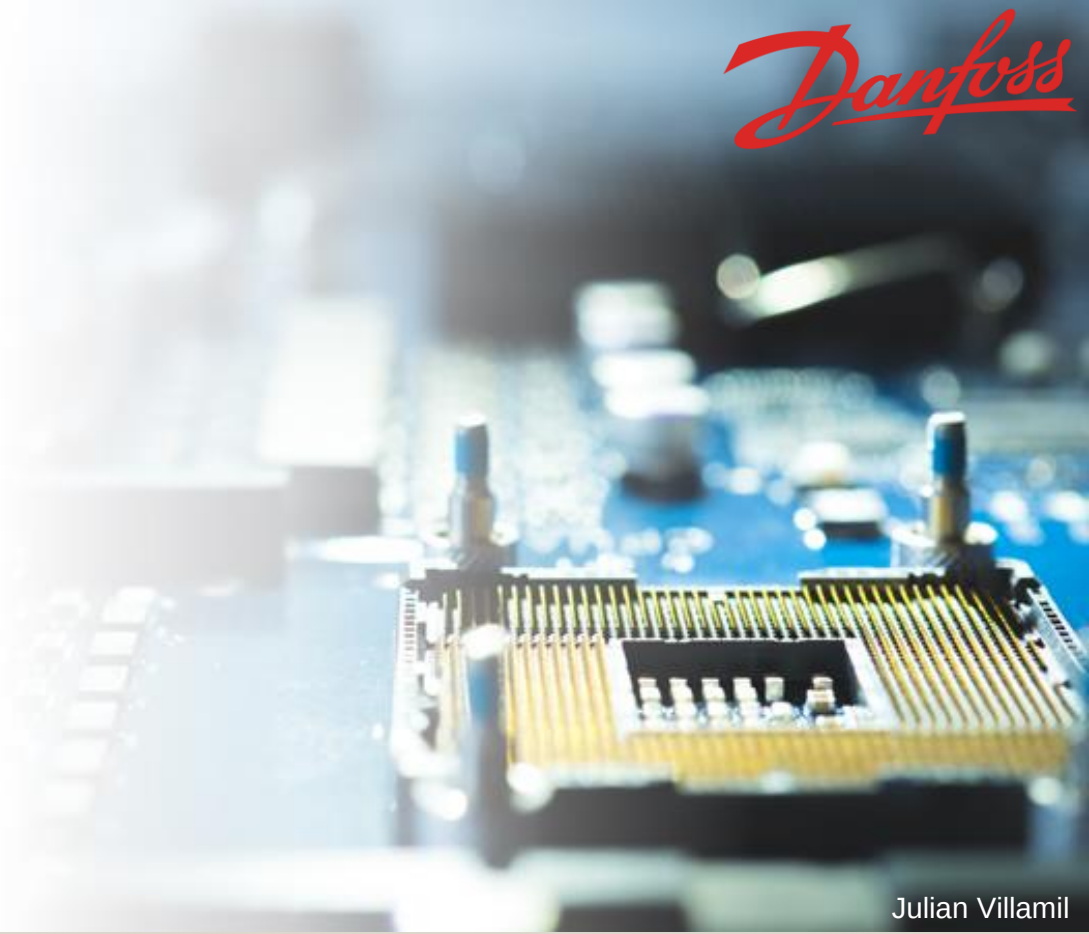
Script and Database Design

CREATE DATABASE

USE DATABASE FOR SCRIPT INPUTS

PROCESS DATA

EXPORT FILES



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Concept 2

Filing System

- Manufacturing engineering solution
  - New responsibilities
    - Investigations
    - Planners
    - Manufacturing Engineers
  - Filing System
    - Part Failure File
    - Part Replacements file
  - Open Loop

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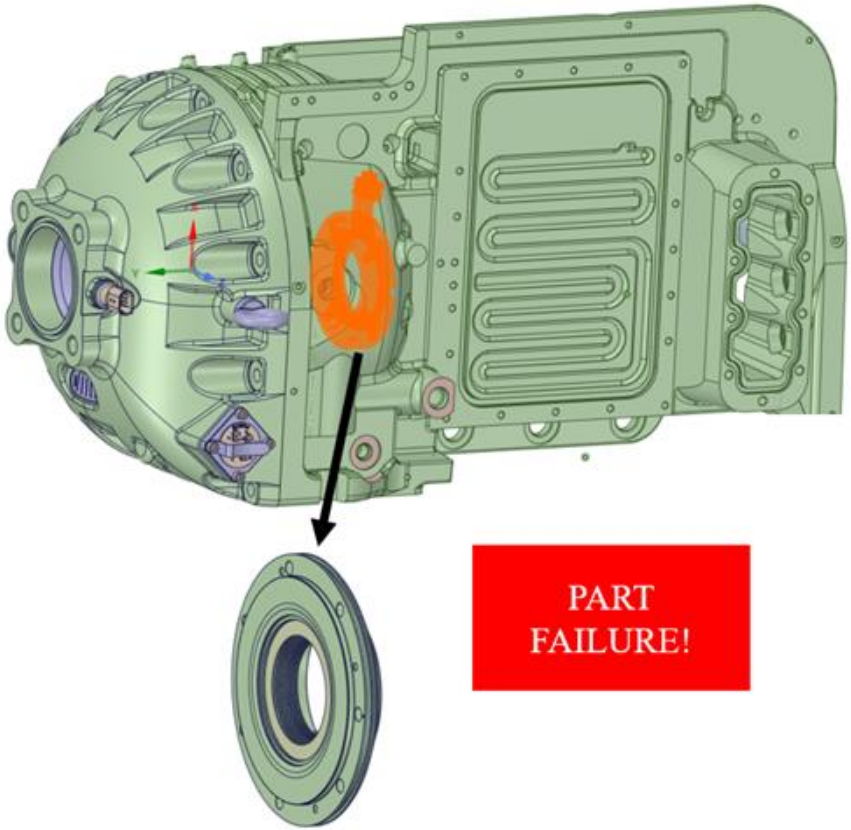
Concept 3

PART FAILURE INPUT FILES

GRAPHIC USER INTERFACE



CAD COMPARISON

BILL OF MATERIALS

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Medium Fidelity Concepts

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Concept 4

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Concept 5

Virtual Compressor Logs

Virtual work space where all aftermarket teams meet.

- Streamlines information
- Updates on real time
- Advanced filing

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Concept 6

Artificial Intelligence

- Advanced script that updates itself after every run.
  - Increases correct part replacement accuracy.
- Can convert handwritten data into digital data.
- Compressor repair data trains AI.
  - Tells AI everything not to try.
  - Helps AI make better part replacements.

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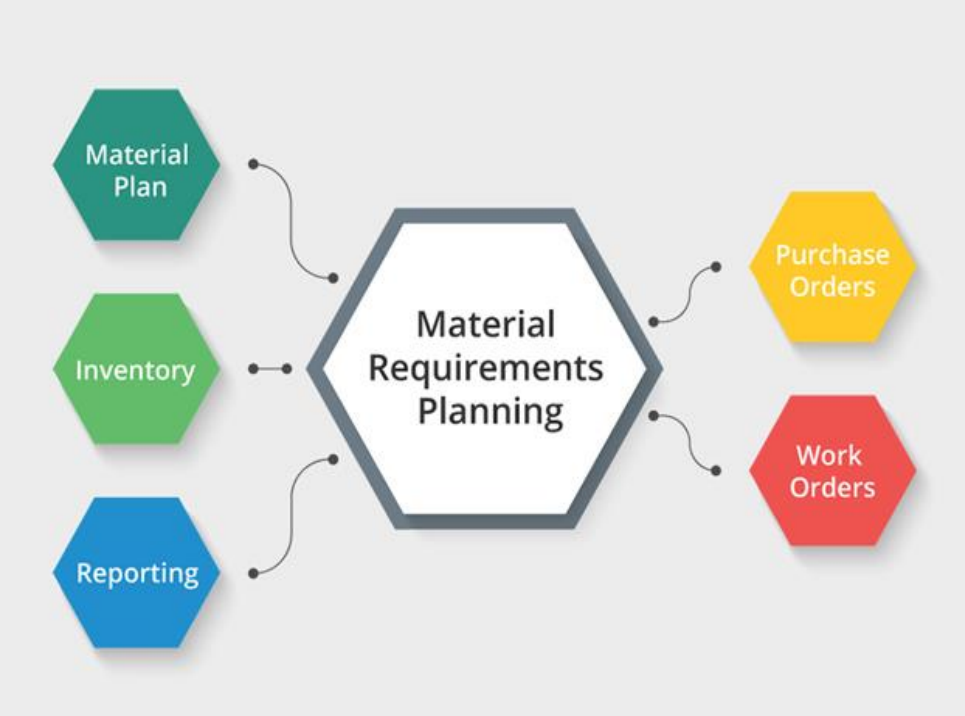
Concept 7

Material Resource Planning System

- MRP ensures there will always be parts available.
- No transfer of data outside their SAP cloud.
- Records parts requested for part replacement planning.



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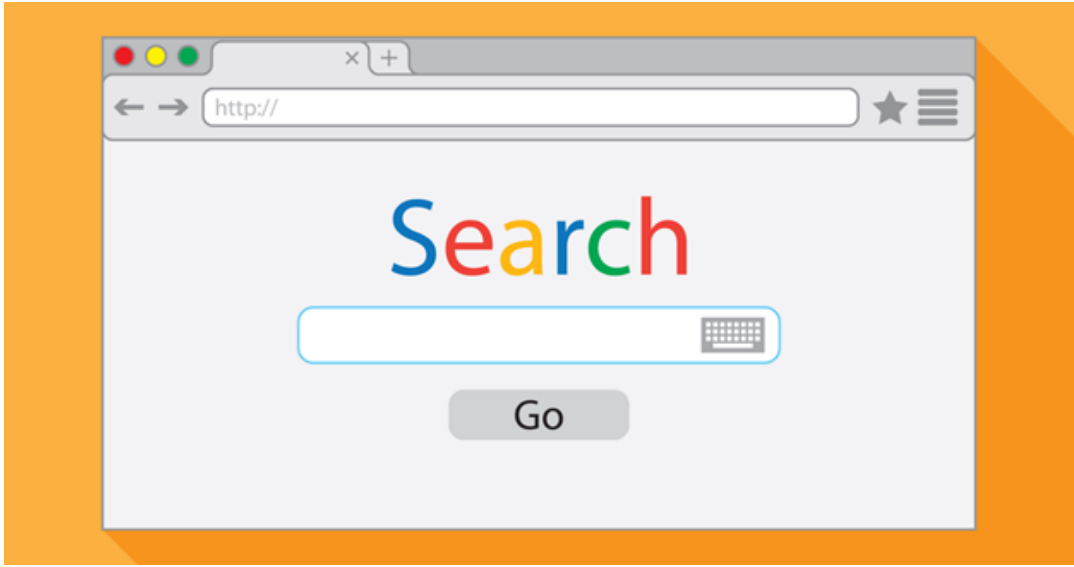
Concept 8

Digital Part Library

- Search engine
  - Search bar
  - File directory based
  - Extensive library

- Part replacement
  - Provides part information
  - Filtering features
  - Records successful repairs



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Concept Selection

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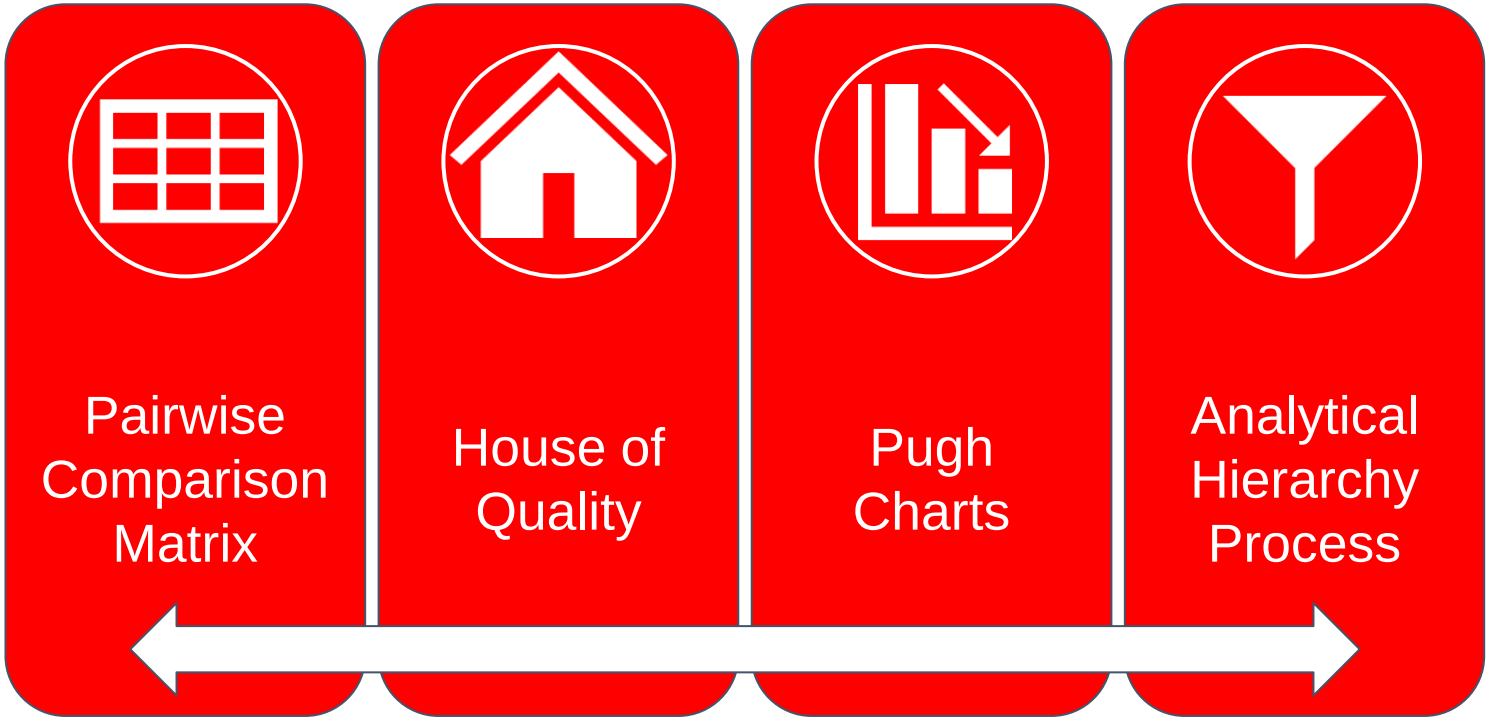
Concept Selection



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Quality Function Deployment

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Quality Function Deployment

Quality Function Deployment

"Infuse the voice of the customer into the design process"

Binary Pairwise

This matrix quantifies the customer requirements

House Of Quality

Quantifies how the engineering characteristics will satisfy the customer requirements

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Quality Function Deployment

Quality Function Deployment

"Infuse the voice of the customer into the design process"

Binary Pairwise

This matrix quantifies the customer requirements

Customer Requirement	Weight Factor
Organization	**4**
Automate	**3**
Quality Control	**2**
User Experience	**0**
Adaptability	**1**

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Quality Function Deployment

Quality Function Deployment

"Infuse the voice of the customer into the design process"

Binary Pairwise

This matrix quantifies the customer requirements

House Of Quality

Quantifies how the engineering characteristics will satisfy the customer requirements

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Quality Function Deployment

Engineering Characteristics	Rank
Speed (sec)	8
Storage Capacity (bytes)	7
Accuracy (%)	2
Usability	3
Aesthetic	5
Maintainability	4
Simplicity	6
Reliability (%)	1

House Of Quality

Quantifies how the engineering characteristics will satisfy the customer requirements

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Pugh Charts

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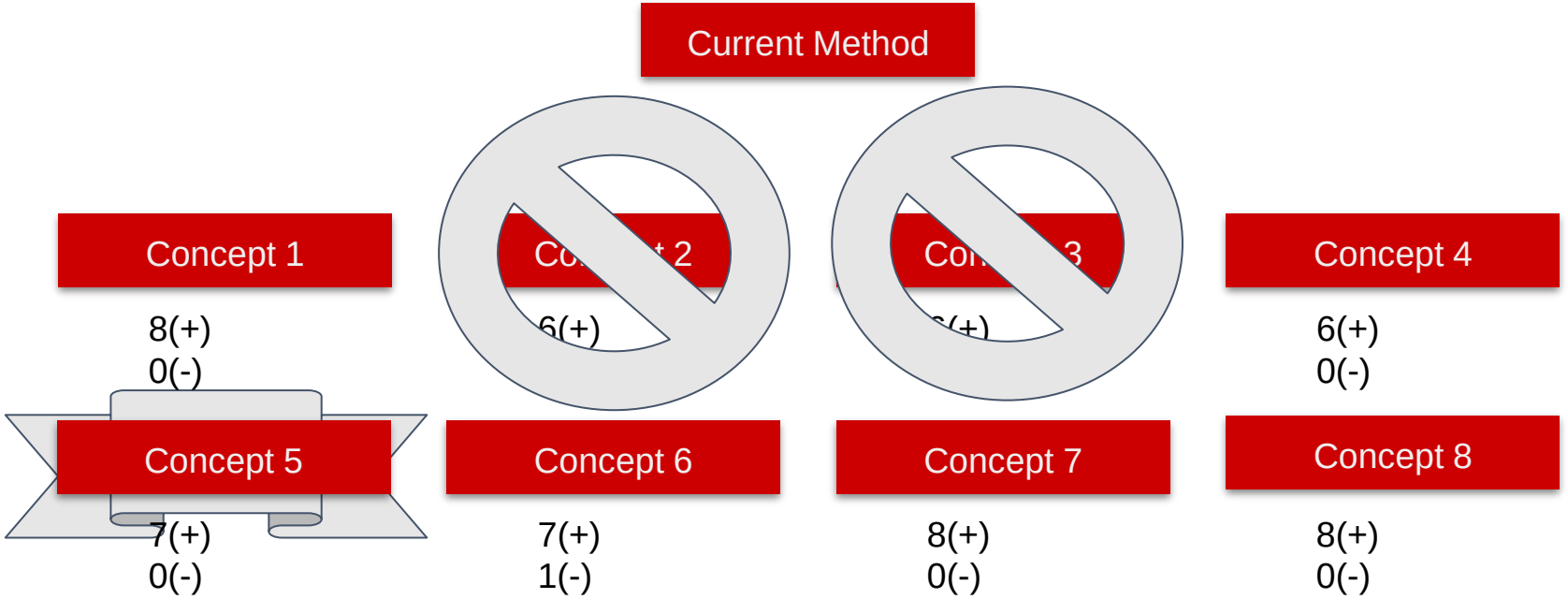
Pugh Chart



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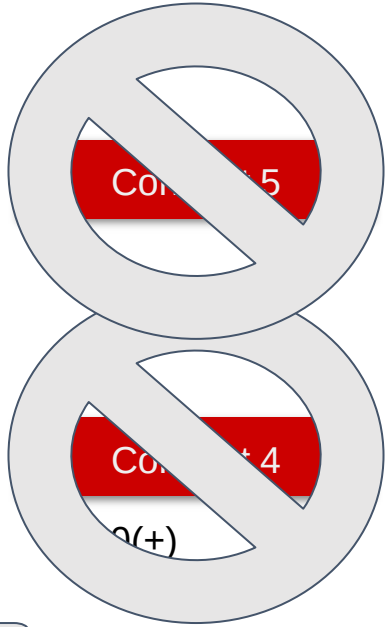
Pugh Chart



Concept 1

8(+)
0(-)

Concept 6

7(+)
1(-)

Concept 7

8(+)
0(-)

Concept 8

7(+)
0(-)

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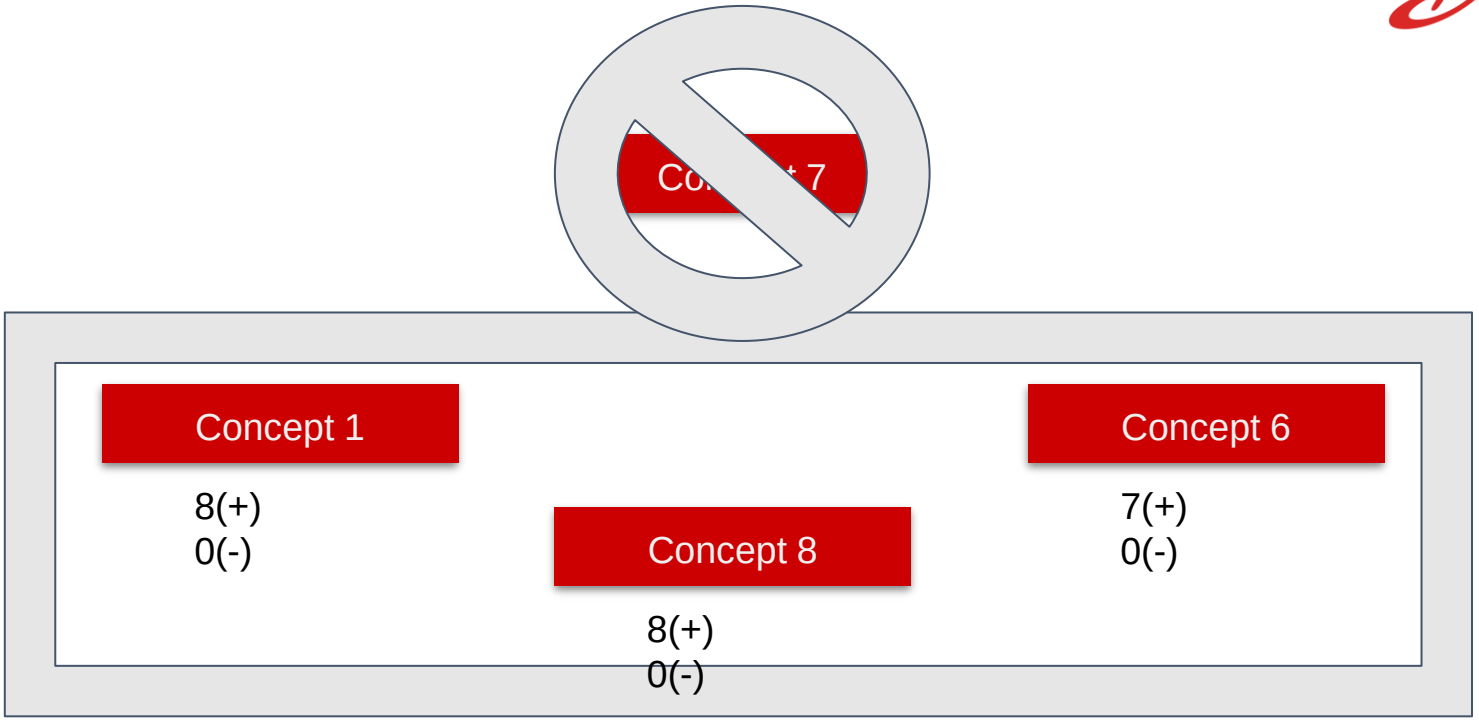
Pugh Chart



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Analytical Hierarchy Process

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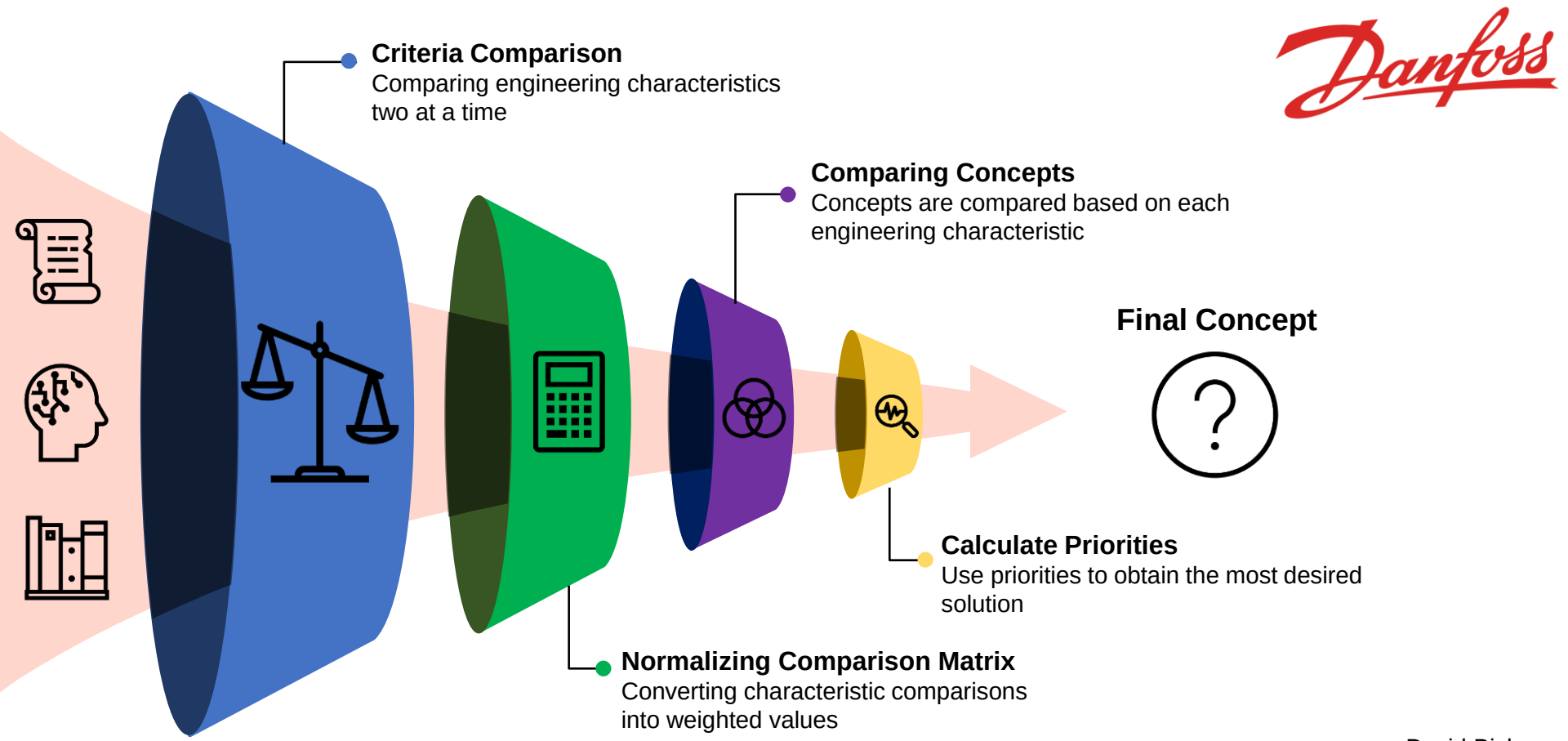

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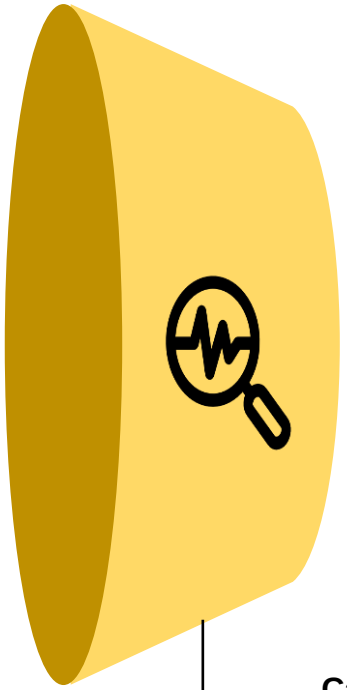

Concept	Alternative Value
Script and Database	0.184
A.I.	0.571
Digital Library	0.245

Highest number is normally best design

There was an error in our calculation

Lowest alternative value is considered best solution

Calculate Priorities
Use priorities to obtain the most desired solution

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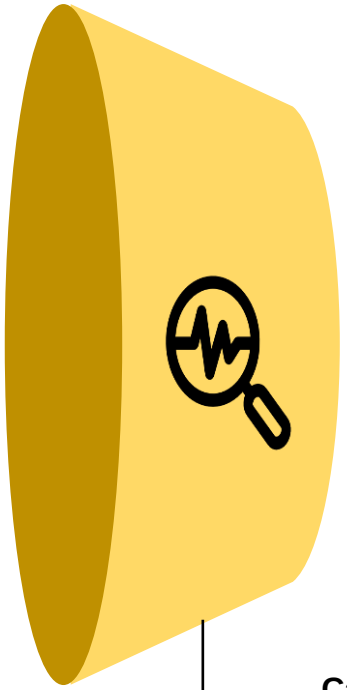

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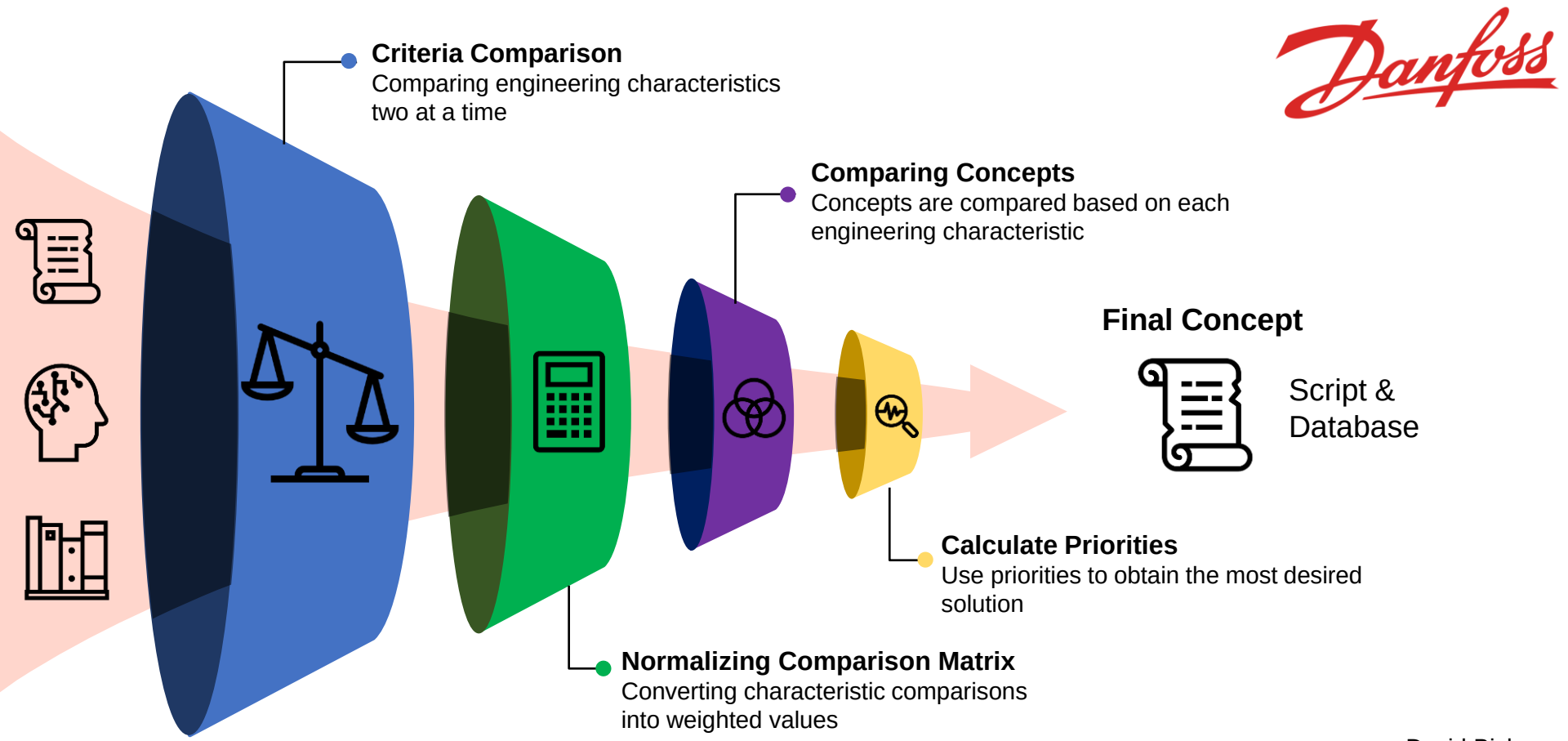

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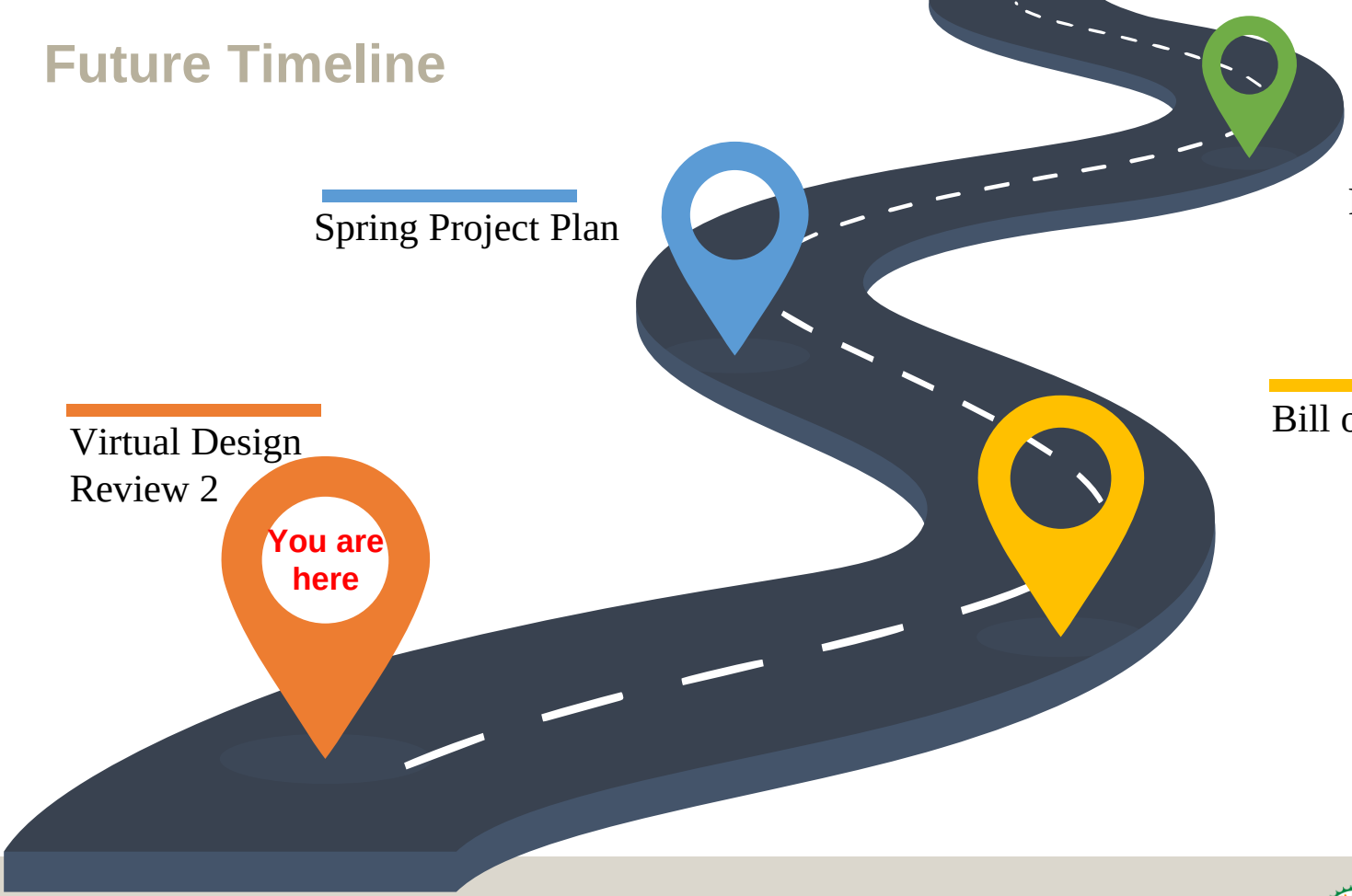
Future Timeline



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Reference

[1] Seymore, Stephen. (2020). Aftermarket Services Danfoss Turbocor® Compressors. [PowerPoint slides]. Retrieved from https://3.basecamp.com/3939307/buckets/18515621/uploads/3119943154

[2] McConomy, Shayne. (2020). Aftermarket Workflow Project 2020. [Word document]. Retrieved from https://3.basecamp.com/3939307/buckets/18515621/uploads/3078752695

[3] Bishop et al. (2020). SD T504 201106 Concept Generation and Selection. [Word document]. Retrieved from https://famu-fsu-eng.instructure.com/courses/4476/assignments/18861/submissions/102840000000061346

[4] Seymore, Stephen. (2020). Special Compressor Process. Danfoss Turbocor®. [PDF file]. Retrieved from https://3.basecamp.com/3939307/buckets/18515621/uploads/3119943196

Questions?

Backup Slides

Morphological Chart

Morphological Chart			
Coding Language	Python	MATLAB	C
Quality Control Method	Pareto Analysis	Stratification	Statistical Sampling
Inventory Control Method	Six Sigma	Drop shipping	Lean Manufacturing

Binary Pairwise

Binary Pairwise Graph

	1	2	3	4	5	Total
1. Organization	-	1	1	1	1	4
2. Automate	0	-	1	1	1	3
3.Quality Control	0	0	-	1	1	2
4. User Experience	0	0	0	-	0	0
5. Adaptability	0	0	0	1	-	1
Total	**0**	**1**	**2**	**4**	**3**	**10**

House of Quality

House of Quality									
		Engineering Characteristics							
Improvement Direction		↑	↑	↑	↑	↑	↑	↑	↓
	Units	sec	byte	%	n/a	n/a	n/a	n/a	%
Customer Requirements	Importance Weight Factor	Speed	Storage Capacity	Accuracy	Usability	Aesthetic	Maintainability	Simplicity	Reliability
Organizes	5	1	3	9	1	1	3	1	9
Automate	4	1	0	1	9	0	9	1	3
Controls Quality	3	0	1	9	1	0	3	3	9
Interacts with User	2	0	1	1	9	9	0	3	1
Adaptible	1	0	3	1	9	1	9	3	3
Raw Score (391)		9	23	79	71	24	69	27	89
Relative Weight %		2.30%	5.88%	20.20%	18.16%	6.14%	17.65%	6.91%	22.76%
Rank Order		8	7	2	3	5	4	6	1

First Pugh Chart

Selection Criteria		Concepts							
		1	2	3	4	5	6	7	8
Speed	Datum (Current Method)	+	+	+	+	+	+	+	+
Storage Capacity		+	-	-	S	S	-	+	+
Accuracy		+	+	+	+	+	+	+	+
Usability		+	+	+	+	+	+	+	+
Aesthetic		+	+	+	S	+	+	+	+
Maintainability		+	+	+	+	+	+	+	+
Simplicity		+	-	-	+	+	+	+	+
Reliability		+	+	+	+	+	+	+	+
Pluses		8	6	6	6	7	7	8	8
Minuses		0	2	2	0	0	1	0	0

Second Pugh Chart

Selection Criteria		Concepts 1	4	6	7	8
Speed	Datum (Concept 5)	+	S	+	+	+
Storage Capacity		+	-	-	+	S
Accuracy		+	-	+	+	+
Usability		+	-	+	+	+
Aesthetic		+	-	+	+	+
Maintainability		+	-	+	+	+
Simplicity		+	-	+	+	+
Reliability		+	-	+	+	+
Pluses		8	0	7	8	7
Minuses		0	7	1	0	0

Third Pugh Chart

Selection Criteria		Concepts		
		1	6	8
Speed	Datum (Concept 7)	S	+	-
Storage Capacity		S	-	S
Accuracy		+	+	S
Usability		-	+	S
Aesthetic		S	S	S
Maintainability		-	+	+
Simplicity		+	-	+
Reliability		+	+	S
Pluses		3	5	2
Minuses		1	2	1

Target Catalog

Metric	Target
Storage Capacity	0 < x < 10 Megabytes
Ease of Use	Number of clicks by user 1
Aesthetic Appeal	1-5 (customer satisfaction survey) 5
Information Obtained to Total Information Needed	100%
Processing Speed	2 GHz to 4.0 GHz
File Conversion Accuracy	Files converted to files requested 100%
Data Format Accuracy	File matches column and row assigned Binary (1-0)
Part Conversion Efficiency	Ratio of parts exchanged correctly to total parts exchanged 100%
Reliability	Below 7% average failure rate
Code Complexity	1-5 (customer satisfaction survey) 5
File Location Accuracy	Files placed in the correct location Binary (1-0)
Organization	1-5 (customer satisfaction survey) 5

Customer Survey

Customer Satisfaction Survey					
Question 1 = unacceptable 2 = poor 3 = satisfactory 4 = good 5 = excellent	Order of Satisfaction				
	1	2	3	4	5
How aesthetically appealing is the display of the product?					
Is the code readable, organized, and reproducible?					
How does the product compare to the previously used method?					

Criteria Comparison Matrix [C]								
	Speed	Storage Capacity	Accuracy	Usability	Aesthetic	Maintainability	Compactness	Reliability
Speed	1	3	5	3	0.33	5	3	5
Storage Capacity	0.33	1	5	0.33	0.20	3	1	3
Accuracy	0.20	0.20	1	0.33	0.20	0.33	0.33	1
Usability	0.33	3	3	1	0.33	3	1	3
Aesthetic	3	5	5	3	1	5	5	5
Maintainability	0.20	0.33	3	0.33	0.20	1	0.33	1
Compactness	0.33	1	3	1	0.20	3	1	3
Reliability	0.20	0.33	1	0.33	0.20	1	0.33	1
Sum	5.60	13.87	26	9.33	2.67	21.33	12	22

Normalized Criteria Comparison Matrix									
	Speed	Storage Capacity	Accuracy	Usability	Aesthetic	Maintainability	Compactness	Reliability	Criteria Weight (W)
Speed	0.179	0.216	0.192	0.321	0.125	0.234	0.250	0.227	0.218
Storage Capacity	0.060	0.072	0.192	0.036	0.075	0.141	0.083	0.136	0.099
Accuracy	0.036	0.014	0.038	0.036	0.075	0.016	0.028	0.045	0.036
Usability	0.060	0.216	0.115	0.107	0.125	0.141	0.083	0.136	0.123
Aesthetic	0.536	0.361	0.192	0.321	0.375	0.234	0.417	0.227	0.333
Maintainability	0.036	0.024	0.115	0.036	0.075	0.047	0.028	0.045	0.051
Compactness	0.060	0.072	0.115	0.107	0.075	0.141	0.083	0.136	0.099
Reliability	0.036	0.024	0.038	0.036	0.075	0.047	0.028	0.045	0.041
Sum	1	1	1	1	1	1	1	1	1

AHP

Consistency Check		
{Ws}=[C]{W} Weighted Sum Factor	{W} Criteria Weights	Cons={Ws}./{W} Consistency Vector
1.932	0.218	8.854
0.834	0.099	8.393
0.298	0.036	8.274
1.087	0.123	8.841
2.986	0.333	8.969
0.417	0.051	8.221
0.844	0.099	8.553
0.345	0.041	8.391

λ=8.562
CI= (λ-n)/(n-1) = (8.562-8)/(8-1)=.0803
CR= CI/RI=.0803/1.4=.0574
CR < 0.1

AHP

Speed Comparison Norm				
	Script and Database	A.I.	Digital Library	Design Alternative Priorities
Script and Database	0.091	0.130	0.048	0.090
A.I.	0.455	0.652	0.714	0.607
Digital Library	0.455	0.217	0.238	0.303
Sum	1	1	1	1

Consistency Check		
{Ws}=[C]{W} Weighted Sum Factor	{W} Criteria Weights	Cons={WS}./{W} Consistency Vector
0.272	0.090	3.031
1.965	0.607	3.238
0.954	0.303	3.145

λ=3.138
CI= (λ-n)/(n-1) = (8.562-3)/(3-1)=.069
CR= CI/RI=.0803/0.52=0.132

AHP

Storage Capacity Comparison Norm				
	Script and Database	A.I.	Digital Library	Design Alternative Priorities
Script and Database	0.143	0.143	0.143	0.143
A.I.	0.714	0.714	0.714	0.714
Digital Library	0.143	0.143	0.143	0.143
Sum	1.000	1.000	1.000	1.000

Consistency Check		
{Ws}=[C]{W} Weighted Sum Factor	{W} Criteria Weights	Cons={WS}./{W} Consistency Vector
0.429	0.143	3
2.143	0.714	3
0.429	0.143	3

λ=3

CI= (λ-n)/(n-1) = (3-3)/(3-1)=0

CR= CI/RI=0/0.52=0

AHP

Usability Comparison Norm				
	Script and Database	A.I.	Digital Library	Design Alternative Priorities
Script and Database	0.231	0.217	0.333	0.260
A.I.	0.692	0.652	0.556	0.633
Digital Library	0.077	0.130	0.111	0.106
Sum	1	1	1	1

Consistency Check		
{Ws}=[C]{W} Weighted Sum Factor	{W} Criteria Weights	Cons={WS}./{W} Consistency Vector
0.790	0.260	3.033
1.946	0.633	3.072
0.320	0.106	3.011

λ=3.137
CI= (λ-n)/(n-1) = (3.137-3)/(3-1)=0.069
CR= CI/RI=0.069/0.52=0.132

AHP

Accuracy Comparison Norm				
	Script and Database	A.I.	Digital Library	Design Alternative Priorities
Script and Database	0.143	0.2	0.077	0.140
A.I.	0.429	0.6	0.692	0.574
Digital Library	0.429	0.2	0.231	0.286
Sum	1	1	1	1

Consistency Check		
{Ws}=[C]{W} Weighted Sum Factor	{W} Criteria Weights	Cons={WS}./{W} Consistency Vector
0.427	0.140	3.049
1.853	0.574	3.230
0.897	0.286	3.133

λ=3.039

CI= (λ-n)/(n-1) = (3.039-3)/(3-1)=0.019

CR= CI/RI=0.019/0.52=0.037

AHP

Aesthetic Comparison Norm				
	Script and Database	A.I.	Digital Library	Design Alternative Priorities
Script and Database	0.2	0.2	0.2	0.2
A.I.	0.6	0.6	0.6	0.6
Digital Library	0.2	0.2	0.2	0.2
Sum	1	1	1	1

Consistency Check		
{Ws}=[C]{W} Weighted Sum Factor	{W} Criteria Weights	Cons={WS}./{W} Consistency Vector
0.6	0.2	3
1.8	0.6	3
0.6	0.2	3

λ=3
CI= (λ-n)/(n-1) = (3-3)/(3-1)=0
CR= CI/RI=0/0.52=0

AHP

Maintainability Comparison Norm				
	Script and Database	A.I.	Digital Library	Design Alternative Priorities
Script and Database	0.2	0.2	0.2	0.2
A.I.	0.6	0.6	0.6	0.6
Digital Library	0.2	0.2	0.2	0.2
Sum	1	1	1	1

Consistency Check		
{Ws}=[C]{W} Weighted Sum Factor	{W} Criteria Weights	Cons={WS}./{W} Consistency Vector
0.6	0.2	3
1.8	0.6	3
0.6	0.2	3

λ=3
CI= (λ-n)/(n-1) = (3-3)/(3-1)=0
CR= CI/RI=0/0.52=0

AHP

Compactness Comparison Norm				
	Script and Database	A.I.	Digital Library	Design Alternative Priorities
Script and Database	0.231	0.429	0.2	0.286
A.I.	0.077	0.143	0.2	0.140
Digital Library	0.692	0.429	0.6	0.574
Sum	1	1	1	1

Consistency Check		
{Ws}=[C]{W} Weighted Sum Factor	{W} Criteria Weights	Cons={WS}./{W} Consistency Vector
0.897	0.286	3.133
0.427	0.140	3.049
1.853	0.574	3.230

λ=3.137
CI= (λ-n)/(n-1) = (3.137-3)/(3-1)=0.069
CR= CI/RI=0.069/0.52=0.132

AHP

Reliability Comparison Norm				
	Script and Database	A.I.	Digital Library	Design Alternative Priorities
Script and Database	0.2	0.2	0.2	0.2
A.I.	0.6	0.6	0.6	0.6
Digital Library	0.2	0.2	0.2	0.2
Sum	1	1	1	1

Consistency Check		
{Ws}=[C]{W} Weighted Sum Factor	{W} Criteria Weights	Cons={WS}./{W} Consistency Vector
0.6	0.2	3
1.8	0.6	3
0.6	0.2	3

λ=3

CI= (λ-n)/(n-1) = (3-3)/(3-1)=0

CR= CI/RI=0/0.52=0

AHP

Final Rating Matrix								
Selection Criteria	Speed	Storage Capacity	Accuracy	Usability	Aesthetic	Maintainability	Compactness	Reliability
Script and Database	0.090	0.143	0.140	0.260	0.2	0.2	0.286	0.2
A.I.	0.607	0.714	0.574	0.633	0.6	0.6	0.140	0.6
Digital Library	0.303	0.143	0.286	0.106	0.2	0.2	0.574	0.2

{W} Criteria Weights
0.218
0.099
0.036
0.123
0.333
0.051
0.099
0.041

Concept	Alternative Value
Script and Database	0.184
A.I.	0.571
Digital Library	0.245