

Verification & Evaluation

Systems Engineering Design
The Australian National University

- *workshop facilitators* -

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Introduction

- ▶ What is Verification & Evaluation?

Introduction

► What is Verification & Evaluation?

Verification & Evaluation are **independent procedures** that are used together to check whether or not your system design **meets your customer requirements** and how to decide the **best design** for this purpose.

(Browne, 2013)

Introduction

► Take home message:

Systems verification and evaluation techniques give you a systematic way of choosing one design option over another.

Verification

- ▶ Verification is the process of performing tests to determine if your system design meets the customer requirements.
- ▶ This is an ongoing process.

5 Stages of Testing

- ▶ Analytical models
- ▶ Proof of concept (Type I)
- ▶ System Prototypes (Type II)
- ▶ Operational Testing (Type III)
- ▶ Support Testing (Type IV)

Attributes Cascade

<i>Primary attribute</i>	<i>Secondary attribute</i>	<i>Tertiary attribute</i>
<i>Accurate</i>		
<i>Long Range</i>	<i>High initial velocity</i>	<i>Weight of the batteries</i>
		<i>Length of moment arm</i>
		<i>Friction resistance of</i>
		<i>Large swing angle</i>
	<i>Correct angle</i>	<i>45 degrees ejecting angle</i>
<i>Low Cost</i>		

Table 1.0 Shortened attribute cascade for a catapult design.

Attributes Cascade

<i>Primary attribute</i>	<i>Secondary attribute</i>	<i>Tertiary attribute</i>
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<i>Low Cost</i>		

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Attributes Cascade

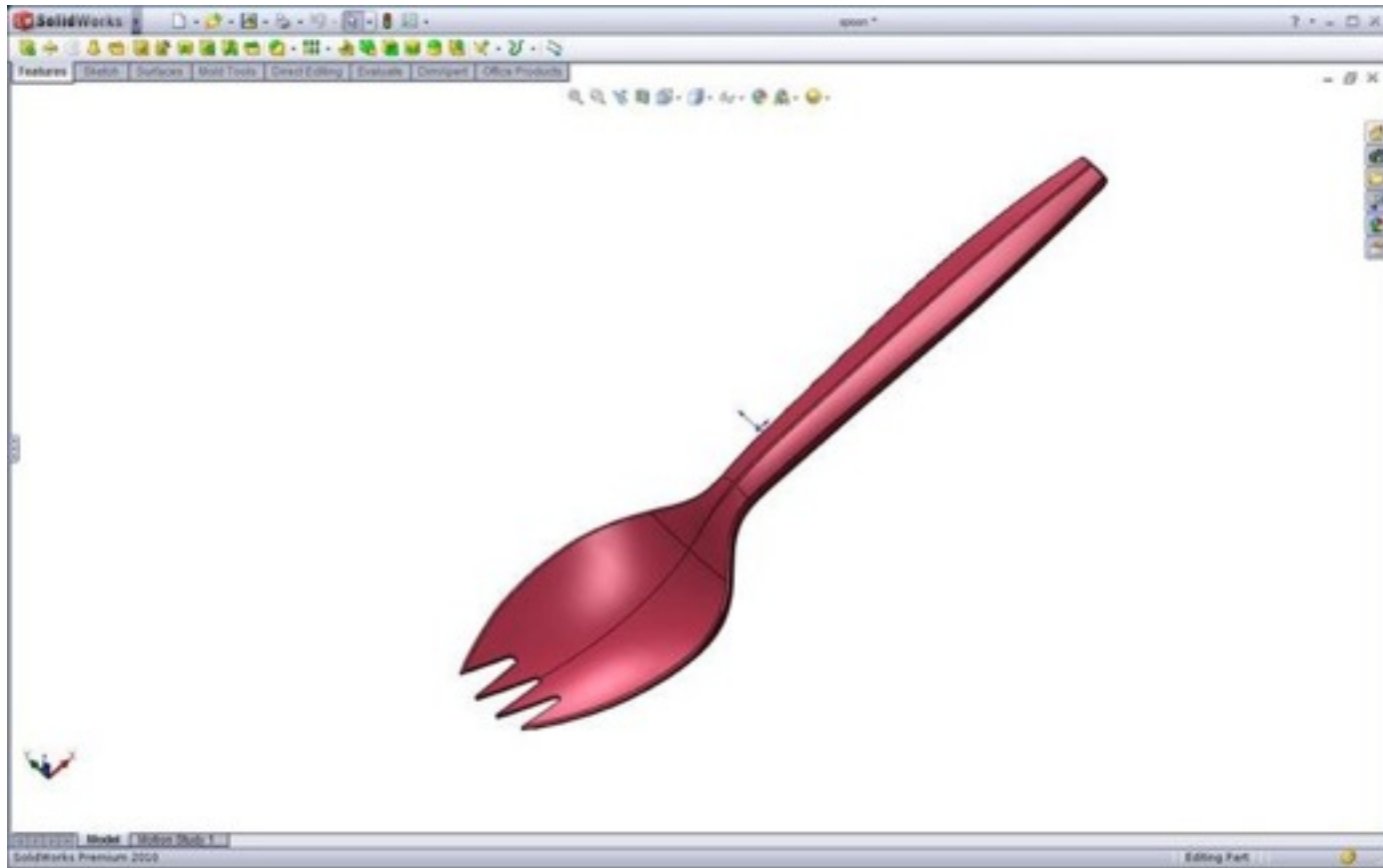


Figure 1.0 CAD design of a spork. (Khan, 2012)

Attributes Cascade

<i>Primary attribute</i>	<i>Secondary attribute</i>	<i>Tertiary attribute</i>
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<i>Low Cost</i>		

Table 1.0 Shortened attribute cascade for a catapult design.

When to perform testing?

- ▶ All throughout the design process, it is important to gain confidence as early as possible that all system requirements will be met.
- ▶ Vee-Model.

Vee-Diagram (for ENGN2225)

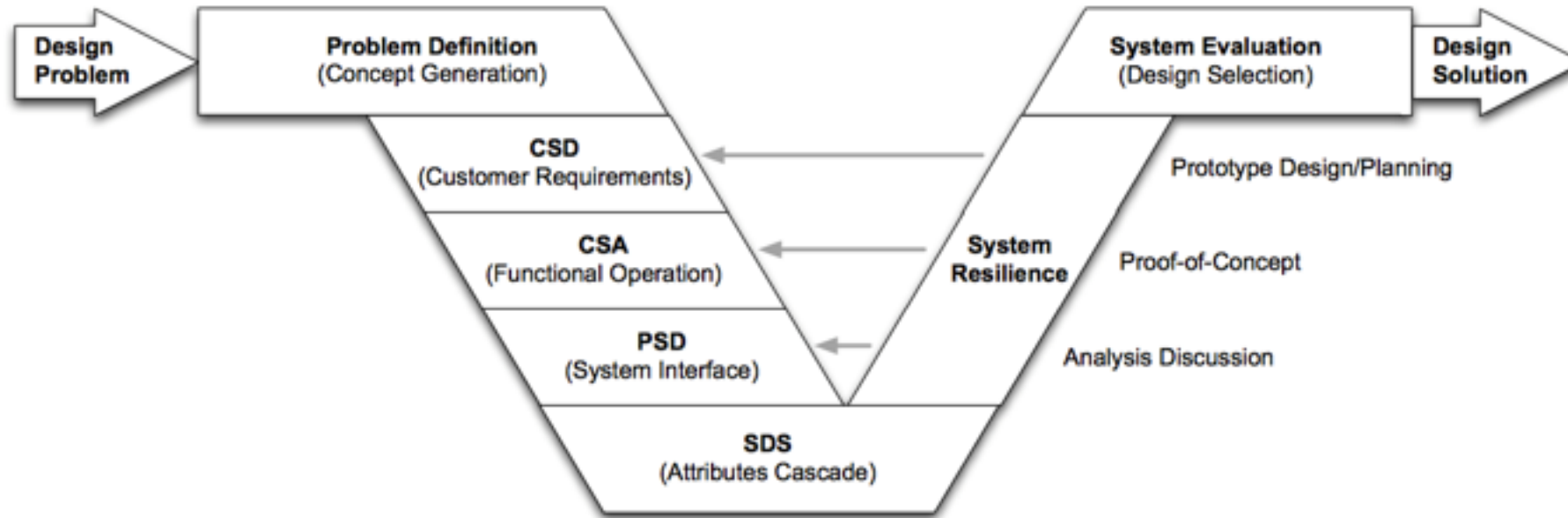


Figure 2.0 Vee-Diagram (Browne, 2013)

Resilience in a system can be built through checking if the system design meets the requirements.

Case Study

The city of men is under attack! Gandalf knows you have done ENGN2225 so he has chosen you (a military engineer) to design a catapult. You have designed five prototypes and now you must test them to find the best one.



Gandalf wants a catapult that has long range, good accuracy and low cost

Requirement vs.	Long range	Accuracy	Low cost	Sum	Rank
Long range		0	1	1	2
Accuracy	1		1	2	1
Low cost	0	0		0	3

Customer Requirement	Metric (TPM)
Low cost	\$
Accuracy	%
Long range	m

Table 2.0 Pairwise Analysis and Metrics

5 Alternative Designs



Design 1



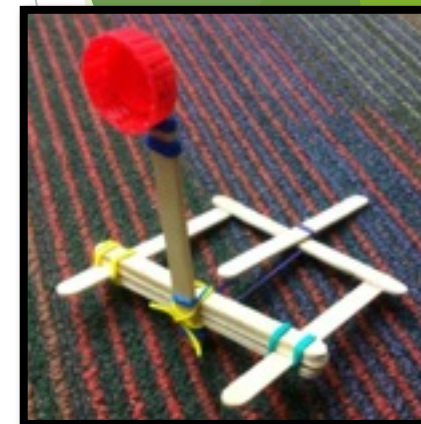
Design 2



Design 3



Design 4



Design 5

Testing method

Basic consideration for procedure

- Selected attribute
- Test person (qualification)
- Procedure outline (repeatable)
- Pass/ fail criteria (benchmark)

Table 2.0 Pairwise Analysis and Metrics

Requirement vs.	Long range	Accuracy	Low cost	Sum	Rank
Long range		0	1	1	2
Accuracy	1		1	2	1
Low cost	0	0		0	3

Table 3.0 Benchmark and Target Value

	Range (m)	Accuracy (%)	Cost (\$)
Customer's benchmark	>1.5	>60	<6

Start!

<http://www.online-stopwatch.com/full-screen-stopwatch/>

Testing time

	popsicle stick	spork	rubber band	clipper	battery
cost/each	0.1	0.5	0.3	2	2

Table 4.0 Cost of materials



Validation

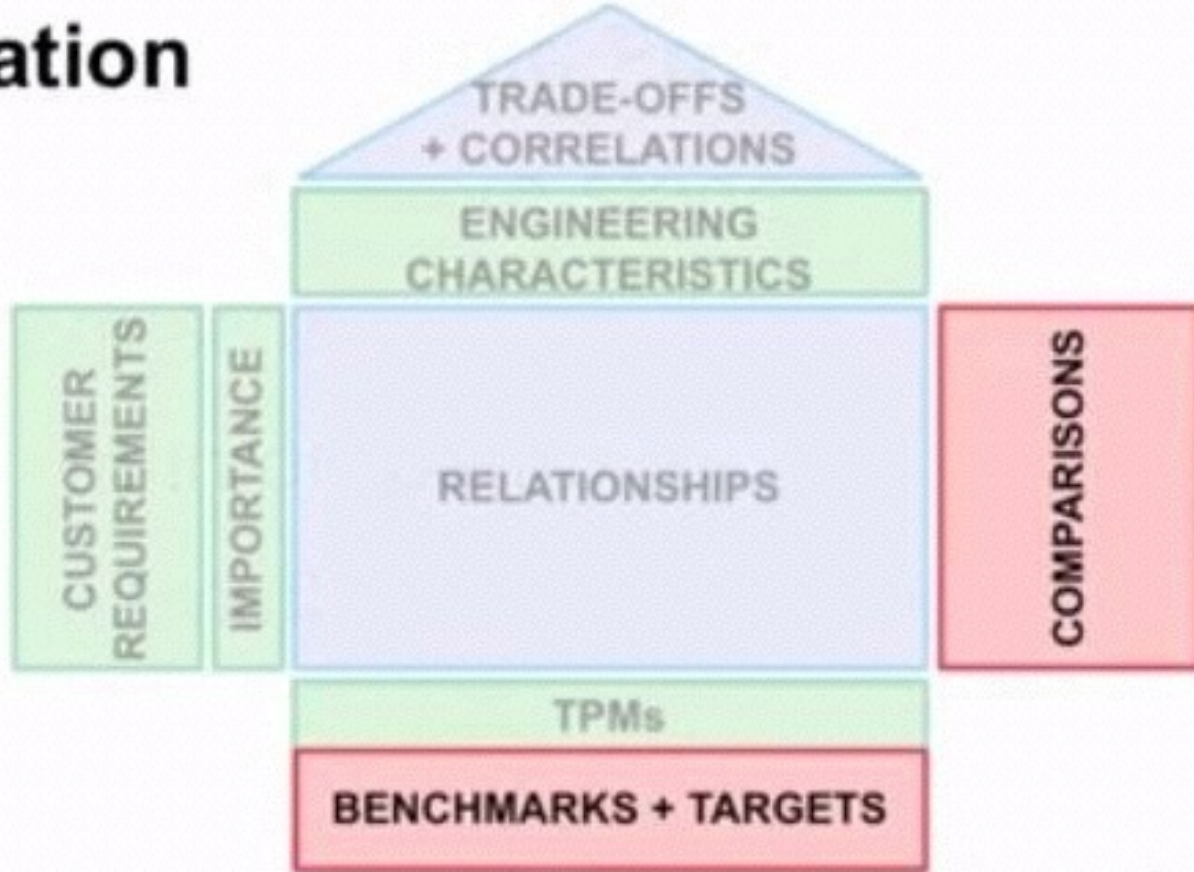


Figure 3.0 House of Quality (Browne, 2013)

Discussion

- ▶ What is your method to measure accuracy?
- ▶ How do you think the differing methods will affect the design output?
- ▶ How can we make the result repeatable different environments?
- ▶ Are the results qualitative or quantitative?
- ▶ Meeting testing standards and regulations.

Evaluation

Why do we evaluate?

1. make a decision on your design
2. improve the design

Different evaluation methods/criteria

1. **direct ranking (weighted ranking)**
2. systematic elimination
3. comparison across alternatives
4. **comparison across a standard**
5. maximax/maximin/Laplace/Hurwicz



Benchmark (Comparison across a Standard)

- ▶ Most commercial products have standards
- ▶ Make sure to use the right standards (different standards may exist in different regions)
- ▶ Resources:
 - Standards Australia website (<http://www.standards.org.au/>) has lots of engineering-related standards in Australia
 - IEEE Standards Association (<https://standards.ieee.org/>) is mainly about global technology standards

Evaluation Matrix (Direct Ranking)

SCALE

- 5 = Exceeds compliance
- 3 = Full compliance
- 1 = Partial compliance
- 0 = Non-compliance

DESIGN REQUIREMENT

	WEIGHTING		OPTION 1 Catapult		OPTION 2 Trebuchet		OPTION 3	
	RANK	WEIGHTING	RELATIVE COMPLIANCE	WEIGHTED VALUE	RELATIVE COMPLIANCE	WEIGHTED VALUE	RELATIVE COMPLIANCE	WEIGHTED VALUE
Accuracy	1	3						
Distance	2	2						
Cost	3	1						
	TOTALS							

Improvement (by referring back to FFBD and system attributes!)

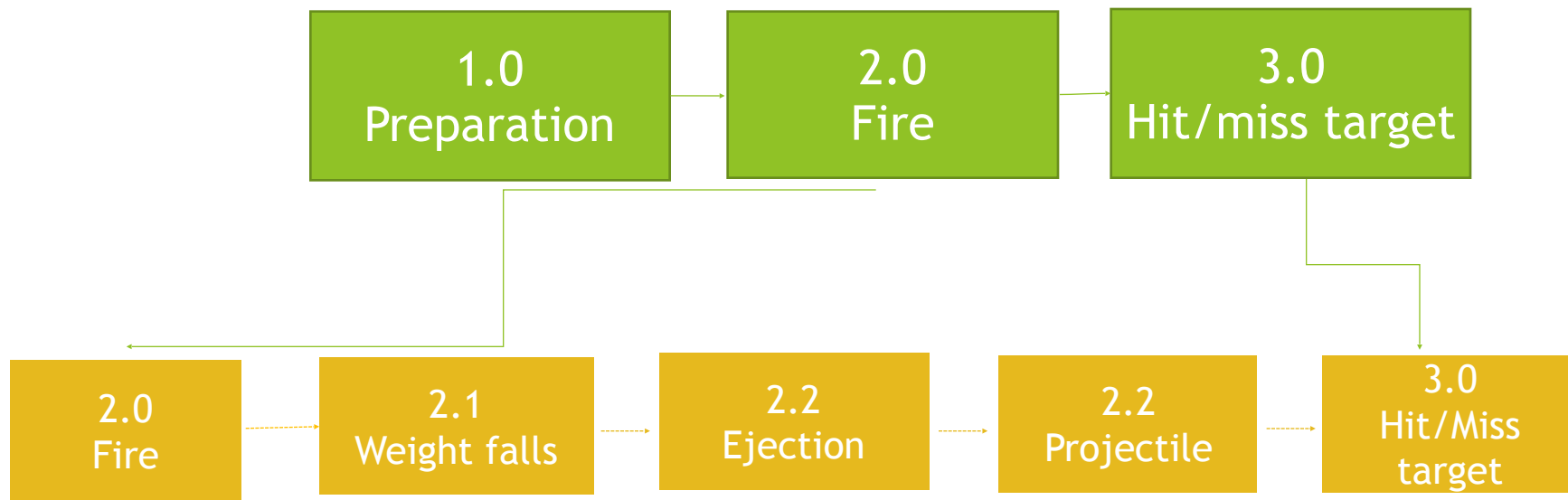


Table 4.0 Functional Flow Block Diagram



Trebuchet

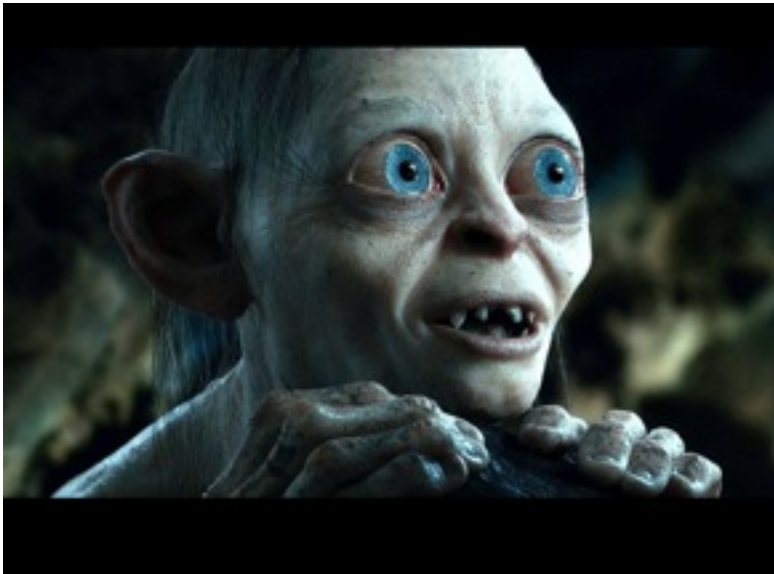
Improvement (by referring back to FFBD and system attributes!)

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Table 1.0 Shortened attributes cascade for catapult design.

Activity

- ▶ Using weighted ranking method, fill up the evaluation matrix (weighted) provided.
- ▶ Choose the design according to the results



Discussion

- ▶ What is the best design?
- ▶ Does this design fulfill the customer requirements?
- ▶ How can you improve the design?
- ▶ Comparison across a standard
 - Range > 1.5 m
 - Accuracy > 60%
 - Cost < \$6

Conclusion

- ▶ What we have covered today:
 - ▶ What is evaluation and verification?
 - ▶ How do we verify a design? Different types of testing?
 - ▶ How do we select the design? How do we improve a design?

Completed House of Quality

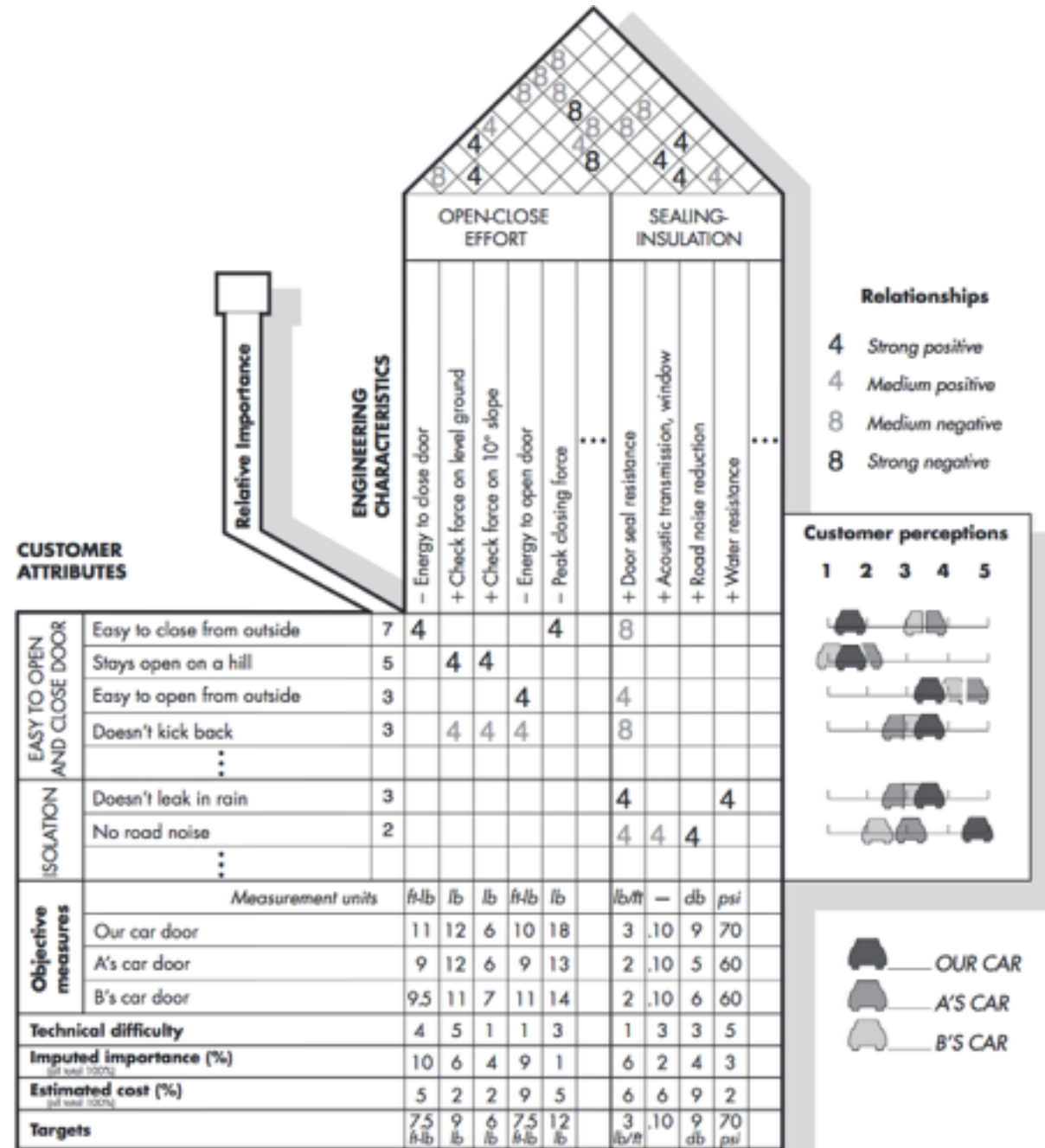


Figure 3.0 House of Quality (Hauser & Clausing, 1988)

Reference List

- ▶ Blanchard, B.S. & Fabrycky, W.J. 2011, *Systems Engineering and Analysis*, Fifth ed. Pearson.
- ▶ Browne, C 2013, *ENGN2225 OC - Evaluation*, online video, viewed 28 April 2014, <<http://www.youtube.com/watch?v=4CglMoAfhSI>>.
- ▶ Browne, C 2013, *ENGN2225 OC - Validation*, online video, viewed 28 April 2014, <<http://www.youtube.com/watch?v=yruHXbsZRzk>>.
- ▶ Hauser J & Clausing D, 1988, 'The House of Quality', *Harvard Business Review*, May, pp. 1-13.
- ▶ Khan, A 2012, *Spoon cum Fork*, digital image of a solidworks 2010 rendering of a spork, GrabCAD, viewed 28 April 2014, <<http://grabcad.com/library/spoon-cum-fork>>.
- ▶ *The Lord of the Ring Trilogy*, 2003. [DVD] Peter Jackson, USA: New Line Cinemas.

Last but not least...

A word cloud featuring the phrase "Thank You" in multiple languages. The words are arranged in a roughly rectangular shape, with "THANK YOU" being the largest and most prominent. Other languages include Spanish (GRACIAS, ARIGATO), Arabic (SHUKRIA, BIYAN, SHUKRIA), Indonesian (TERIMA KASIH, TERIMA KASIH), and others. The background is white with a green geometric pattern on the right side.

GRACIAS
ARIGATO
SHUKRIA
JUSPAXAR
DANKSCHEEN
TASHAKKUR ATU
YAQHANYELAY
SUKSAMA
EKHMET
MEHRBANI
PALDIES
BOLZIN
MERCY
BIYAN
SHUKRIA
TINGKI
MIMMONCHAR