Agenda

1. FMC Technologies and the subsea processing domain
2. Overview of the Pugh Matrix
3. Research Methodology
4. Current Concept Selections
5. Applied Matrices
6. Evaluation of Pugh Matrices
7. Questions

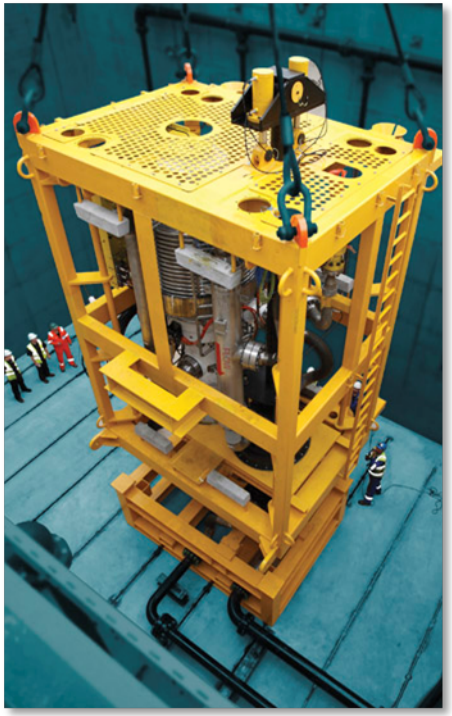
Stuart Pugh (1929 – 1993)

1. FMC Technologies
&
the Subsea Processing Domain

FMC Technologies

The World's largest oil field equipment and services company

- $7.1 billion revenue in 2013
  - 66% subsea technologies
  - 25% surface technologies
  - 9% energy infrastructure
- 19,300 employees worldwide*
- 30 production facilities in 17 countries



* As of December 31, 2013.

FMC Technologies Norway

Kristiansund – 88 employees

Bergen – 782 employees

Stavanger – 167 employees

Florø – 11 employees

Kongsberg – 1,858 employees

Asker – 401 employees
(60 in Processing)

Total in Norway – 3,307 per April 2014

* As of December 31, 2013

Subsea Processing

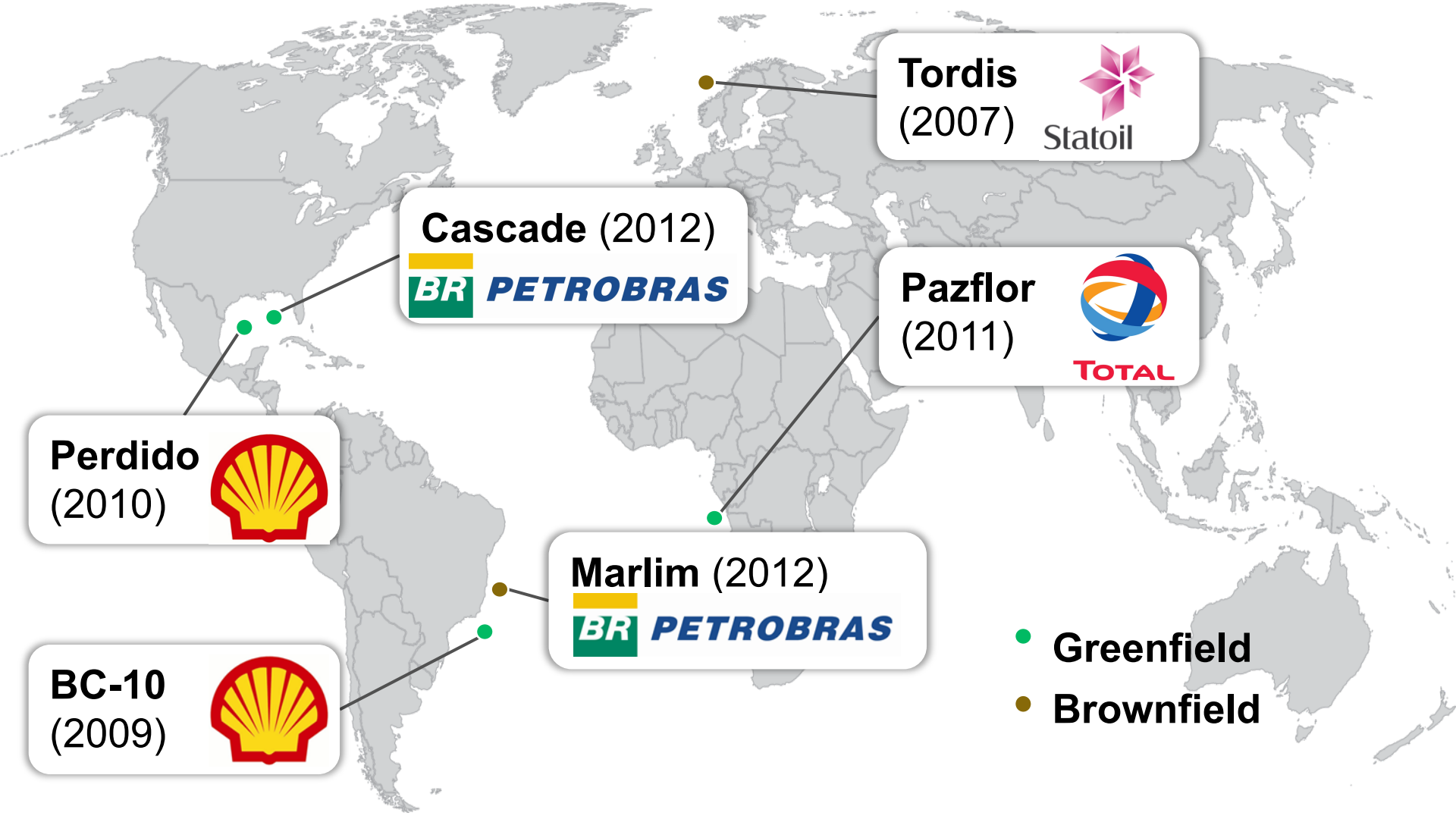
Active treatment of hydrocarbons at the seabed

Subsea processing can:

- enable new field developments
- extend the life of mature fields and
- reduce cost of field development

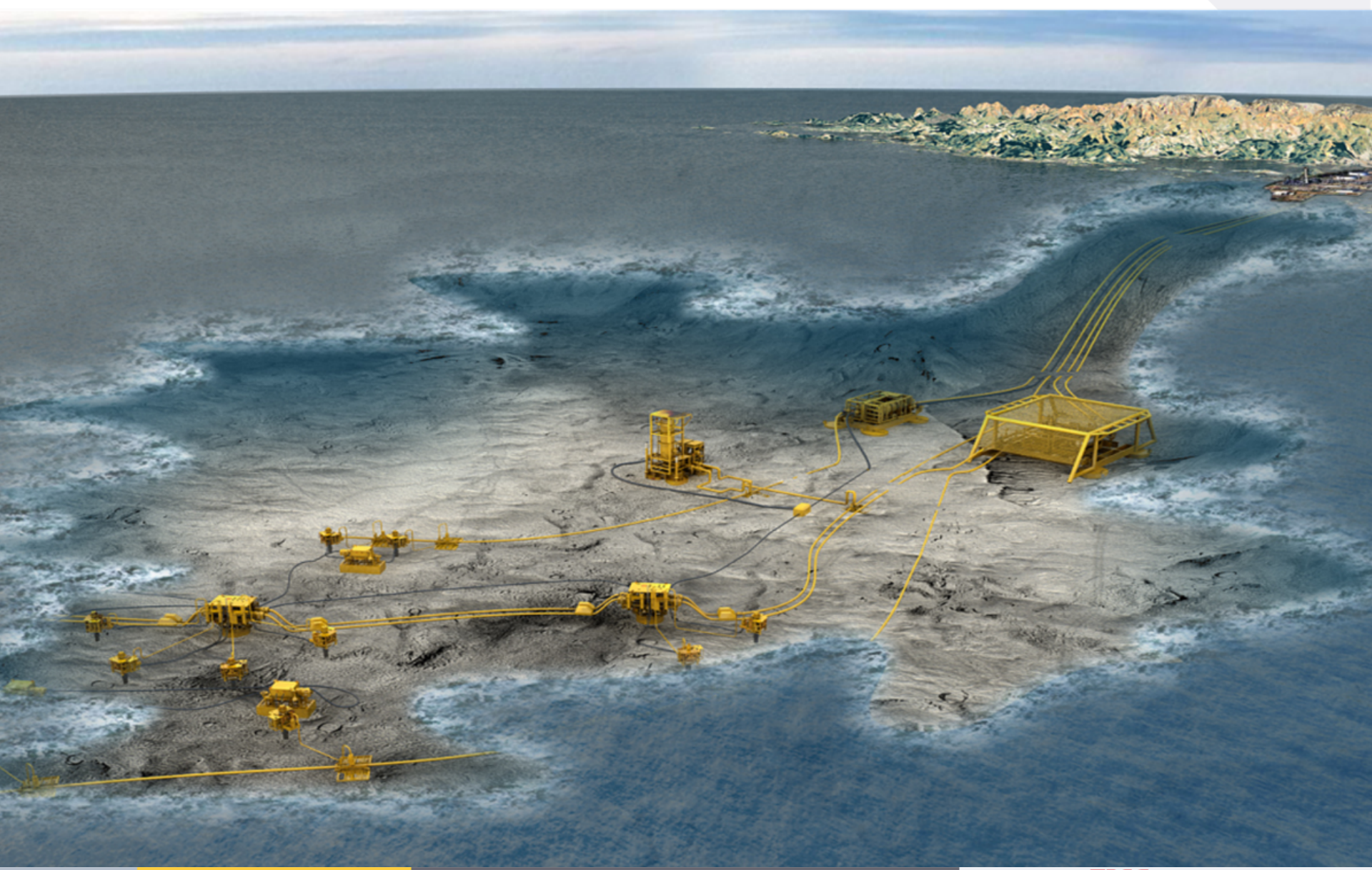
Subsea Processing*: in all major deepwater basins

*Not including subsea pump stations



FMC Technologies

All Subsea™ – FMC Technologies' vision



All Subsea™ – FMC Technologies' vision

2. Overview of the Pugh Matrix

Concept Selection - Decision Making

The average human makes about:

- **612*** decisions a day
- this equals to **4,900*** decisions in a week
- and **254,800*** in a year

* Unsupported Facts

Standard Pugh Matrix

Linda's means of transport (reference: Toyota Yaris)

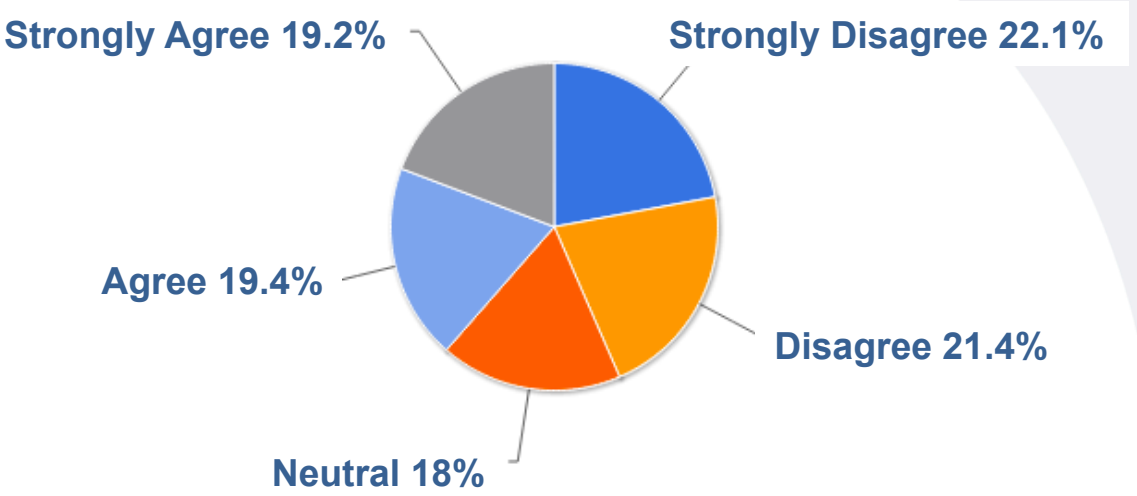
Criteria	Harley	Avensis	Horse
Cost	+	-	+
Luggage capacity	-	+	-
Weather window	-	S	-
Speed	S	+	-
SUM +	**1**	**2**	**1**
SUM -	**2**	**1**	**3**
SUM S	**1**	**1**	**0**

Scoring can also be colors, number range etc.

S = same as
+ = better than
- = worse than

- Easy to use – no specific software required
- Forces a disciplined and structured approach
- Qualitative method – not intended to be mathematical
- Prevents jumping into the first feasible solution
- Contributes to selecting the right concept

Scoring - Likert Scales



- Single select scale
- Rank order, but the intervals between values is not necessarily equal
- The numbers represent verbal statements
- Results shall not be presented by mathematical analysis (e.g mean)

If the topic is sufficiently mature and well defined a calibrated quantification of the scoring will often bring additional value.
If the topic is less mature or defined, then it might create noise and a false sense of precision.

Key Outputs using evaluation matrices

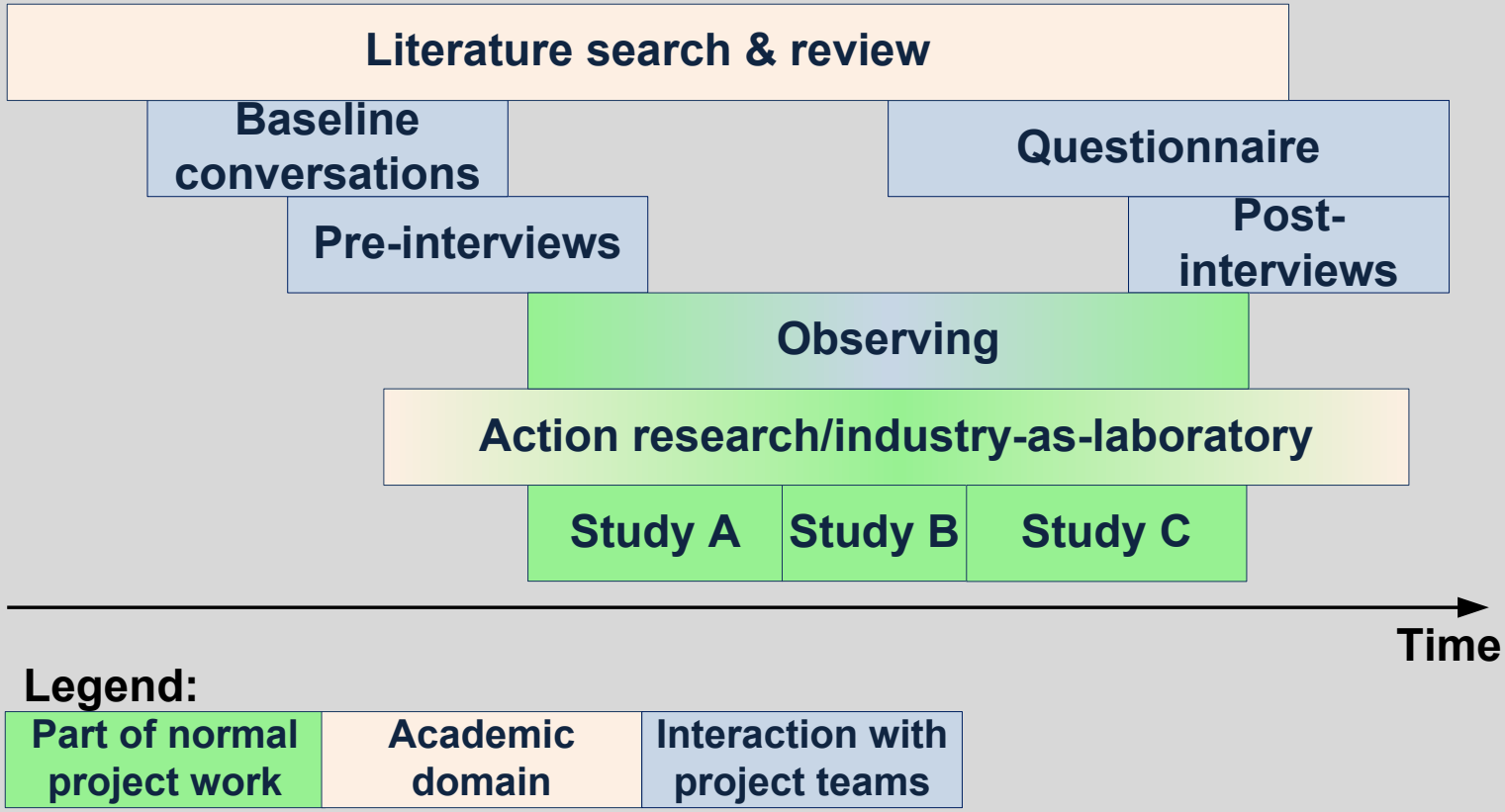
Pugh claims the evaluation matrix gives:

- a greater **insight into the requirements**
- a greater **understanding** of the design problem
- a greater **understanding of the potential solutions**
- an understanding of the interaction between the proposed solutions → **additional solutions/concepts**
- a knowledge of the reasons why one concept is stronger or weaker than another

Difficult for people to push their own ideas for irrational reasons or to deliberately attempt to eliminate the bad features of some less acceptable concepts

3. Research Methodology

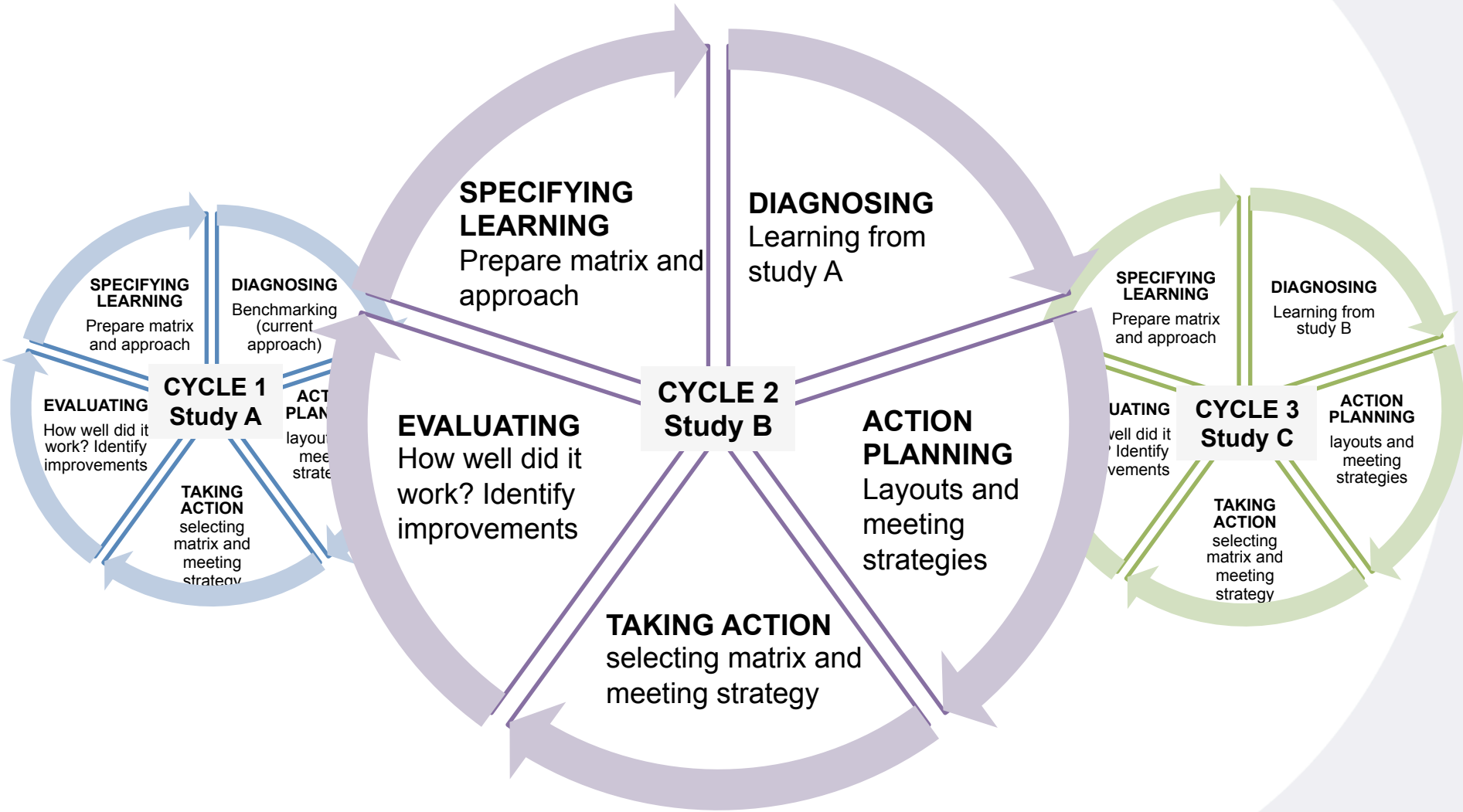
Research Methodology Overview



- Focus: interaction with team
- 3 different study teams

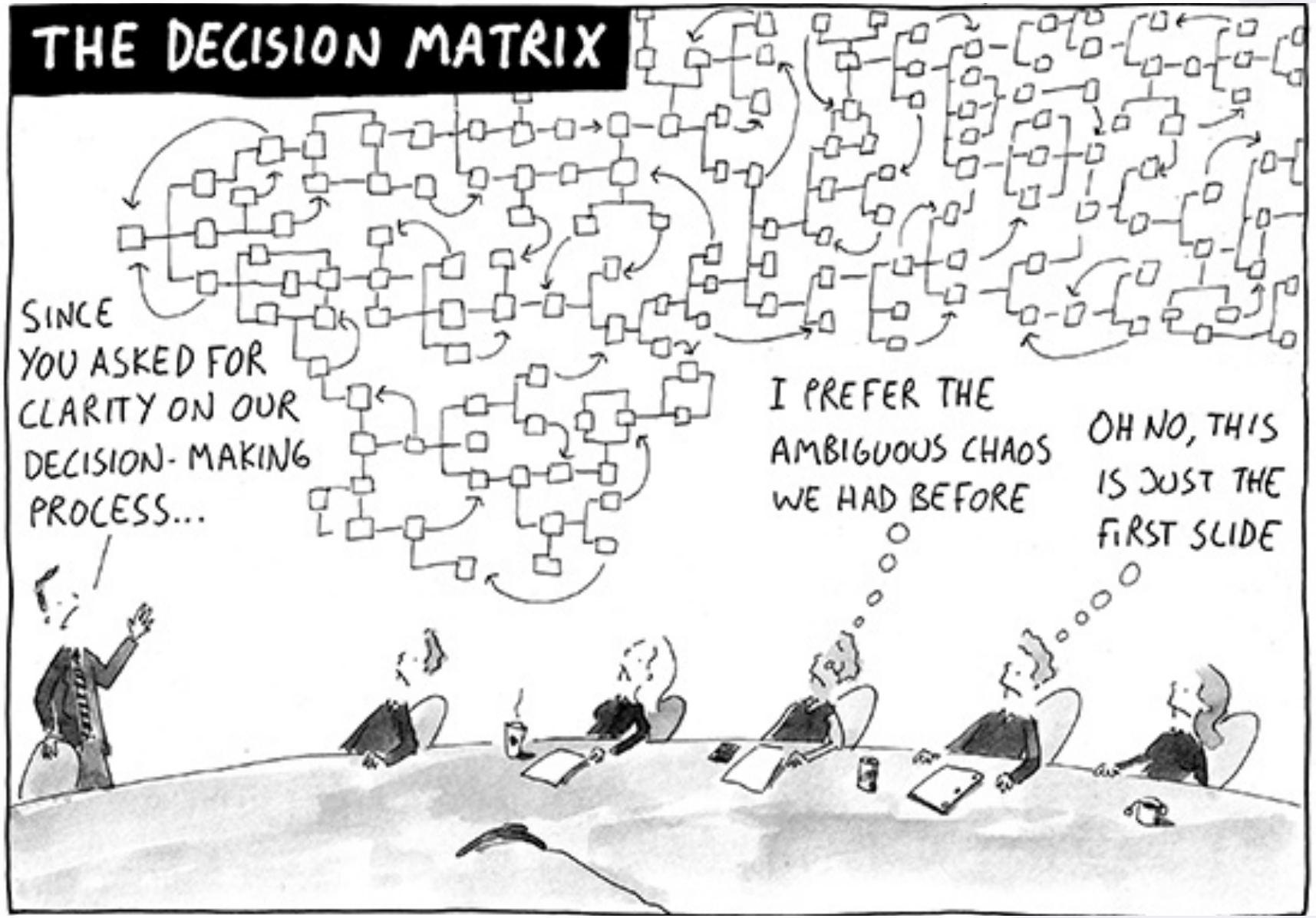
- 13 engineers in total
- ”Young” engineers

Action Research / Industry-as-laboratory



4. Current Concept Selections

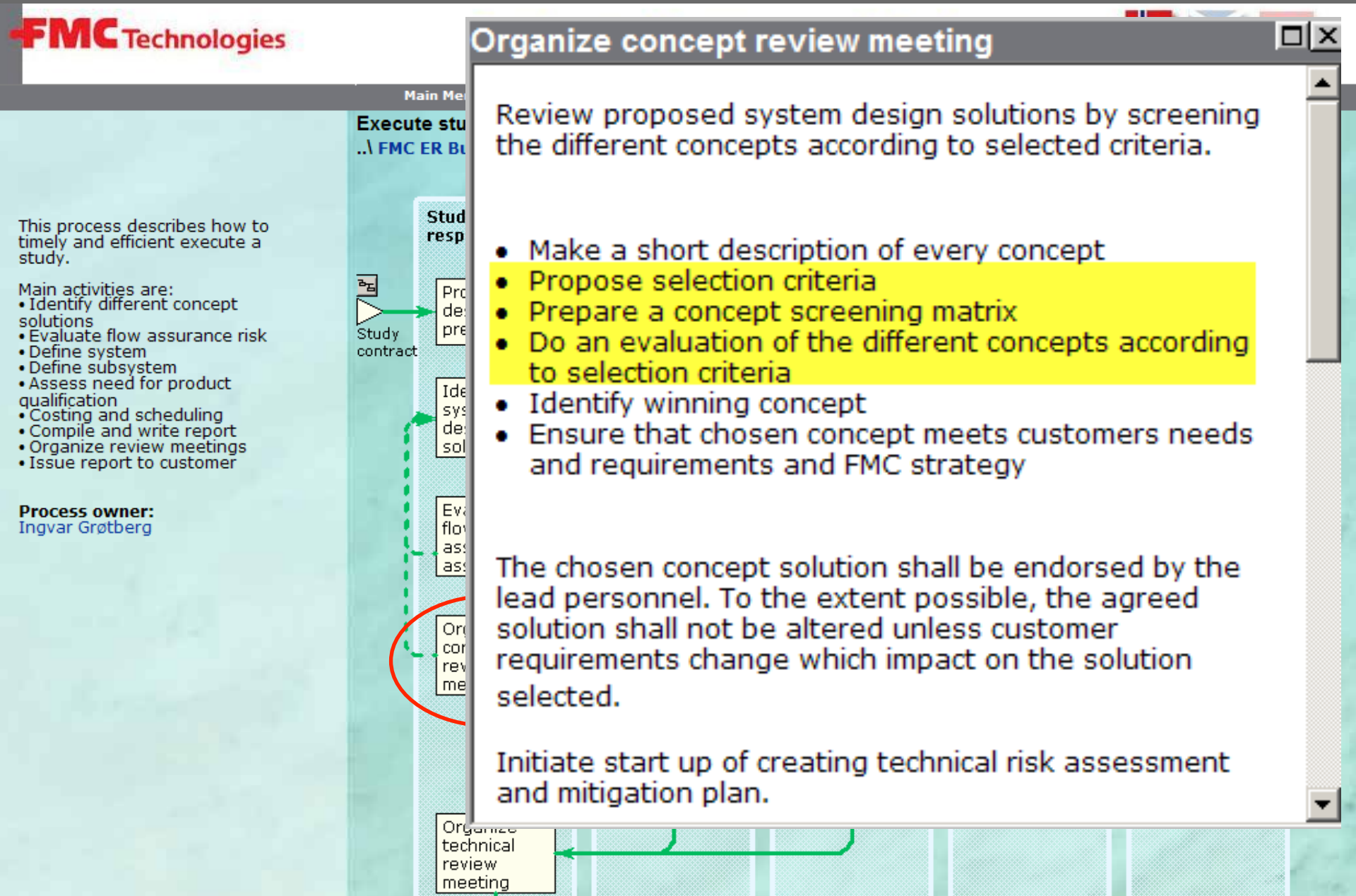
Concept Selections



Current Concept Selections

- **Work meetings** after pre-screening of alternatives
- **PowerPoint** presentation of concepts
- **Subjective** and **unstructured** discussions
- Frequent **interruptions, heated discussion** and random change of topic
- **No documentation** of the reasoning
- **Time and cost pressure** + lack of resources

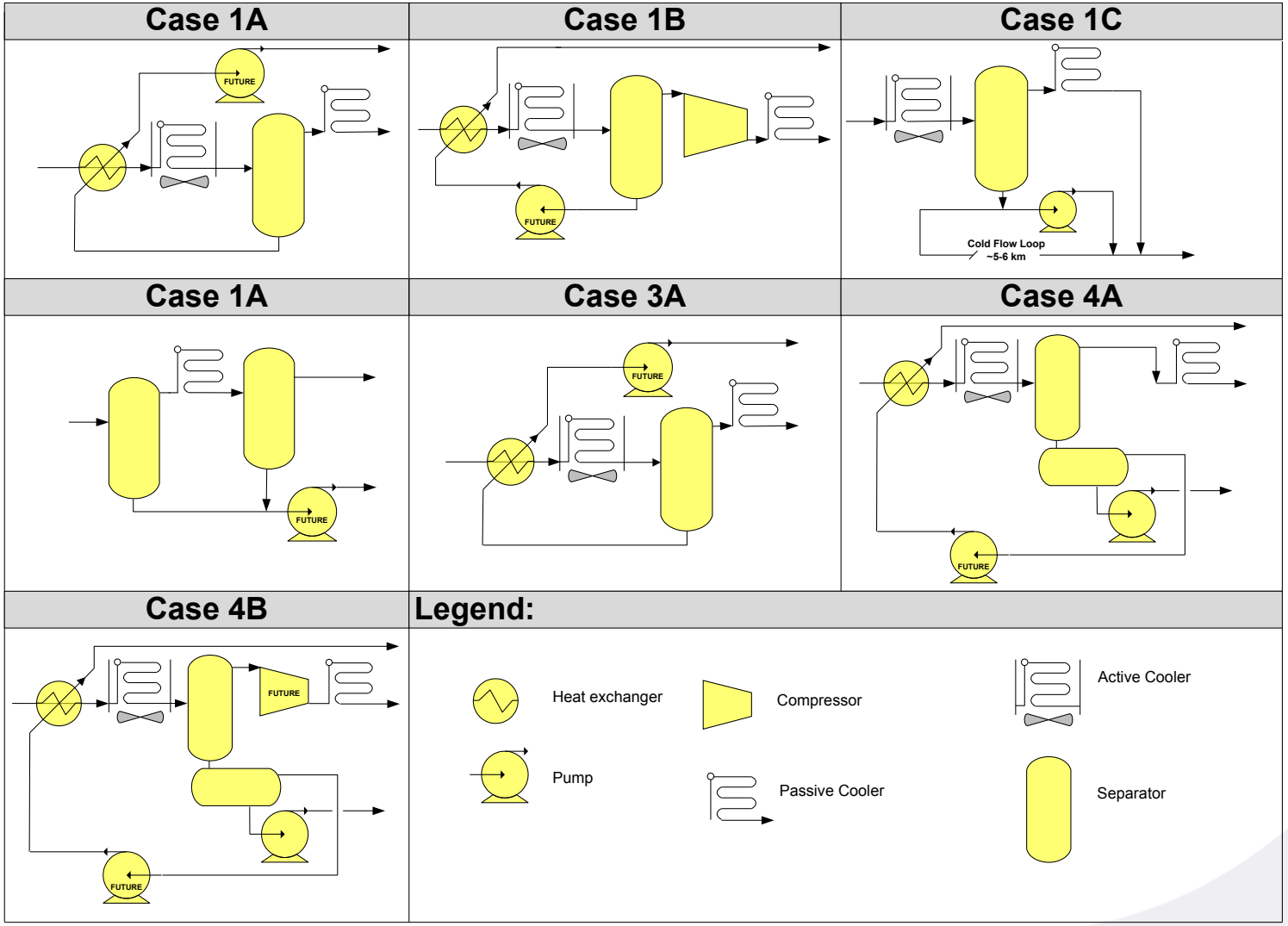
Concept Selections



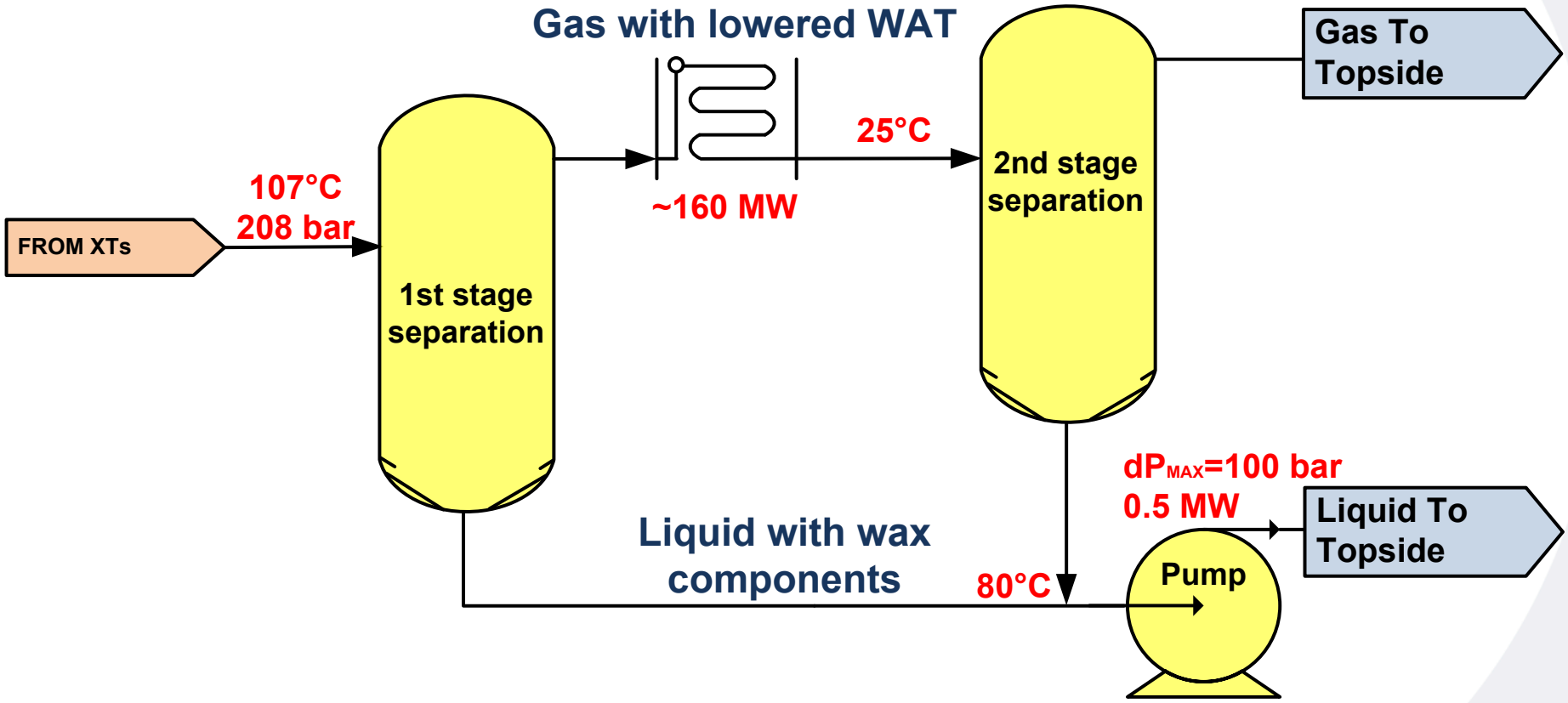
5. Applied Matrices

Study A – Introduction

- Generic scores – ranking of concepts
- 1 to 5 Likert Scale, where 5 is best



Option 1



WAT = Wax Apperance Temperature

Study A - Matrix

Criteria/Challenges		Priority	Weight	Case 1A	Case 1B	Case 1C	Case 3A	Case 4A	Case 4B	Option 1
Cost	SPS CAPEX									
	SPS OPEX									
Technology	**Maturity**									
	TQP duration									
	System complexity									
	Technical safety									
Flow Assurance	Wax									
	Hydrates									
	Corrosion									
	Sand									
	Turn-down									
	Start-up									
	Shut-down									
	MEG-injection									
Operation	Production capacity									
	Personnel requirement									
	Flexibility for future tie-ins									
	Phased development									
	Intervention (lift capacity)									
Location	Reef									
	Distributed wells									
	Weather conditions									
	Sea currents									
	Sand waves									
	Coral breakage									

Study A - Matrix

Criteria/Challenges		Priority	Weight	Case 1A	Case 1B	Case 1C	Case 3A	Case 4A	Case 4B	Option 1
Cost	SPS CAPEX	3	5							
	SPS OPEX		3							
			SUM							
Technology	**Maturity**	4	**5**							
	TQP duration		3							
	System complexity		4							
	Technical safety		2							
			SUM							
Flow Assurance	Wax	4	5							
	Hydrates		5							
	Corrosion		5							
	Sand		1							
	Turn-down		3							
	Start-up		4							
	Shut-down		4							
	MEG-injection		2							
			SUM							
Operation	Production capacity	3	5							
	Personnel requirement		2							
	Flexibility for future tie-ins		3							
	Phased development		4							
	Intervention (lift capacity)		5							
			SUM							
Location	Reef	1	5							
	Distributed wells		5							
	Weather conditions		1							
	Sea currents		1							
	Sand waves		5							
	Coral breakage		5							
			SUM							

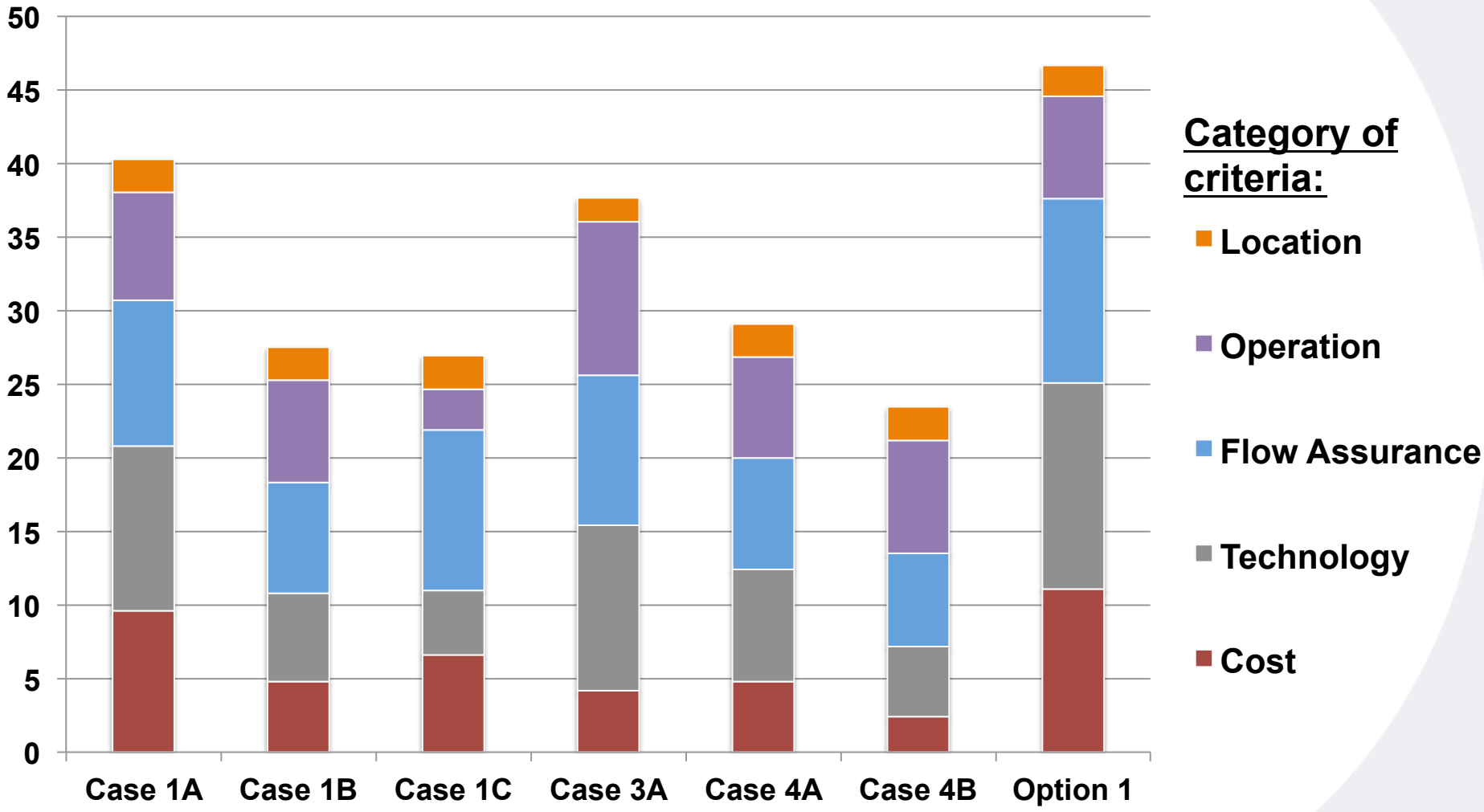
Study A - Matrix

Criteria/Challenges		Priority	Weight	Case 1A	Case 1B	Case 1C	Case 3A	Case 4A	Case 4B	Option 1
Cost	SPS CAPEX	3	5							
	SPS OPEX		3							
			SUM							
Technology	**Maturity**	4	**5**	**4**	**2**	**1**	**4**	**3**	**2**	**5**
	TQP duration		3	4	2	1	4	3	2	5
	System complexity		4	4	2	3	4	2	1	5
	Technical safety		2	4	3	1	4	3	2	5
			SUM	**11.2**	**6.0**	**4.4**	**11.2**	**7.6**	**4.8**	**14.0**
Flow Assurance	Wax	4	5							
	Hydrates		5							
	Corrosion		5							
	Sand		1							
	Turn-down		3							
	Start-up		4							
	Shut-down		4							
	MEG-injection		2							
			SUM							
Operation	Production capacity	3	5							
	Personnel requirement		2							
	Flexibility for future tie-ins		3							
	Phased development		4							
	Intervention (lift capacity)		5							
			SUM							
Location	Reef	1	5							
	Distributed wells		5							
	Weather conditions		1							
	Sea currents		1							
	Sand waves		5							
	Coral breakage		5							
			SUM							

Category sum including priority – contribution on end result

Criteria/Challenges		Priority	Weight	Case 1A	Case 1B	Case 1C	Case 3A	Case 4A	Case 4B	Option 1
Cost	SPS CAPEX	3	5	4	2	2	1	2	1	5
	SPS OPEX		3	4	2	4	3	2	1	4
			SUM	9.6	4.8	6.6	4.2	4.8	2.4	11.1
Technology	**Maturity**	4	**5**	**4**	**2**	**1**	**4**	**3**	**2**	**5**
	TQP duration		3	4	2	1	4	3	2	5
	System complexity		4	4	2	3	4	2	1	5
	Technical safety		2	4	3	1	4	3	2	5
			SUM	11.2	6.0	4.4	11.2	7.6	4.8	14.0
Flow Assurance	Wax	4	5	3	3	4	1	2	2	5
	Hydrates		5	3	1	5	4	2	1	3
	Corrosion		5	4	3	3	5	4	3	5
	Sand		1	4	4	3	2	1	1	5
	Turn-down		3	3	4	4	2	3	4	5
	Start-up		4	3	3	1	5	2	2	4
	Shut-down		4	4	2	5	4	3	2	4
	MEG-injection		2	4	2	5	4	3	2	4
			SUM	9.9	7.5	10.9	10.2	7.6	6.3	12.5
Operation	Production capacity	3	5	2	3	1	5	3	4	2
	Personnel requirement		2	4	2	3	3	3	1	5
	Flexibility for future tie-ins		3	2	3	1	5	3	4	2
	Phased development		4	3	5	1	4	3	5	3
	Intervention (lift capacity)		5	5	2	1	5	3	2	4
			SUM	7.3	7.0	2.8	10.4	6.8	7.7	7.0
Location	Reef	1	5	3	3	3	1	3	3	3
	Distributed wells		5	3	3	3	4	3	3	3
	Weather conditions		1	4	4	4	4	4	4	4
	Sea currents		1	4	4	4	4	4	4	4
	Sand waves		5	3	3	3	1	3	3	2
	Coral breakage		5	3	3	3	2	3	3	3
			SUM	2.3	2.3	2.3	1.6	2.3	2.3	2.1
Weighted Average:				**40**	**28**	**27**	**38**	**29**	**23**	**47**

Study A – Bar Chart

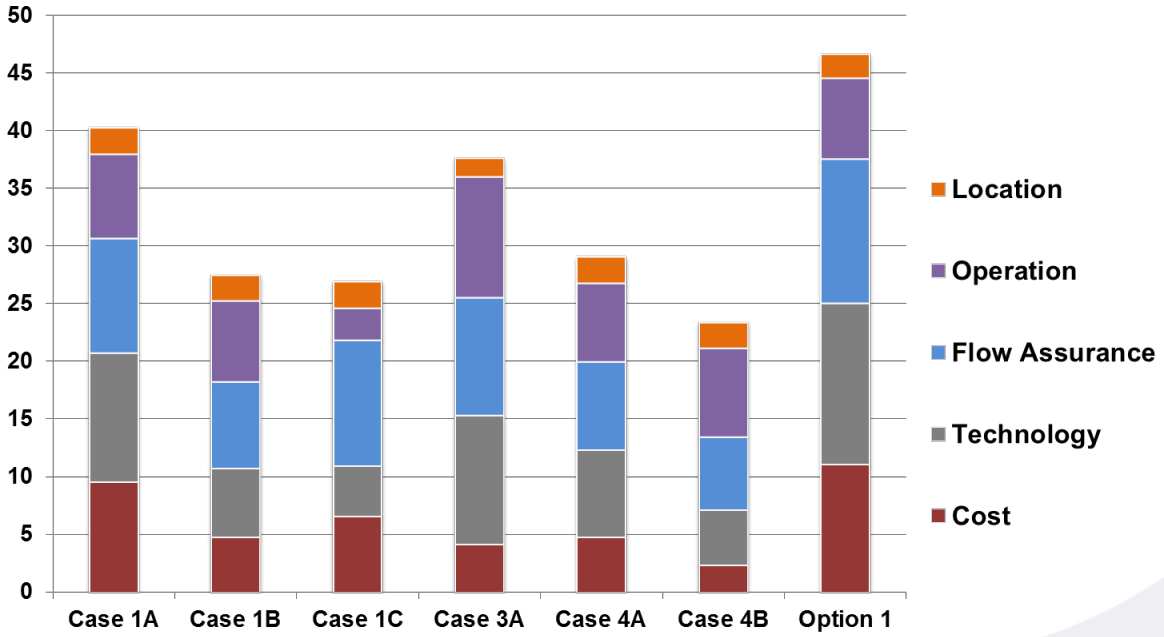


Study A – Findings

- **Initial confusion**
  - Explain matrix more thoroughly
  - Hidden sums
  - Uniform matrix - add more colors
- **Toggling between different screen views was confusing**
  - Add sketches of concepts to matrix
- **Difficult to see small differences in the bar chart**
  - Add data labels

Study A – Findings

- Option 1 **discovered during the process** – selected case
- **Re-work avoided** due to early understanding of requirements
- Bar chart helps to **get overview and to communicate** with others
- Priority of categories to **improve visibility** of contribution on result



Study B & C – Introduction

Criteria **score between 1 and 6** based on compliance to requirements:

1 - not compliant
2 - major compliance gap
3 - compliance gap
4 - minor compliance gap
5 - insignificant compliance gap
6 - fully compliant

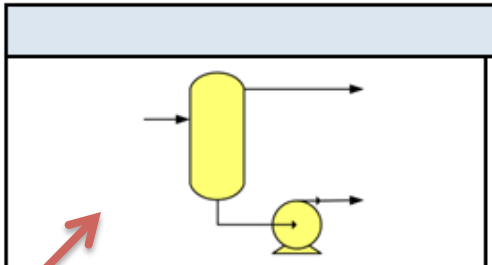
Weights and priorities in percentage:

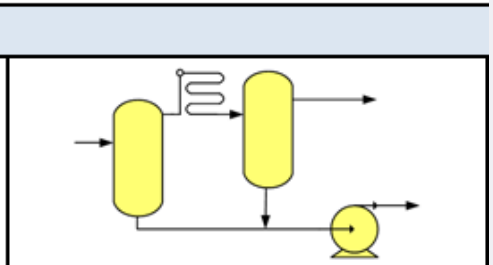
0-5%: unimportant
5-25%: slightly important
25-50%: important
50-75%: very important
75-100%: critical

(The sum of weights and priority shall be exactly 100%).

Study C – Matrix

Blue = score input by user





		Priority [%]	Evaluation Criteria	Weight [%]	Case 1 - Vertical Scrubber		Case 2 - Scrubbers + Cooler	
					Scores	Weighted	Scores	Weighted
	Cost	10	Hardware Cost (CAPEX)	65	6	65 %	2	22 %
			Life of Field Cost (OPEX)	35	4	23 %	4	23 %
			Sub-category weighted score			88 %		45 %
			Category Sum		9 %		5 %	

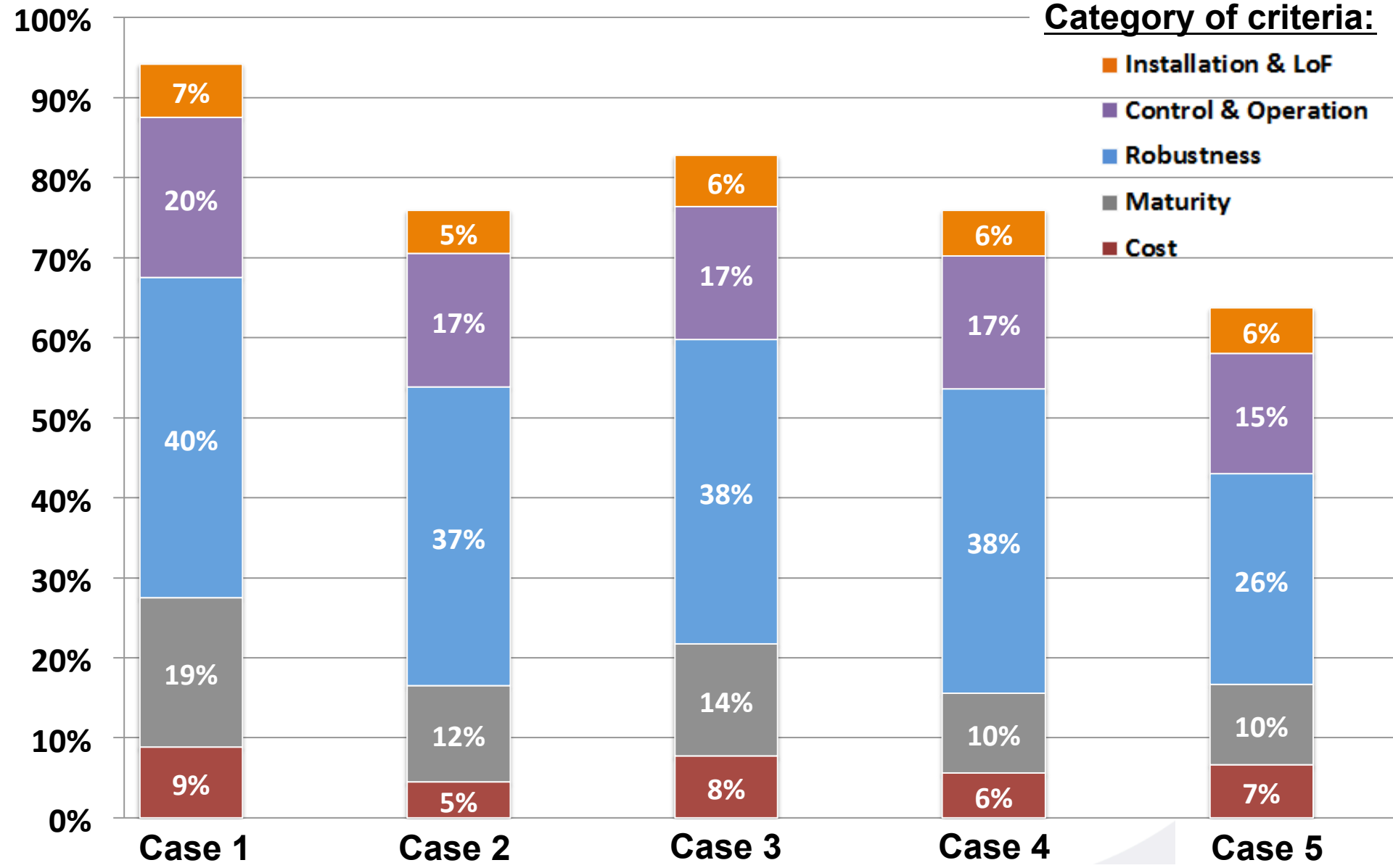
- Case sketches
  - Notes area
    - Weighted criteria score
      - Contribution within category
        - Contribution to overall score

Study C – Matrix

Blue = score input by user

CATEGORIES		Priority [%]	Evaluation Criteria	Weight [%]	Design Alternatives: Case 1 - Vertical Scrubber		Case 2 - Scrubbers + Cooler		Case 3 - Horizontal Vessel		Case 4 - Multipipe		Case 5 - Inline	
					Scores	Weighted	Scores	Weighted	Scores	Weighted	Scores	Weighted	Scores	Weighted
	Cost	10	Hardware Cost (CAPEX)	65	6	65 %	2	22 %	5	54 %	3	33 %	4	43 %
			Life of Field Cost (OPEX)	35	4	23 %	4	23 %	4	23 %	4	23 %	4	23 %
			Sub-category weighted score			88 %		45 %		78 %		56 %		67 %
			Category Sum		9 %		5 %		8 %		6 %		7 %	
	Maturity	20	TRL	40	TRL=6		Cooler TRL = 4		TRL for evenflow=6 TRL=3 based on sandflushing		TRL=3		Ref compacsep. TRL=3.	
					5	33 %	3	20 %	3	20 %	3	20 %	3	20 %
			Qualfication Effort	60			Qualification of control valve		Qualification of sand handling with oil/water as motive fluid		Qualification of sand handling with oil/water as motive fluid		Qualification of sand handling with oil/water as motive fluid	
					6	60 %	4	40 %	5	50 %	3	30 %	3	30 %
			Sub-category weighted score			93 %		60 %		70 %		50 %		50 %
			Category Sum		19 %		12 %		14 %		10 %		10 %	
	Robustness	40	Turn down	15									No parallell operation	
					6	15 %	6	15 %	6	15 %	6	15 %	1	3 %
			Intervention frequency	40			Uncertainty related to cooler						No parallell operation, one intervention	
					6	40 %	5	33 %	6	40 %	6	40 %	5	33 %
			Ability to handle changing inlet conditions	15									Sensitive towards GVF	
					6	15 %	6	15 %	6	15 %	6	15 %	4	10 %
			Ability to handle upset conditions	30					Requires more sand flushing.		Requires more sand flushing.		Requires more sand flushing. Slugging may affect the gas quality.	
					6	30 %	6	30 %	5	25 %	5	25 %	4	20 %
			Sub-category weighted score			100 %		93 %		95 %		95 %		66 %
			Category Sum		40 %		37 %		38 %		38 %		26 %	
	Control & Operation	20	Operability	50	6	50 %	5	42 %	5	42 %	5	42 %	5	42 %
			Simplicity of control	50	6	50 %	5	42 %	5	42 %	5	42 %	4	33 %
			Sub-category weighted score			100 %		83 %		83 %		83 %		75 %
			Category Sum		20 %		17 %		17 %		17 %		15 %	
	Installation & LoF	10	System size and weight	20	6	20 %	2	7 %	5	17 %	3	10 %	4	13 %
			Flexibility for future tie-ins of fluid with different properties.	25	6	25 %	6	25 %	6	25 %	6	25 %	Deliquidiser may require replacement. 4	17 %
			Module size and weight	40	1	7 %	3	20 %	1	7 %	1	7 %	3	20 %
			No of modules	15	6	15 %	1	3 %	6	15 %	6	15 %	3	8 %
			Sub-category weighted score			67 %		54 %		63 %		57 %		58 %
			Category Sum		7 %		5 %		6 %		6 %		6 %	
Σ [%]:		100	Overall weighted score		94 %		76 %		83 %		76 %		64 %	

Study C – Bar Chart



LoF = Life of Field

Study C – Findings

- Useful to look more often at the **bar chart** while populating the matrix
  - Shift focus from **detail level to high level** (bar chart)
- Toggling between **only two screen views** was not confusing
- Matrix and bar chart **good visual communication** tool
- Customer wanted the spreadsheet for internal use

6. Evaluation of Pugh Matrices

Questionnaire Results – Part 1

Legend:

agree	somewhat agree	neutral	somewhat disagree	disagree	not relevant	blank

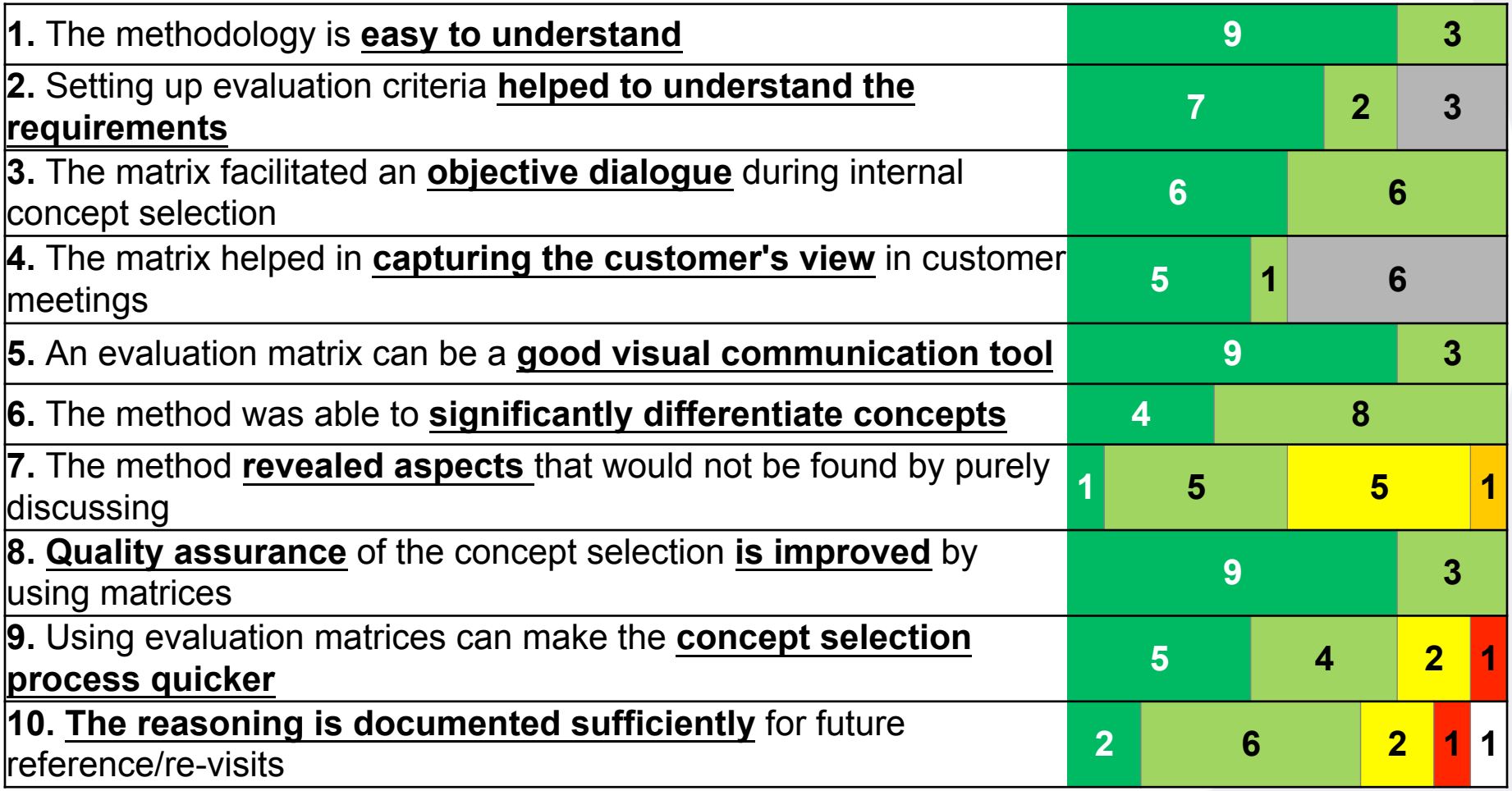
1. The methodology is **easy to understand**	9	3

12 out of 13 answered the questionnaire

Questionnaire Results – Part 1

Legend:

agree	somewhat agree	neutral	somewhat disagree	disagree	not relevant	blank



Questionnaire Results – Part 2

Legend:

yes no

	yes	no
11. Have you used similar kinds of evaluation matrices before?	6	6
12. Will you start/continue to use evaluation matrices?	12	
13. Will you recommend using evaluation matrices to colleagues?	11	1
14. Do you believe that evaluation matrices can be embedded in our BPMS?	10	2

BPMS - Business Process Management System

Conclusion

Advantages:

- helps to **understand** the **customer requirements**
- are a **good visual communication** tool
- facilitates an **objective dialogue**
- improves **quality assurance** of the **concept selection**
- **captures** a high number of **interrelated criteria** that he human mind struggles to handle
- helps the customer **expressing** what he/she really needs

Why it went better this time:

- Increasingly complex technical solutions
- Customers want more insight
- Young engineers
- Improve quality campaigns

Conclusion

Disadvantages:

- **FMC strategy** may be **difficult to incorporate** when having full visibility towards the customer
- **Incorrect selection of criteria** may result in a **wrong concept** being selected

Don’t forget your gut feeling, but make it explicit!

Questions?