Developing Representative Costs

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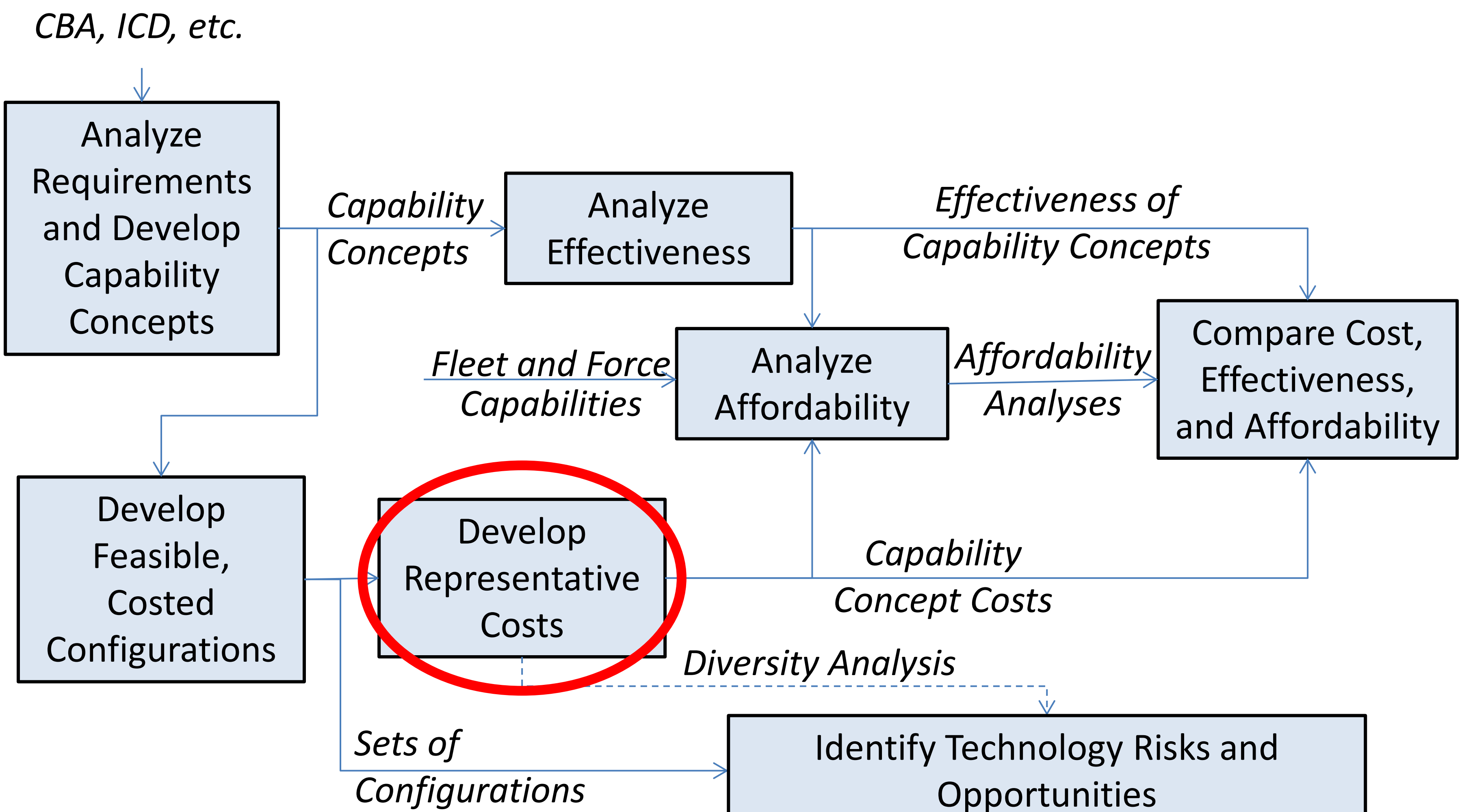
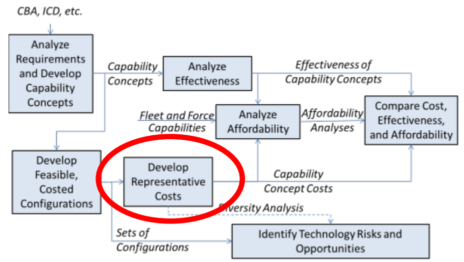
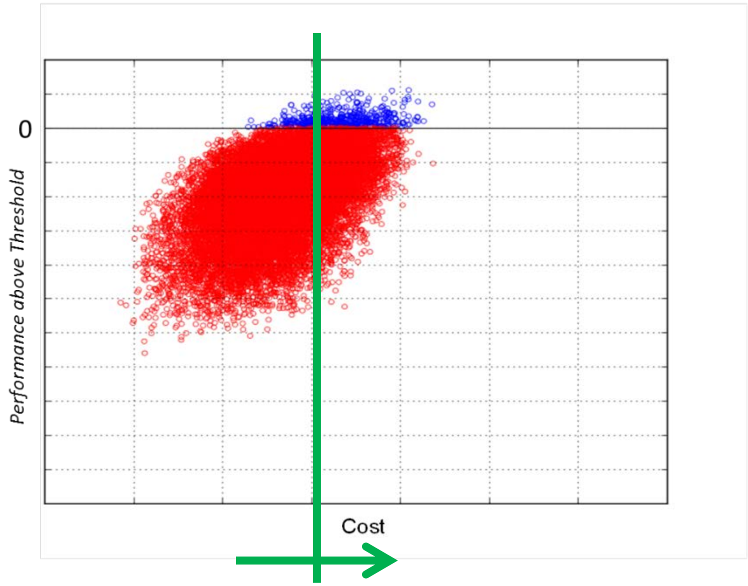
Reference Concept Exploration Process



Develop Representative Costs (review)



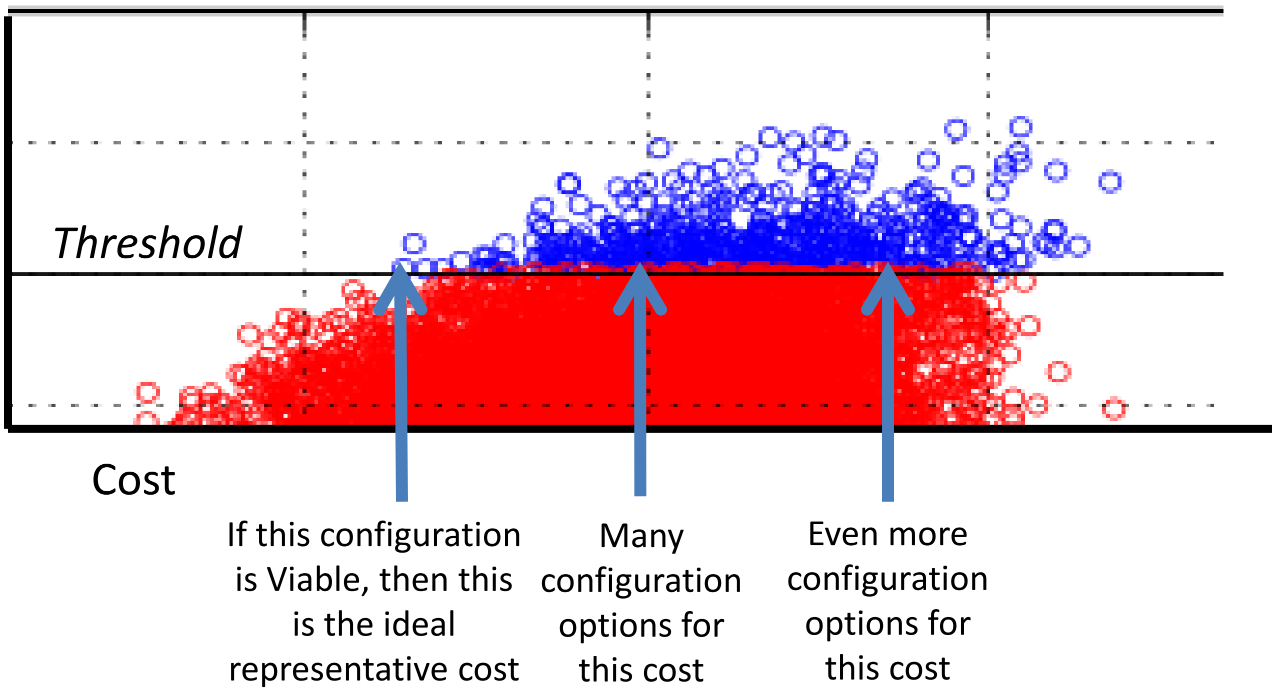
- A representative cost is developed for each capability concept based on the set of feasible configurations.
- Representative costs should be comparable among different capability concepts.
  - Diversity Metric is an enabler
- Representative costs should be presented as ranges
  - Uncertainty in technical solution
  - Uncertainty in cost modeling



How far to move the line?

What is a good representative cost?

Answer: The lowest cost with a low risk that all feasible configurations with a lower or equal cost are not viable.
(or alternately, the lowest cost where there is a high probability that at least one feasible configuration of equal to or less cost is viable)
The risk can be evaluated via a Diversity Metric



Diversity Metric

- Measures how different the feasible configurations within a set of configurations are from each other
  - Higher diversity implies a lower risk that all feasible configurations below a specified cost are not viable
- Based on a set of "Diversity Variables"
  - A subset of the "Design Variables"
  - Aligned with degree of risk

Proposed Diversity Metric Approach

- Identify a subset of the feasible configurations which are the lowest cost, yet are likely to contain at least one viable configuration.
  - For each diversity variable, identify the number of options that must be represented in the subset (MIN_NBR_OPTIONS)
  - For each of the MIN_NBR_OPTIONS options for the diversity variable, the subset must have a minimum of MIN_NBR_CONFIGS_PER_OPTION configurations.

This approach requires Discrete Diversity Variables

Proposed Diversity Metric Approach (continued)

- Calculate BASE_SUM which is the sum of the product of MIN_NBR_OPTIONS and MIN_NBR_CONFIGS_PER_OPTION for all the diversity variables
- Order all of the feasible configurations from lowest cost to highest cost
- For each configuration and each diversity variable, construct an array of the diversity variable options and the number of times that option exists in the configuration and all lower cost configurations.
- Calculate DV_NBR_METRIC by selecting the MIN_NBR_OPTIONS array elements with the highest numbers and adding together the minimum of MIN_NBR_CONFIGS_PER_OPTION and the array element value.
- The DIVERSITY_SCORE is the sum of DV_NBR_METRIC for all the diversity variables.
- The DIVERSITY_METRIC is the DIVERSITY_SCORE divided by the BASE_SUM.
  - The lowest value is for the lowest cost configuration and is equal to the number of diversity variables divided by BASE_SUM
  - DIVERSITY_METRIC monotonically increases in ascending order of cost
  - The maximum value is 1.0.

Should this approach be implemented in a design tool?

Translating the Diversity Metric into a Representative Cost

- Direct Assessment
  - Use the cost for the configuration with specific diversity metrics to establish a range.
    (e.g. 0.75 and 1.00)
- Indirect Assessment
  - Create a subset of the feasible configurations by only including those with diversity variable options that first meet the MIN_NBR_OPTIONS and MIN_NBR_CONFIGS_PER_OPTION.
  - Use the mean and standard deviation of the costs for this subset.
  - In some cases, may have to consider groups of highly interdependent variables as a single diversity variable

Simple Example

CONFIG_ID	COMPONENT A	COMPONENT B	COMPONENT C	COST
1	A1	B1	C1	111
2	A1	B2	C1	121
3	A2	B1	C1	211
4	A2	B2	C1	221
5	A3	B1	C1	311
6	A3	B2	C1	321
7	A1	B1	C2	112
8	A1	B2	C2	122
9	A2	B1	C2	212
10	A2	B2	C2	222
11	A3	B1	C2	312
12	A3	B2	C2	322
13	A1	B1	C3	113
14	A1	B2	C3	123
15	A2	B1	C3	213
16	A2	B2	C3	223
17	A3	B1	C3	313
18	A3	B2	C3	323
19	A1	B1	C4	114
20	A1	B2	C4	124
21	A2	B1	C4	214
22	A2	B2	C4	224
23	A3	B1	C4	314
24	A3	B2	C4	324

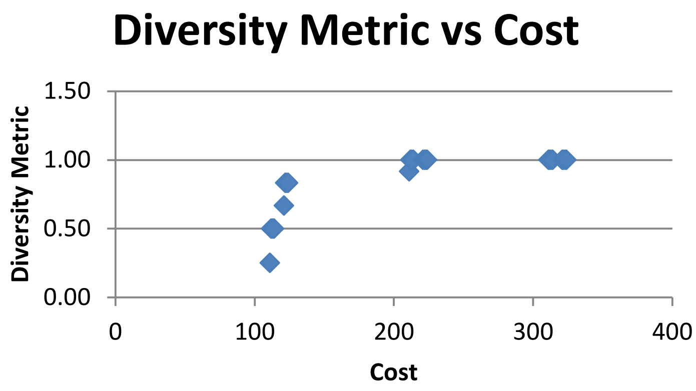
Simple Example (cont)

CONFIG ID	COMPONENT A	COMPONENT B	COMPONENT C	COST	Diversity Metric
1	A1	B1	C1	111	0.25
7	A1	B1	C2	112	0.50
13	A1	B1	C3	113	0.50
19	A1	B1	C4	114	0.50
2	A1	B2	C1	121	0.67
8	A1	B2	C2	122	0.83
14	A1	B2	C3	123	0.83
20	A1	B2	C4	124	0.83
3	A2	B1	C1	211	0.92
9	A2	B1	C2	212	1.00
15	A2	B1	C3	213	1.00
21	A2	B1	C4	214	1.00
4	A2	B2	C1	221	1.00
10	A2	B2	C2	222	1.00
16	A2	B2	C3	223	1.00
22	A2	B2	C4	224	1.00
5	A3	B1	C1	311	1.00
11	A3	B1	C2	312	1.00
17	A3	B1	C3	313	1.00
23	A3	B1	C4	314	1.00
6	A3	B2	C1	321	1.00
12	A3	B2	C2	322	1.00
18	A3	B2	C3	323	1.00
24	A3	B2	C4	324	1.00

For each Component:
MIN_NBR_OPTIONS = 2
MIN_NBR_CONFIGS_PER_OPTION = 2

BASE_SUM = 12

Direct Method Range



Simple Example (Indirect Method)

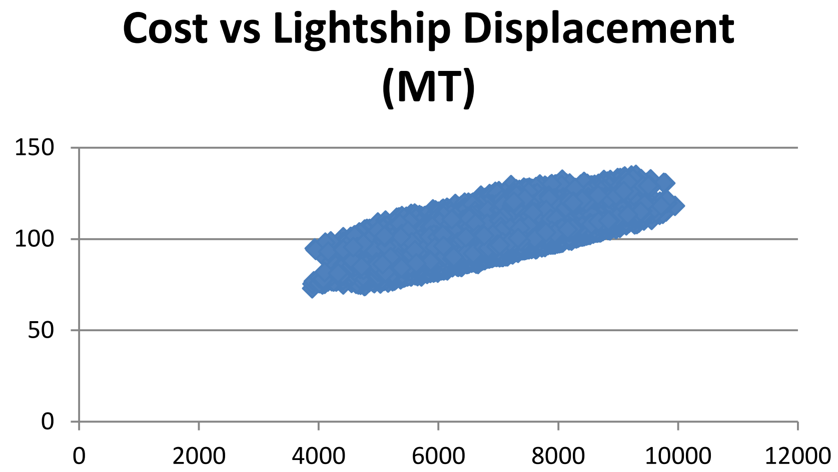
CONFIG_ID	COMPONENT A	COMPONENT B	COMPONENT C	COST	Diversity Metric
1	A1	B1	C1	111	0.25
7	A1	B1	C2	112	0.50
2	A1	B2	C1	121	0.67
8	A1	B2	C2	122	0.83
3	A2	B1	C1	211	0.92
9	A2	B1	C2	212	1.00
4	A2	B2	C1	221	1.00
10	A2	B2	C2	222	1.00

Mean Cost = 166.5
Standard Deviation of Cost = 53.7

Discard configurations with A3, C3, and C4
(SBD approach: Eliminate dominated component solutions)

Ship Design Example

- Dataset of 51,000 Feasible Configurations
- 164 Configurations needed to achieve a diversity metric of 1.0
- Direct Assessment cost [76.6 ,78.6]
- Indirect Assessment
  - Included 3352 configurations
  - Average Cost = 90.4
  - Std Deviation = 6.7



Diversity Variable	Total Number of Options	MIN_NBR_OPTIONS	MIN_NBR_CONFIGS_PER_OPTION
Propulsion Architecture	5	4	10
Weight Equation	2	2	10
Main Engine Power	6	3	10
Hogging Constant	2	2	10
Deckhouse Material	2	2	10
AAW suite	8	3	10
ASW suite	6	3	10
SUW suite	7	3	10

Ship Design Example (cont)

Diversity Variable	Number of Configurations to meet criteria
AAW suite	40
SUW suite	43
ASW suite	51
Weight Equation	54
Deckhouse Material	57
Propulsion Architecture	119
Main Engine Power	153
Hogging Constant	164

COST DRIVERS: Concentrate near term design activity on understanding these options

Other Alternatives for calculating Representative Cost

- Use the minimum cost
  - Must ensure concept has sufficient margin to ensure design will be viable
  - Sufficient margins may hide opportunities
  - May still result in cost growth due to acquisition risks (diminishing sources, etc.)
- Use mean and standard deviation of all the feasible configurations
  - Will likely result in too high of a cost
  - Includes configurations that are highly dominated
    - Many other configurations perform as well at lower cost
    - Introducing an expensive component that exceeds requirements will skew results

Which approaches to developing a representative cost should be supported?

Reference Concept Exploration Process