Assessing the Economic Impacts of Architectural Decisions

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A Holistic Approach to Architecture Analysis and Design

Why do I use the word "holistic"?

Definition:

1. Emphasizing the importance of the whole and the interdependence of its parts.
2. Concerned with wholes rather than analysis or separation into parts.

How is this Relevant?

We have been doing architectural analyses (using SAAM and ATAM) for years.

In the ATAM we analyze architectural tradeoffs: performance vs. modifiability vs. security vs. availability...

But the biggest tradeoffs always have to do with ***economics***.

When we neglect economics we neglect the hardest part of the problem.

Investments

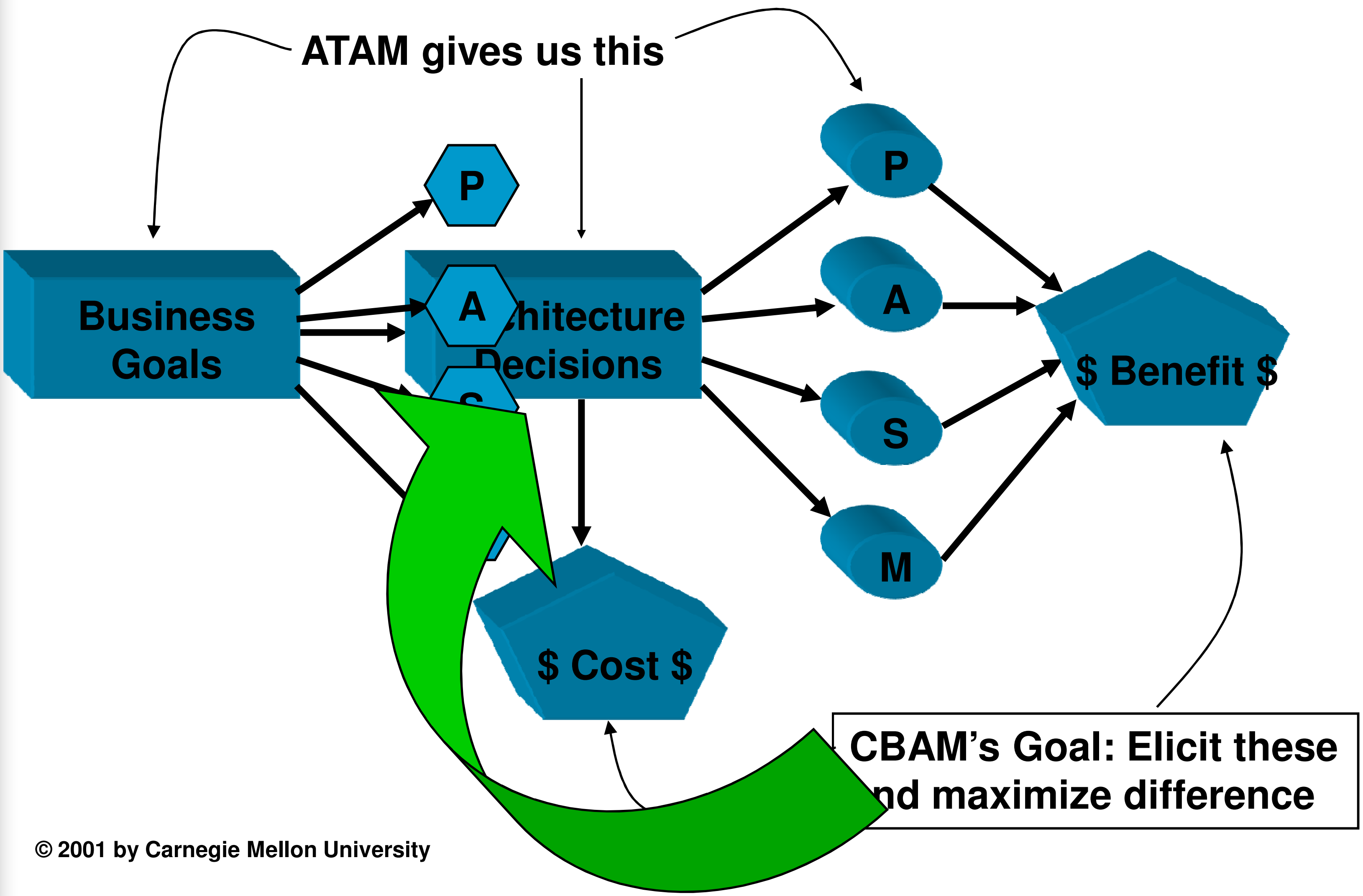
In any investment you should consider the:

- Potential benefit
- Cost
- Risk/uncertainty

How do we quantify these when the investment is software?

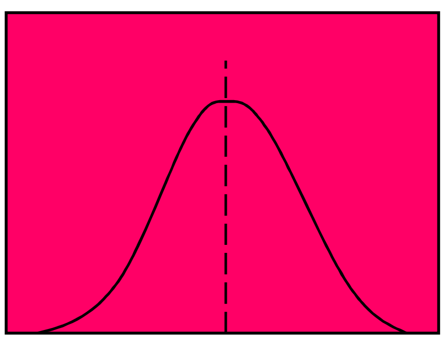
The CBAM (Cost Benefit Analysis Method) extends the ATAM framework to elicit and model costs, benefits, and uncertainty.

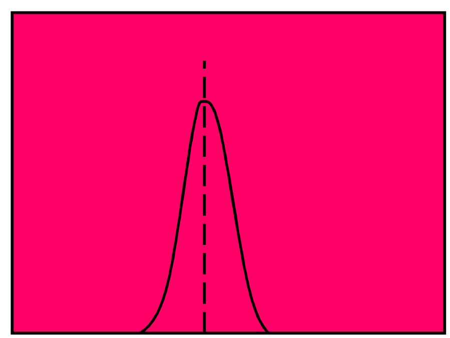
Context for the Work



Example

	Design A	Design B
Avg Latency	500 ms.	200 ms.
Availability	99.9%	99%
Cost	3000	2500
Benefit	6000	5000
Profit	3000	2500


3000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Ramifications of the Example

This example is, of course, over-simplified.

However, even this simple example brings up complex issues:

- **What architectural decisions achieve these responses? What is their risk/uncertainty?**
- **How risk averse are you?**
- **How do you assess your level of uncertainty?**
- **How do you compare the *value* of different system qualities?**
- **What are the personnel/schedule implications of the architectural decisions?**

The CBAM

The aim of the CBAM (Cost Benefit Analysis Method) is:

To explicitly associate costs, benefits, and uncertainty with architectural decisions, as a means of optimizing the choice of such decisions.

Dealing with Uncertainty

There are three functions that we must elicit when we do architecture-based economic modeling:

- **Architecture -> Quality Attribute**
- **Architecture -> Cost**
- **Quality Attribute -> Benefit**

Each of these functions has uncertainty associated with it.

We must elicit and record this uncertainty.

Building Upon ATAM

When the CBAM commences, the ATAM must have the following information documented:

The system's architecture-level design

- **The prioritized business goals of the system**
- **The technical and business constraints**
- **A ranking of the scenarios**
- **The identification of the technical architectural decisions that are sources of uncertainty/risk in the existing architecture**

The Steps of the CBAM

Starting from this base, we then execute the steps of the CBAM (simplified):

1. Collate, Refine, and Prioritize Scenarios
2. Assign Intra-Scenario Utility
3. Develop Architectural Strategies and Determine their Utility
4. Calculate an Architectural Strategy's Costs, Benefits, & Schedule Implications
5. Confirm with Intuition
6. Make Decisions

The Phases of the CBAM

Typically making architectural decisions involves a significant amount of effort.

To attempt to optimize the use of our time in the CBAM, we split it into several phases:

- *Triage*, where we quickly choose a set of architectural decisions to consider.
- *Detailed Examination*, where we more carefully consider the costs, benefits, and interactions of a *subset* of the architectural decisions.

1. Collate, Refine, and Prioritize Scenarios

(To make architecture investment decisions, we begin by asking what system scenarios are important for the business goals.)

Collate the scenarios elicited during the ATAM exercise.

Prioritize based on satisfying the business goals of the system and choose the top 1/3 for further study.

1. Collate, Refine, and Prioritize Scenarios

Example:

S22: After 24 hours of downtime, operations re-prioritizes workload to ensure tasks are worked off in priority order.

- **S/R: System able to re-prioritize 1000 orders in 20 minutes by user class, data types, media type, destination or user (and work off backlog in accordance with these priorities).**

S25: Increase the workload up to and beyond max load. Do not degrade throughput & response time for registered users.

- **S/R: Maintain 24 hour response time for high priority orders while supporting a 2-fold data volume over 90 days without operations intervention.**

S28: Workload from one provider exceeds its rated input. System handles variations in data arrival from with max throughput and minimal operator intervention.

- **S/R: Able to support 2X spike in data volume without operations intervention and work off in priority order.**

1. Collate, Refine, and Prioritize Scenarios

Refine the scenarios focusing on their stimulus/response measures.

Elicit the worst, current, desired and best quality attribute (QA) level for each scenario.

Example: for S22 Backlog Management; system can re-prioritize 1000 orders in:

Worst Case	Current Case	Desired Case	Best Case
120 min	40 min	20 min	10 min

1. Collate, Refine, and Prioritize Scenarios

Allocate 100 votes to each stakeholder and have them vote on the scenarios.

Total the votes and choose the top 50% of the scenarios for further analysis.

Example:

Scenario	# of Votes
22	34
25	18
18	12
36	12
19	10
4	8

2. Assign Intra-Scenario Utility

(How do we compare the various scenarios? We need a shared measure of goodness. We use "utility".)

Determine the *utility* for each response level (worst case, current, desired, best case).

Example (S22):

Worst Case	Current Case	Desired Case	Best Case
0	***80***	***90***	***100***
120 min	40 min	20 min	10 min

2. Assign Intra-Scenario Utility

Note that in this step we are converting from technical measures (latency, mean time to failure, # of requests served per minute, etc.) to generic measures of *goodness*.

This key step supports holism.

Worst Case	Current Case	Desired Case	Best Case
0	***80***	***90***	***100***
120 min	40 min	20 min	10 min

3. Develop Architectural Strategies and Determine their Utility

Develop ASs that address the chosen scenarios. Determine the response levels that result from implementing these ASs.

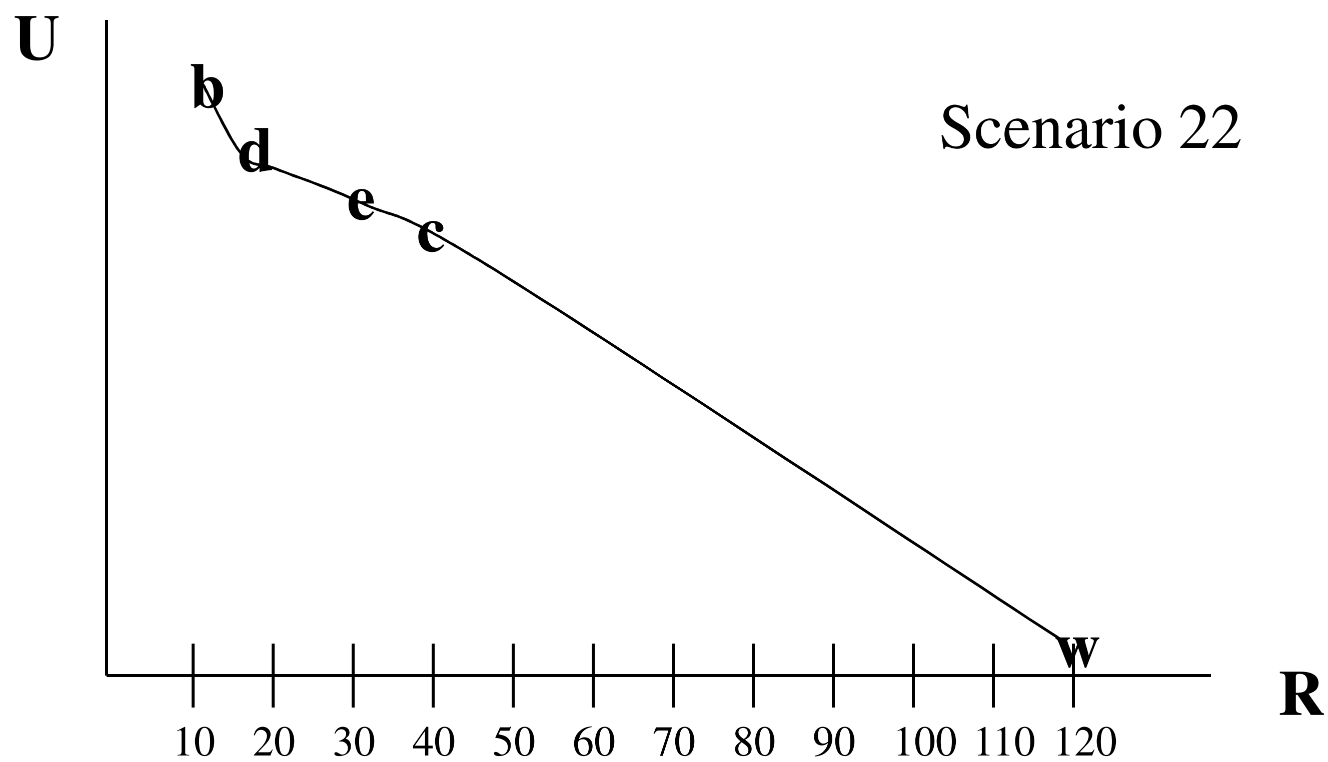
Call these the "expected" levels. We can interpolate their utility values.

Arch Strategy	Worst Case	Current Case	Expected Case	Desired Case	Best Case
RM80	120	40	32.5	20	10

3. Develop Architectural Strategies and Determine their Utility

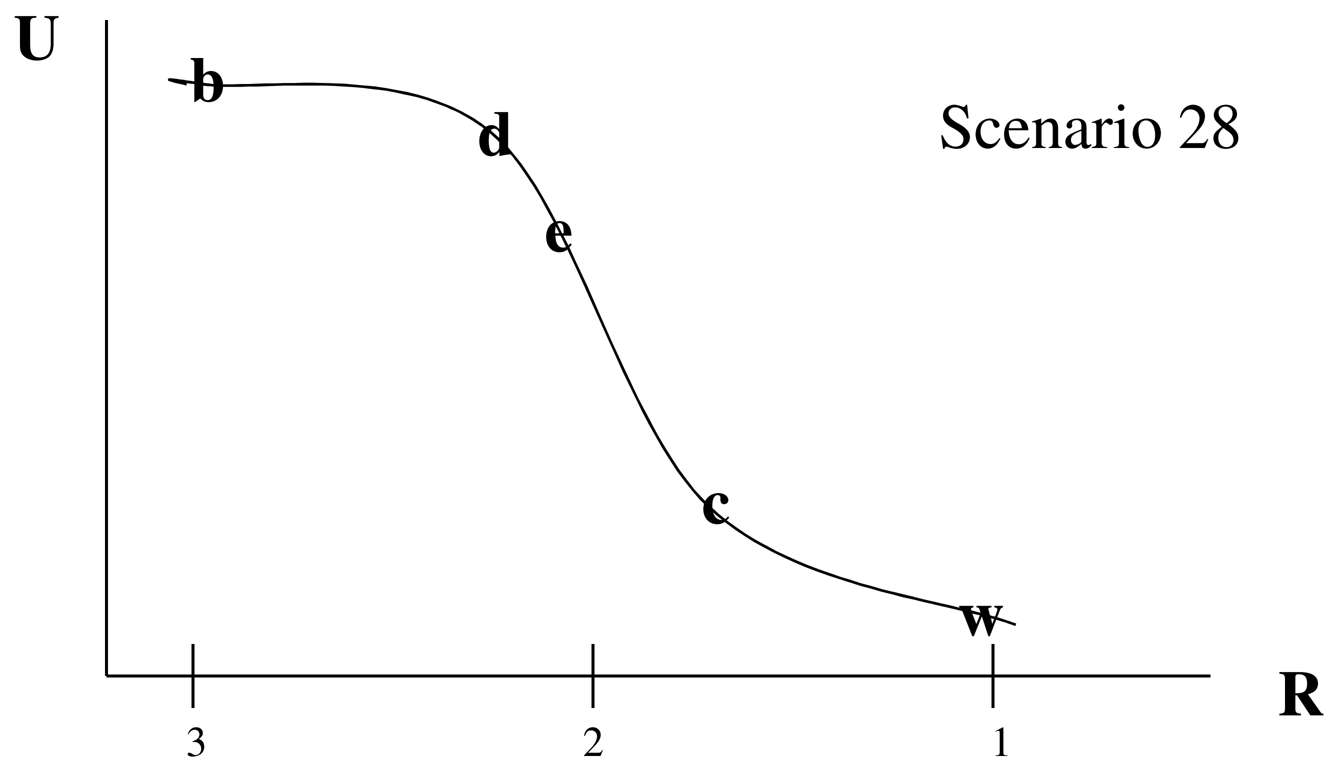
What have we elicited and developed here?

A response/utility curve!



3. Develop Architectural Strategies and Determine their Utility

These curves will be different for different scenarios.



4. Calculate an Architectural Strategy's Costs, Benefits, & Schedule Implications

Calculate the expected benefit of each architectural strategy AS_i.

For each scenario where AS_i is used:

- *calculate* the relative improvement in utility as the difference between the 'current' level and the 'expected' level.
- *normalize* this benefit amount using the votes collected in step 1
- *sum* these normalized values

4. Calculate an Architectural Strategy's Costs, Benefits, & Schedule Implications

AS	Scenario	Benefit	Votes	Normalized Benefit	Total Benefit
RM80	22	7.5	34	255	
RM80	25	8.0	18	208	
RM80	18	3.75	12	45	508
RM20	4	5.0	8	40	
RM20	19	16.5	10	165	205
RM120	28	31.0	6	186	186
RM100	36	12.0	12	144	144

4. Calculate an Architectural Strategy's Costs, Benefits, & Schedule Implications

- Calculate the expected *cost* of implementing each architectural strategy AS_i that results in the expected benefit.
- Estimate the *schedule* implications of each AS_i in terms of person-months of effort and/or elapsed time.
  - **Note any contention for shared resources among these estimates (hardware, software, or personnel).**

4. Calculate an Architectural Strategy's Costs, Benefits, & Schedule Implications

Now we can calculate the return (ROI) on each AS investment, and its rank.

AS	Benefit	Cost	Return	Rank
RM80	508	120	4.83	2
RM20	205	40	5.12	1
RM120	186	85	2.19	3
RM100	144	110	1.31	4

5. Confirm With Intuition

Each of these steps involves stakeholder input, and hence subjectivity.

To ensure that the results are well-founded we examine the results, with respect to the *business goals* of the system.

If the results conflict with intuition we need to determine if there are other issues that have not been considered while making these decisions.

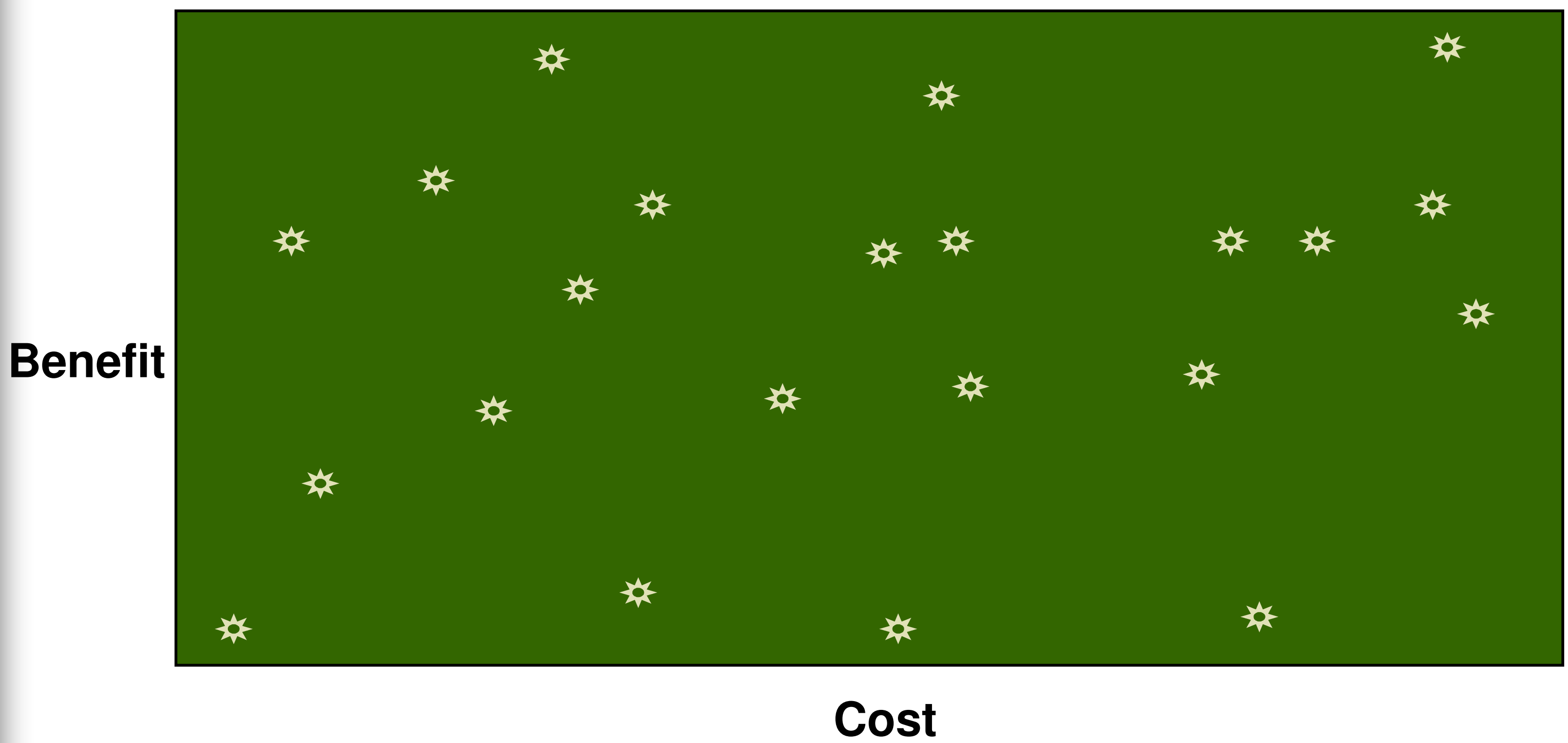
5. Confirm With Intuition

An important aspect to consider is at this point is the uncertainty associated with the benefit and cost judgements.

We capture uncertainty as statistical measures of the variation in judgements among the stakeholders.

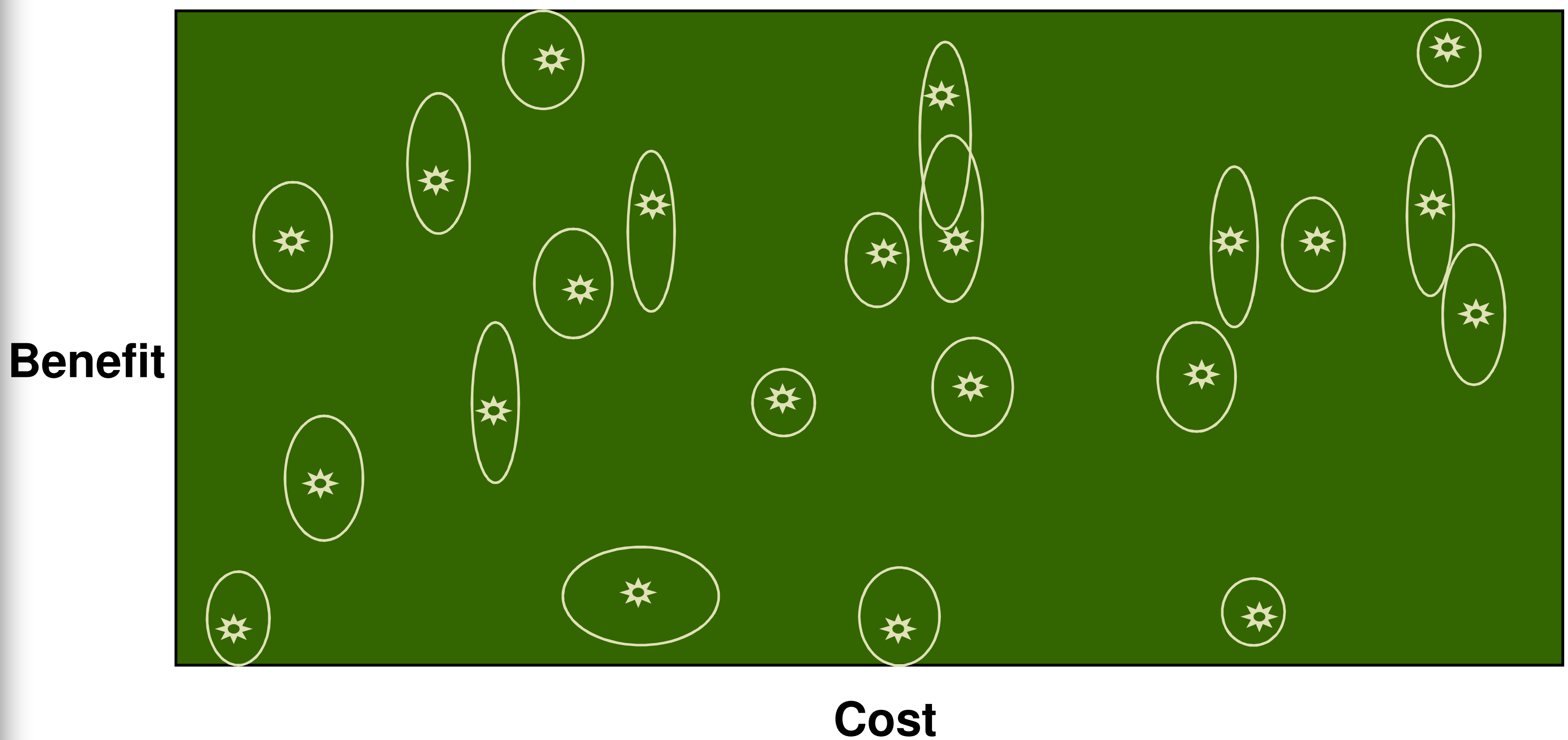
6. Make Decisions

The benefits and costs can now be plotted.



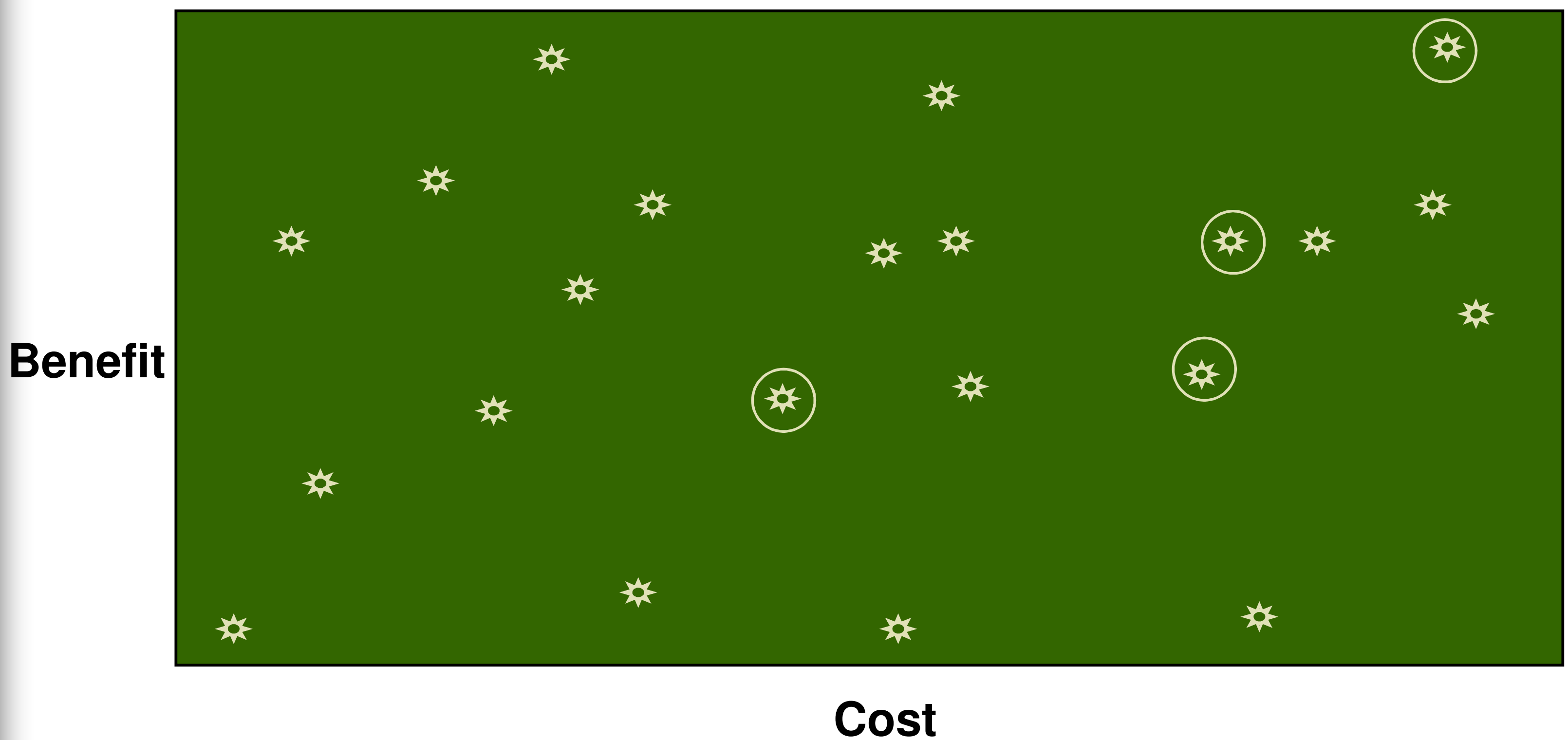
6. Make Decisions

The benefits and costs can now be plotted. We can also plot their associated uncertainty.



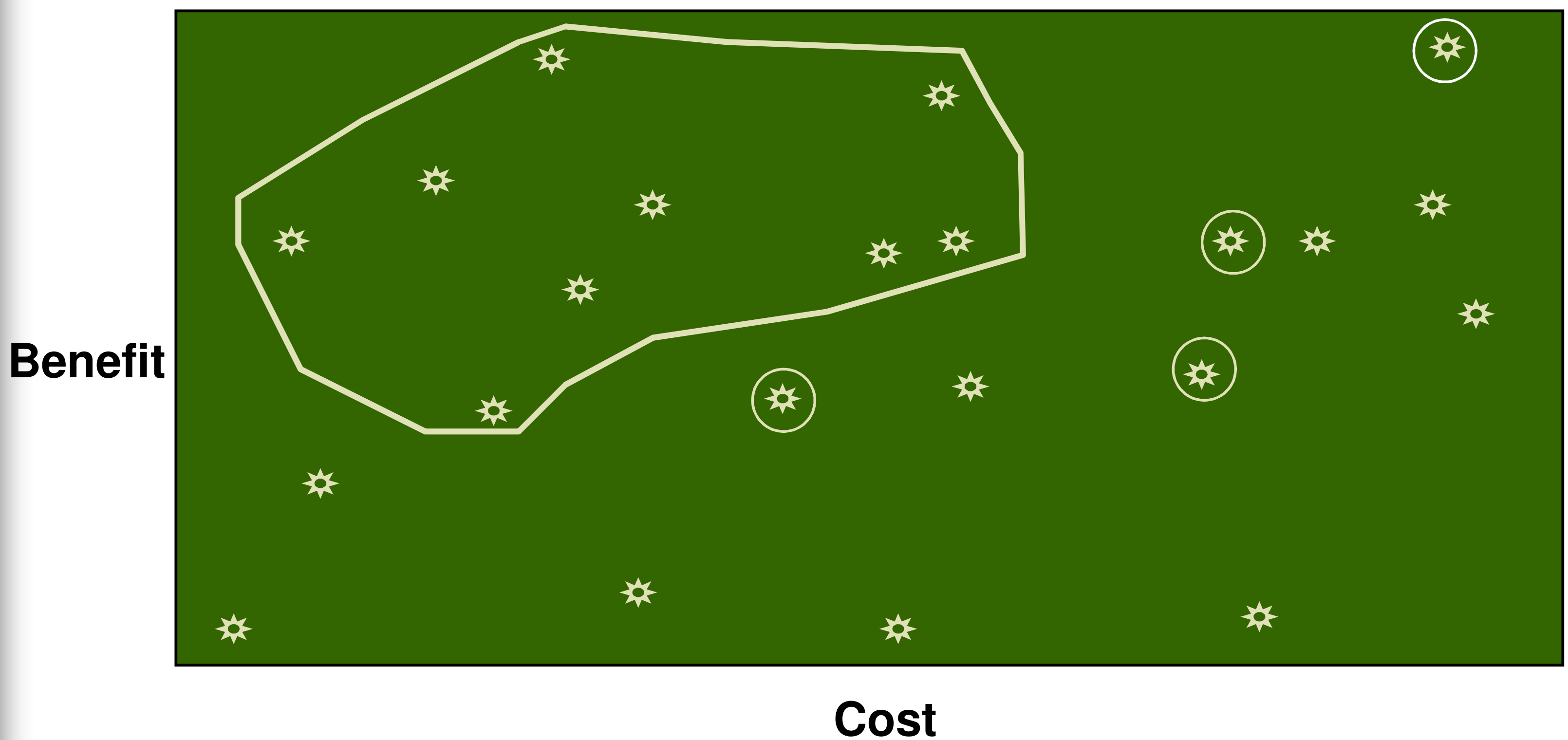
6. Make Decisions

Some ASs *must* be chosen. Remove these from consideration.



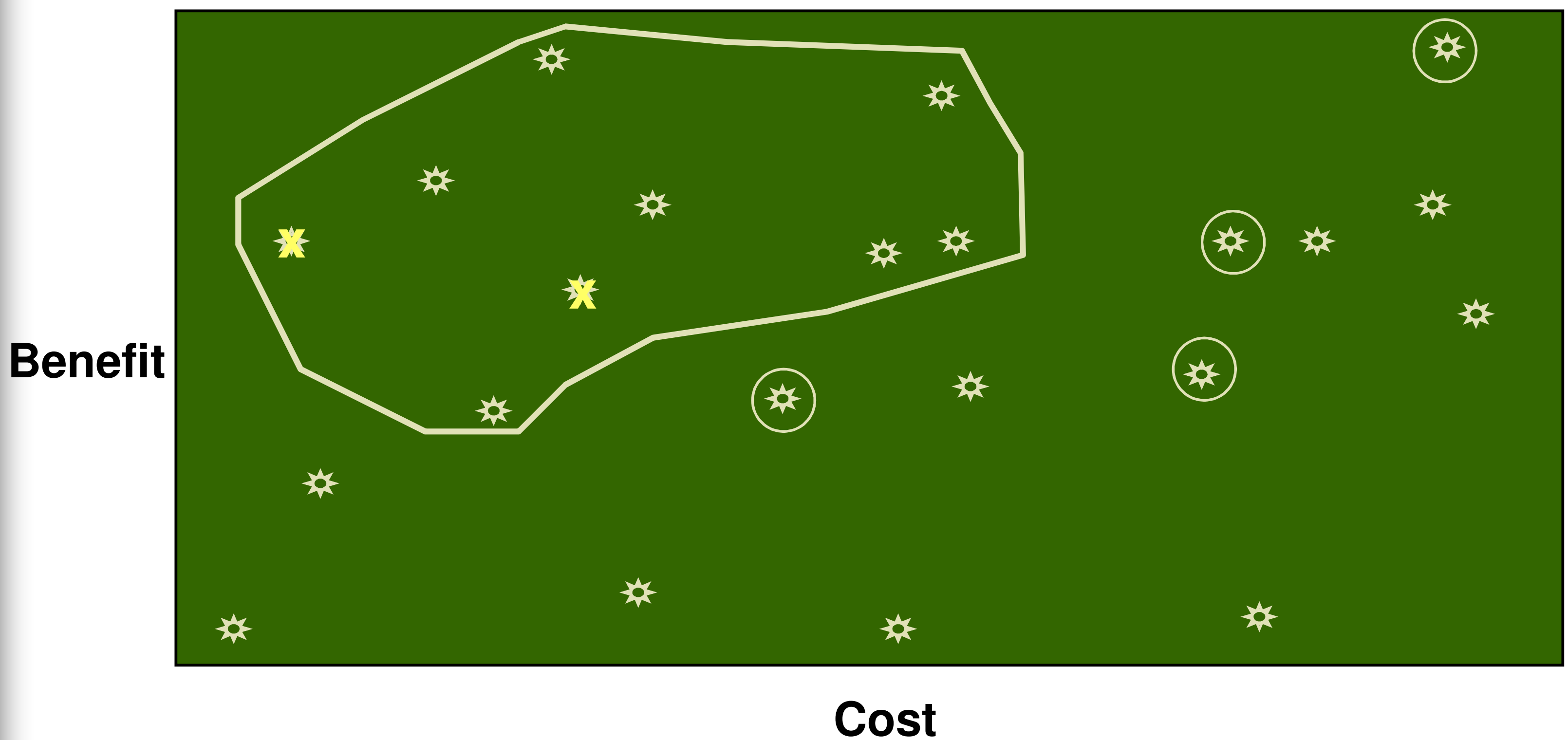
6. Make Decisions

Now consider the set of high benefit, low cost ASs.



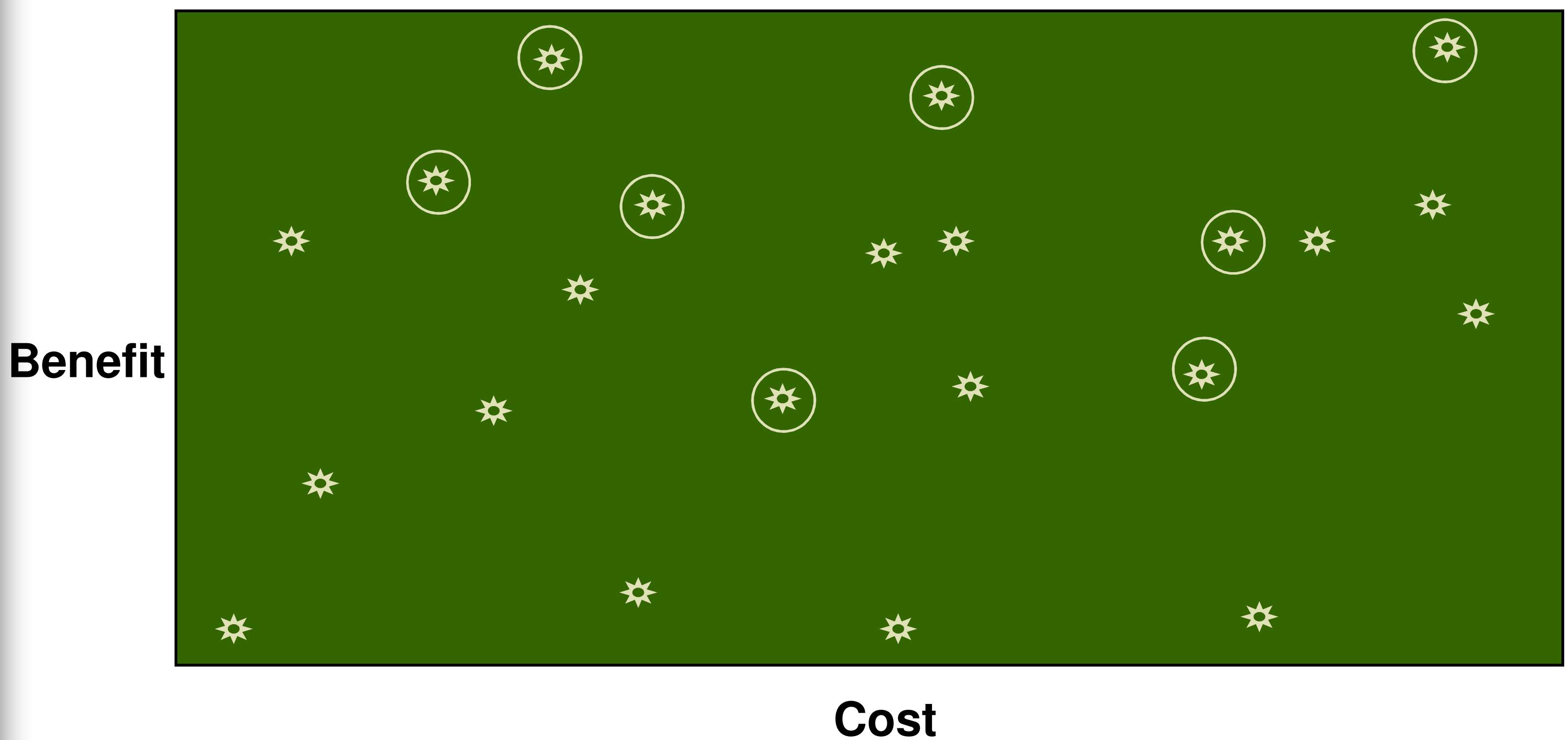
6. Make Decisions

Some of these may be excluded because of resource or time-to-market conflicts.



The Final Result

Choose a final set. Some decisions may be in/excluded because of dependencies.



The Final Result

After this exercise, we have determined a set of architectural strategies that address our highest priority scenarios.

These chosen strategies furthermore represent the optimal set of architectural investments.

They are optimal based upon considerations of:

- **benefit**
- **cost**
- **schedule**
- **uncertainty**

Status

The CBAM v1 was developed in 2000.

We are now developing and piloting CBAM v2. What has been presented here is a simplification of the steps of CBAM v2.

We are piloting the CBAM v2 with NASA's EOSDIS project:

- **1.1 million lines of custom code**
- **12,000 modules**
- **50 COTS products**

Status

The early results from our pilot are encouraging:

- **We have achieved considerable consensus from the stakeholders.**
- **We have provided a means for them to focus their attention and discussion.**
- **They have dramatically reduced the size and complexity of their decision space.**
- **We have given them a disciplined technique for determining a set of architectural strategies to pursue that are within budget and schedule constraints.**

Conclusions

The CBAM is a method for optimizing architecture investment decisions, considering cost, benefit, and uncertainty.

It augments the ATAM and starts where the ATAM leaves off: the ATAM allows one to analyze quality attributes; the CBAM adds costs and benefits as attributes to be "traded off". This is holistic.

The CBAM helps stakeholders prioritize changes to an existing architecture, or consider strategies for a new architecture.

Challenges for the Future

- Extracting/validating information: e.g. Delphi technique
- Cost modeling that is "architecture aware"
- Incorporating portfolio theory
- Explicitly dealing with uncertainty
- Creating generic quality attribute/benefit characterizations
- Balancing decision making considerations: time frame, risk aversion, personnel availability…

Questions?