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Developing Case-Based Costs Estimation: A Recursive Approach and Case Study

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Outline

- Introduction
- Overall Estimation Framework
- Component Level Cost
- System Level Cost
- Properties
- Example – HVAC
- Experience and Conclusion

Introduction

- Costs
  - Raw Cost
    - Build from scratch
  - Switching Cost
    - Build from prior products

- Methods for raw costs may not be suitable for switching costs
  - E.g. Linear regression

  Significant errors!

Literature
(Before DARPA AVM 2011)

Most studies were on raw costs

- Manufacturing parts
- Development costs

Switching costs for a generic system: unanswered

AVM: Adaptive Vehicle Make

Switching costs studied for specific domains/systems

- Software-intensive systems

  E.g. (Wang, G., et. al., 2009)

- Tools:

  E.g. SEER-H (hardware systems)

  SEER-SYS, COSYSMO II (Systems engineering costs only)

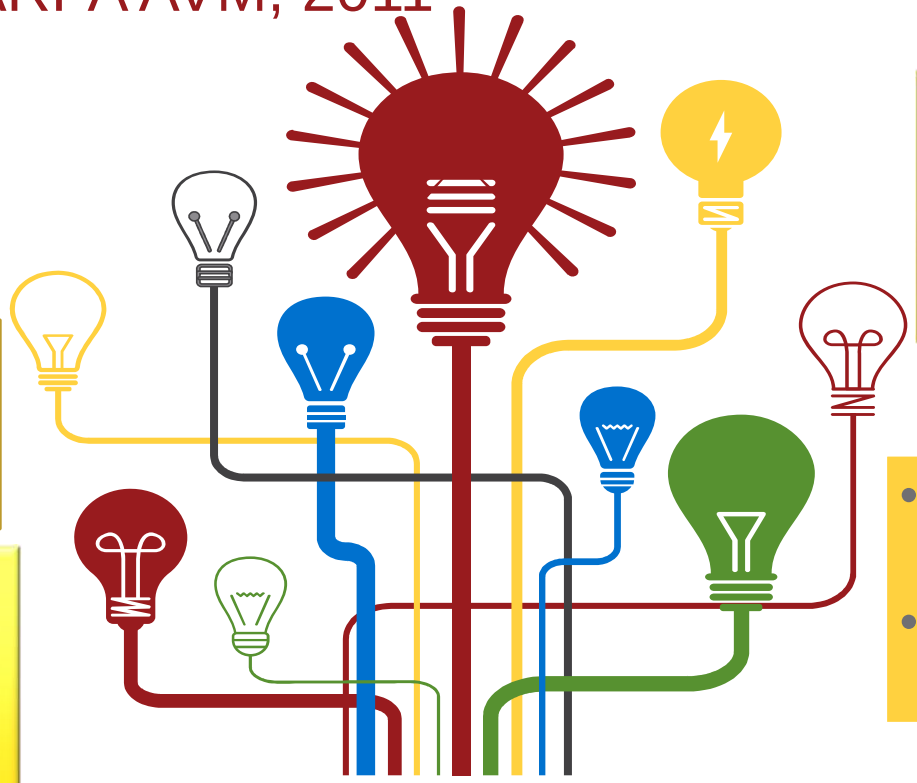
Our Work

-Performed in DARPA AVM, 2011

Concept and Properties of Switching Costs

Methods of Calculating Switching Costs

- Activity-Based Approach;
- Support Early-Stage Estimation



Applicable to Systems Generated With Different Processes

- Minimize manual EJ (Expert Judgment)
- Do not explicitly require data calibration

Definitions

- Architecture/Design
  - Components

  Flows/Connections are special components
- AA (All Activities) Set
  - Include all design activities
- Primitives:

  SAME(), SWITCHABLE(), etc.

Switching Cost AA $\widehat{C}_{sw}(A,B)$ Raw cost AA $\hat{C}(A)$

Switching Cost Csw (A, B) Raw cost C(A)

Overall Estimation Framework

Process: Top down, recursion back

Raw Cost:

$$C(A) = f(\hat{C}(A)) = C(\alpha, A) + C(\sigma, A)$$

$$\hat{C}(A) = \hat{C}(\alpha, A) \cup \hat{C}(\sigma, A)$$

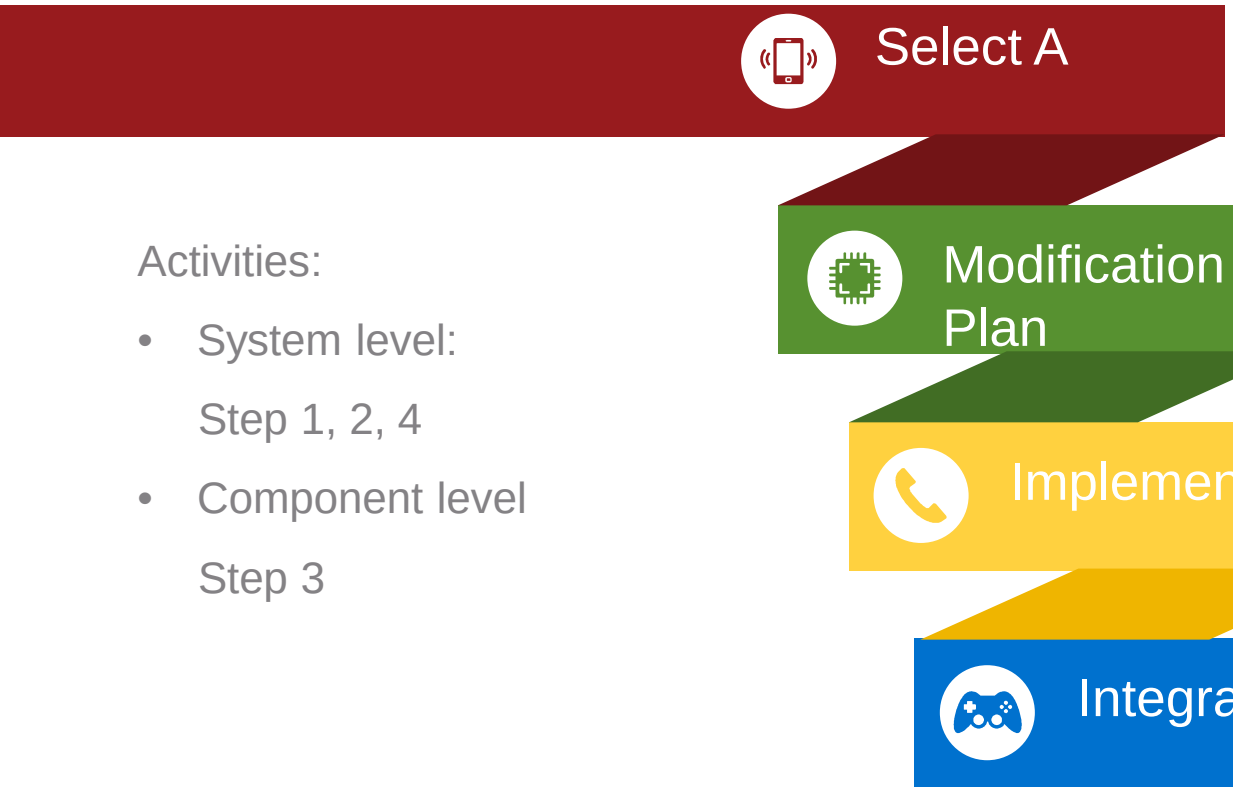
Switching Cost:

$$Csw(A, B) = f(\hat{C}_{sw}(A, B))$$

$$= Csw(\alpha, A, B) + Csw(\sigma, A, B)$$

$$\hat{C}_{sw}(A, B) = \hat{C}_{sw}(\alpha, A, B) \cup \hat{C}_{sw}(\sigma, A, B)$$

Switching Design Process



A is prior product

Activities:

- System level:

  Step 1, 2, 4
- Component level

  Step 3

Match each component with some prior components

Implement switch designs

Remaining steps: integrate, V&V, etc.

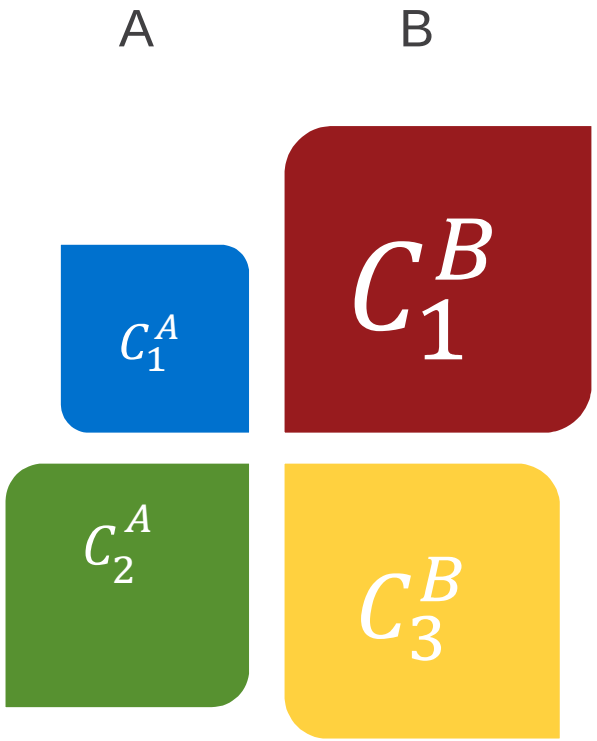
Component Level

Component Activities

Design

$$\hat{C}_{sw}(\sigma, A, B) = \bigcup_{n=1}^{|\sigma|} \hat{\Gamma}_{\sigma_n, A, B}$$

Compare by types



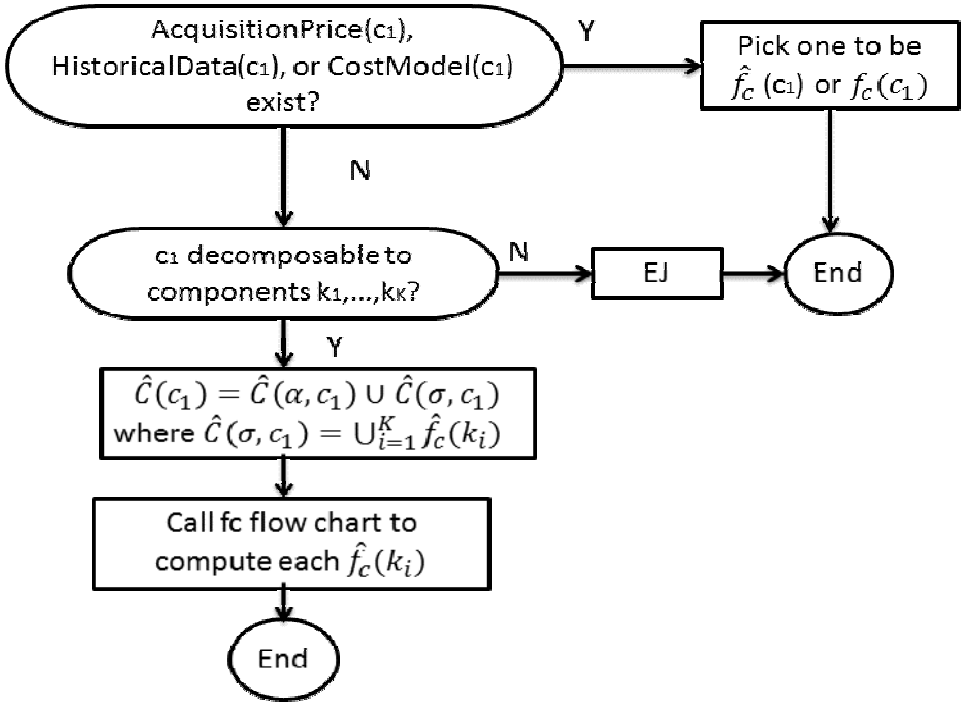
Three types of changes:

$f_c(c_3^B)$: Add from scratch

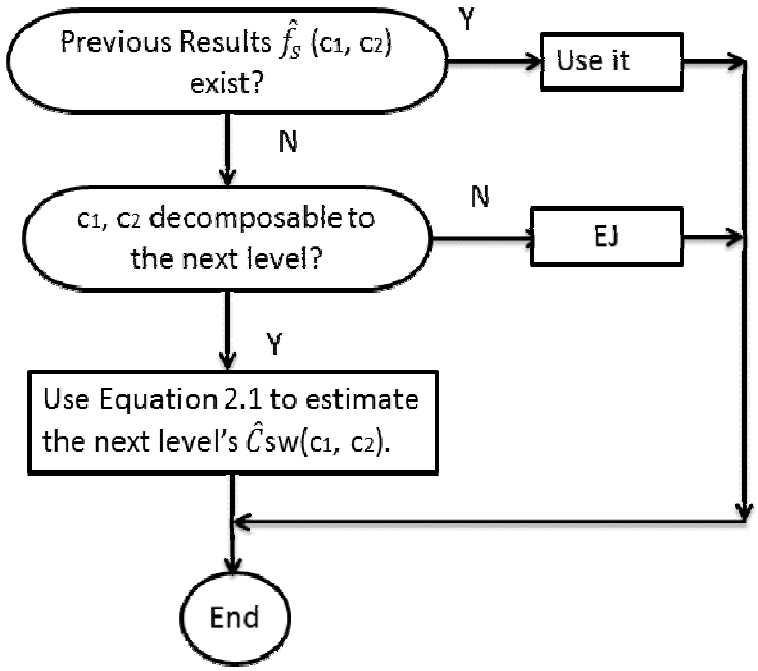
$f_s(C_1^A, C_1^B)$: Modify from a prior component

$f_r(C_2^A)$: remove a component

Recursions



fc()



fs()

System Level

$$C_{sw}(\alpha, A, B) = f(\hat{C}_{\alpha}(A, B), \hat{C}_{sw}(\alpha_1, B))$$
$$= C_{\alpha}(A, B) + C_{sw}(\alpha_1, B)$$

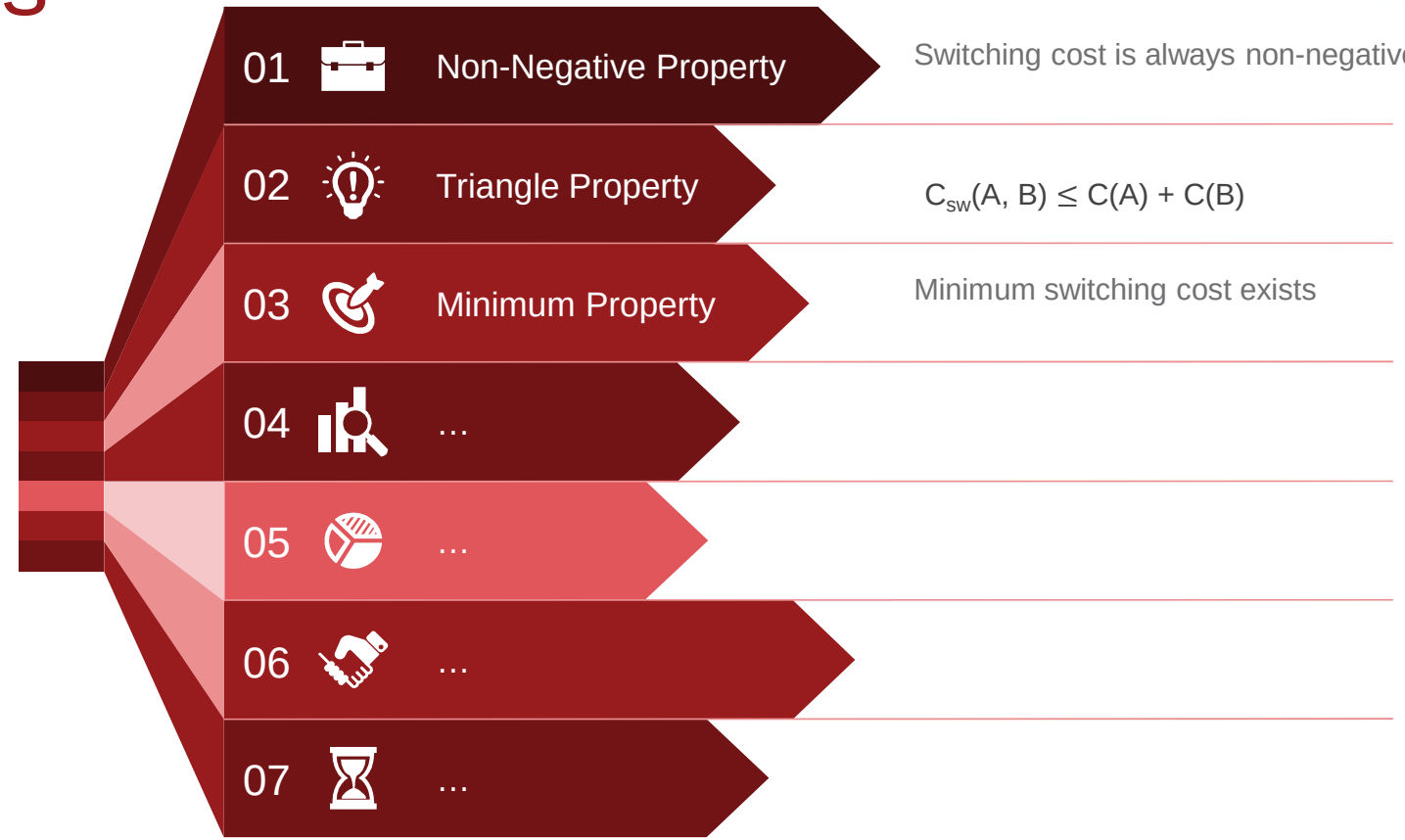
$\hat{C}_{\alpha}(A, B)$: system level activities on analyzing and selecting arrangements

$\hat{C}_{sw}(\alpha_1, B)$: system level activities on building B besides the costs on B's components

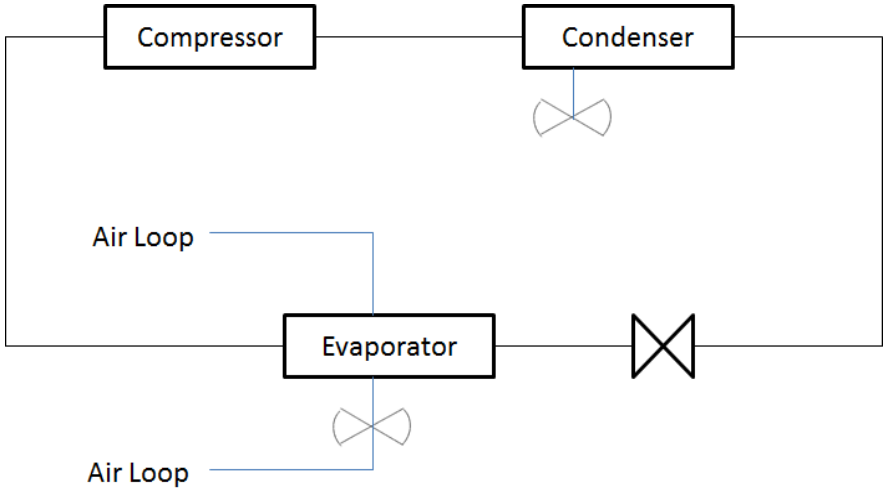
- E.g. designing, integrating and verifying/validating system B

Properties

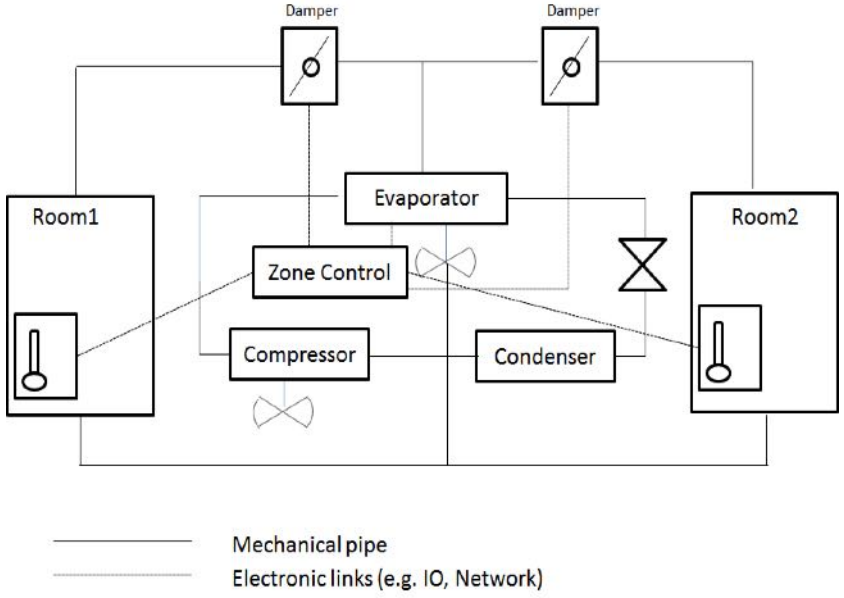
Switching Cost



Example - HVAC



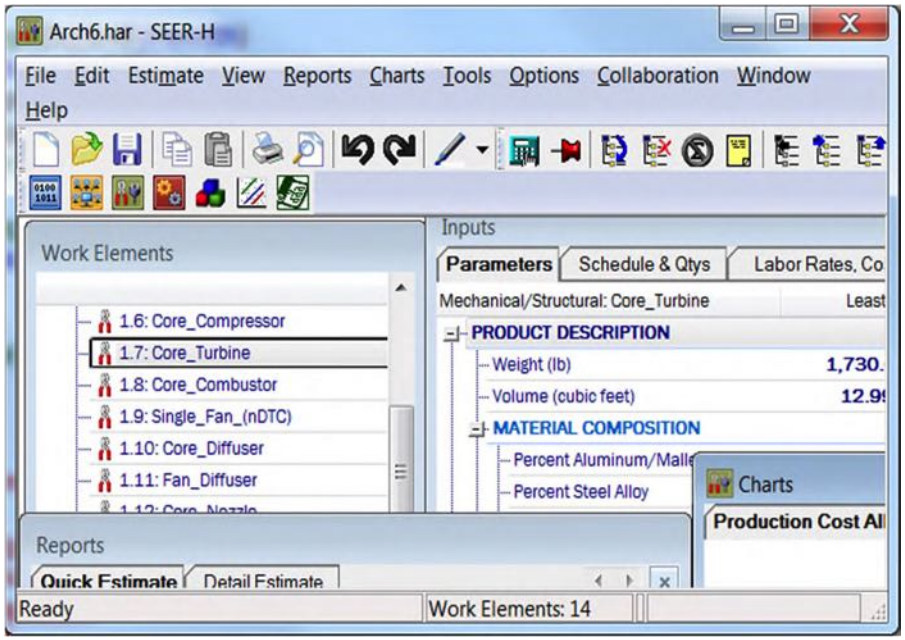
A



B

Process and Tools

σ_1 = compressor, $\sigma_{1,A} = \{c_{1,1}\}$, $\sigma_{1,B} = \{c_{1,2}\}$
σ_2 = condenser, $\sigma_{2,A} = \{c_{2,1}\}$, $\sigma_{2,B} = \{c_{2,2}\}$
σ_3 = vaporizer, $\sigma_{3,A} = \{c_{3,1}\}$, $\sigma_{3,B} = \{c_{3,2}\}$
σ_4 = damper, $\sigma_{4,A} = \phi$, $\sigma_{4,B} = \{c_{4,1}, c_{4,2}\}$
σ_5 = controller, $\sigma_{5,A} = \{c_{5,1}\}$, $\sigma_{5,B} = \{c_{5,2}\}$
σ_6 = user control panel, $\sigma_{6,A} = \phi$, $\sigma_{6,B} = \{c_{6,1}\}$
σ_7 = software on controller, $\sigma_{7,A} = \{c_{7,1}\}$, $\sigma_{7,B} = \{c_{7,2}\}$
σ_8 = software on user control panel, $\sigma_{8,A} = \phi$, $\sigma_{8,B} = \{c_{8,1}\}$
σ_9 = IO link between controller and controlled components (e.g.damper/condenser), $\sigma_{9,A} = \{c_{9,1}\}$, $\sigma_{9,B} = \{c_{9,2}\}$
σ_{10} = Network link between user control panel and zone controller, $\sigma_{10,A} = \phi$, $\sigma_{10,B} = \{c_{10,1}\}$



SEER-H*

*courtesy Galorath Inc.

Conclusion

- Switching cost
  - Concept, Properties, Methods, Principles
- Our method
  - Automation: Minimize EJ
  - Not parametric
    - Unlike COSYSMO II etc.
    - Do not explicitly require data calibration, thus reduce it
  - Leverage existing tools, models, prices, data
  - First answered the question of switching cost for a complete generic system (AVM)