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DEFINING THE FUTURE

SE/IT/PM Estimating Approaches for Service-Oriented Architecture Environments

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Outline

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Definitions

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- SE/IT/PM
  - Systems Engineering, Integration and Test, and Program Management
  - Refers to the costs of performing the above activities
- PME
  - Prime Mission Equipment
  - Refers to software development, hardware development, and COTS software and hardware purchases
- CER
  - Cost-Estimating Relationship
- SOA
  - Service-Oriented Architecture
  - Refers to a standards-based (e.g., Extensible Markup Language (XML) messaging, Simple Object Access Protocol (SOAP), etc.) software architecture consisting of an application front-end, services, and an enterprise level service bus
  - In layman's terms: An architecture that allows additional system or functions to easily "plug into" it[1]

[1] For more information on SOAs and cost-estimating challenges, please see "*Service Oriented Architecture: SOA How is it Estimated*?," Snyder and McDonald, SCEA 2007

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Problem statement

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- Within the Intelligence Community, there is a movement towards breaking down stovepiped architectures and implementing SOAs.
  - The idea is that new programs will be integrated into an existing SOA framework, thus allowing data sharing between programs.
- While the SE/IT/PM cost of simply adding PME to an existing system can be modeled using a regression-based CER, at this time the SOA framework is still immature.
  - The SOA does not have all the capabilities required to accommodate incoming systems
  - As such, a program cannot simply “plug ‘n’ play” into the SOA framework.
  - Frequently some reengineering of the SOA must occur to accommodate a new program, so a new program cannot simply capitalize on capabilities that are already there
- We are faced with the question: How do we estimate the SE/IT/PM costs of these new programs plugging into an immature SOA?

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Data set

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- Two sets of cost data corresponding to unique services
  - One service hardware-intensive, the other software-intensive
- Cost account data organized by quarter and WBS for the entire development period of both functions
  - Both services on the same contract, but separate WBS numbers were used for the two services
- Costs were then mapped to SE/IT/PM or PME for each service
  - Contractor confirmed mappings are appropriate and accurate

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Linear approach

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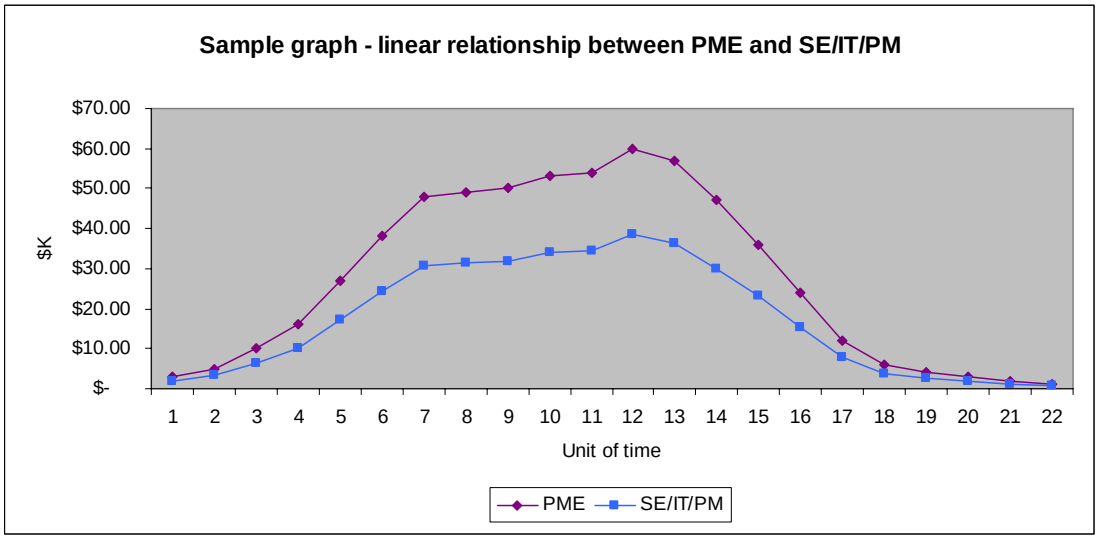
- Many cost analysts model SE/IT/PM costs using a linear coefficient on PME costs
  - SE/IT/PM costs are assumed to "ride along" with PME costs
  - Very straightforward and easy to understand and calculate



- Because quarterly cost data was available (as opposed to simply cumulative), a regression-based CER approach was explored first
  - *X*-values for regression were PME costs; *Y*-values were SE/IT/PM costs

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Linear approach: Regression-based CER: Analysis results (with y-intercept)

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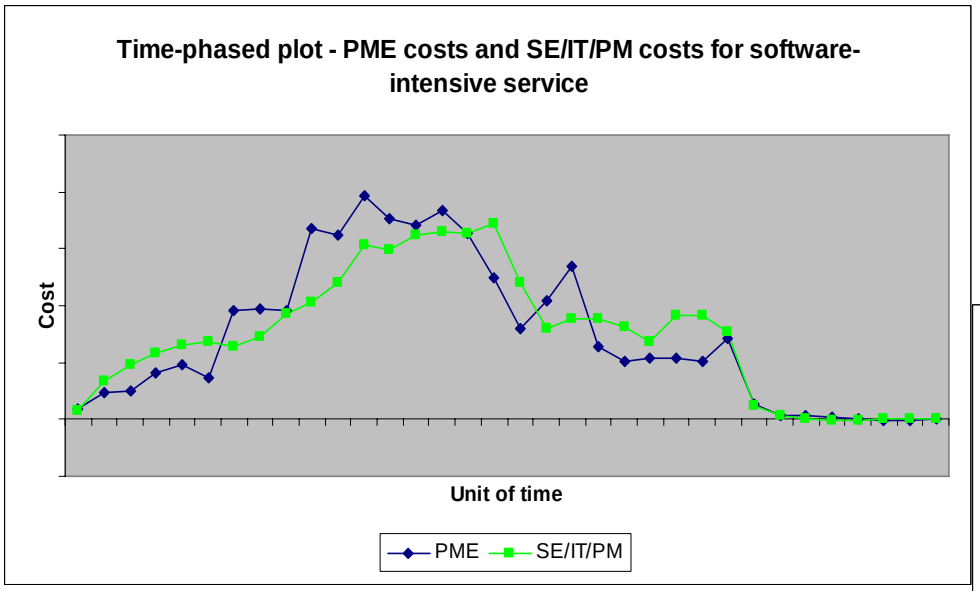
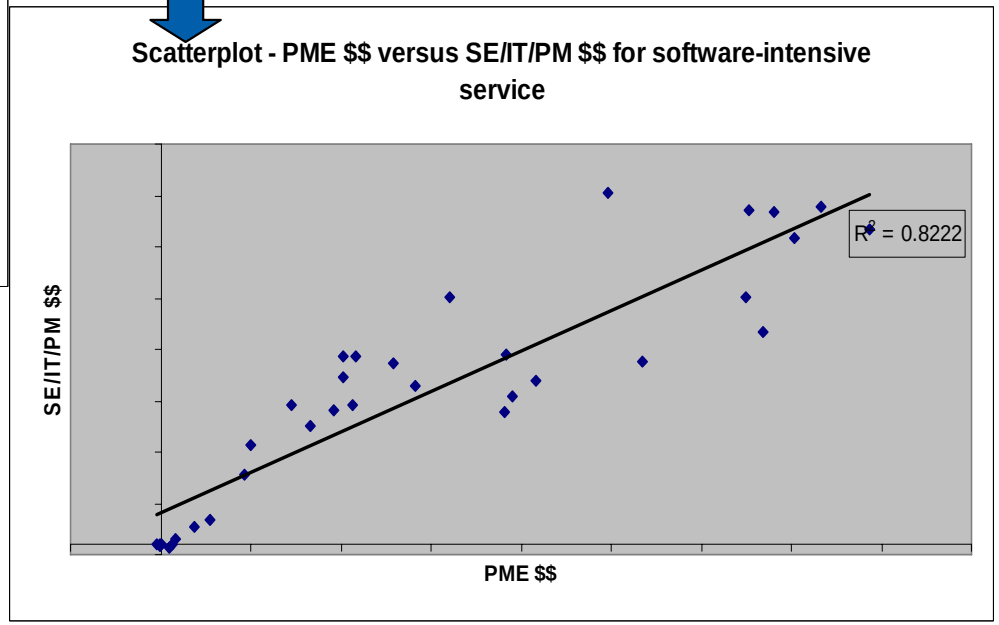
- Regression analysis for the software-intensive service indicated that a linear approach may be a very good option
  - Statistically significant CER and intercept (p-value < 0.02) and high R^2 value (~0.82)



Because the SE/IT/PM appears to follow the same trend as PME, we expect a reasonably good linear relationship to emerge from regression analysis.

And so it does!



X-values for regression:
Quarterly PME costs

Y-values for regression:
Quarterly SE/IT/PM costs

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Linear approach: Regression-based CER: Analysis results (with y-intercept)

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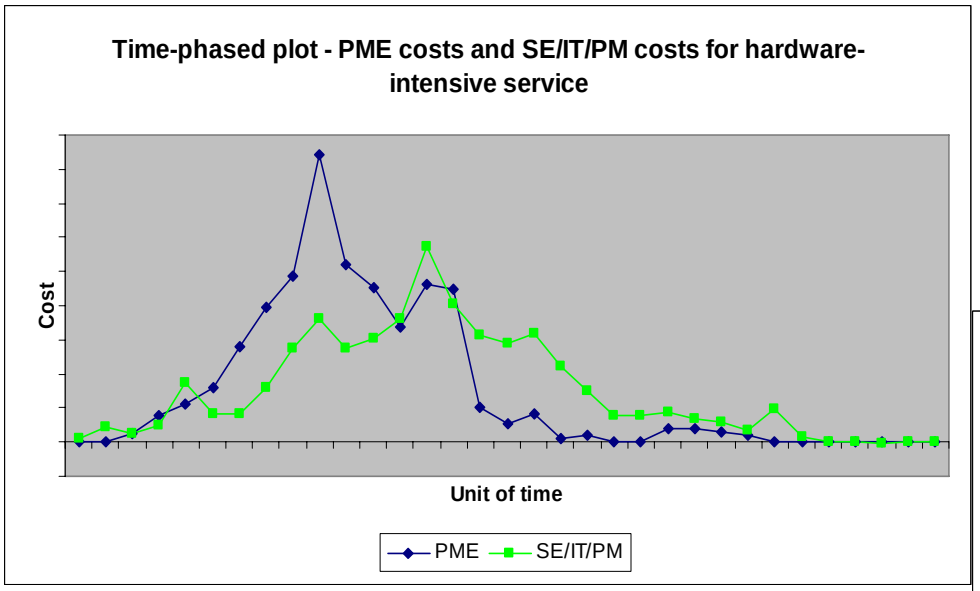
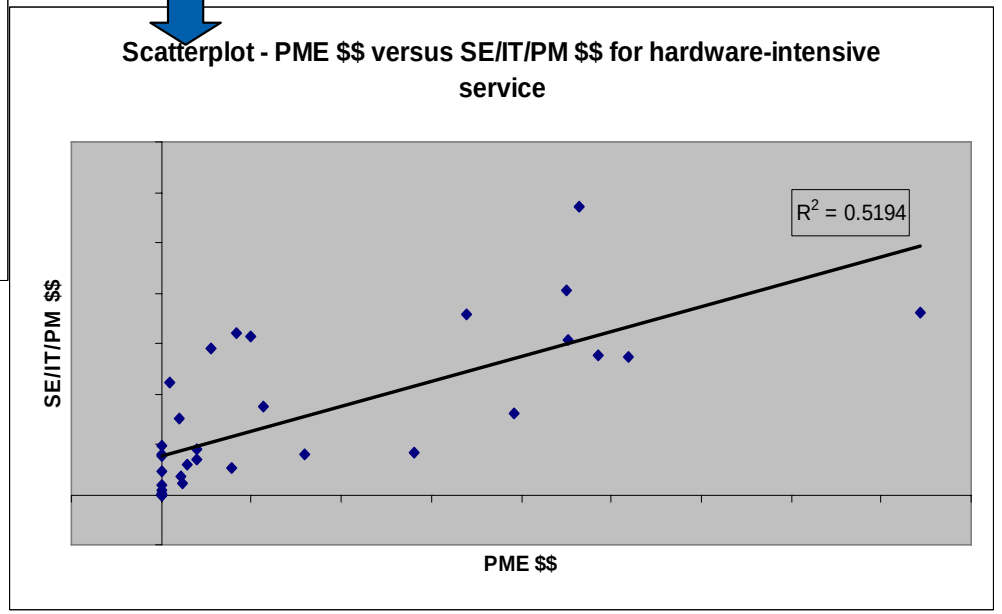
- Regression analysis for the hardware-intensive service indicated that a linear approach may not be the best option
  - Statistically significant CER and intercept (p-value < 0.002 for both), but R^2 value was middling (~0.52)



SE/IT/PM does not appear to follow the same trend as PME, so we do not expect a strong linear relationship to emerge from the regression.

Regression relationship is not strong.



X-values for regression:
Quarterly PME costs

Y-values for regression:
Quarterly SE/IT/PM costs

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Linear approach: Regression-based CER: Concern about the coefficient

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- The coefficient of a regression equation is "the change in the mean of the probability distribution of *Y* per unit increase in *X*"[2]
  - In this case, it is the additional incremental SE/IT/PM cost of adding PME to the existing system or framework
  - Ideally, this is all we would need to estimate SE/IT/PM costs for a program "plugging into" an existing SOA framework
- However, the SOA framework in question, as mentioned previously, is not a mature framework
  - To date each program hoping to utilize the existing framework has had to take into consideration both of the following:
    - The costs associated with the additional PME it is bringing in
    - The costs for updates and changes to the framework to allow it to "plug in"
  - Because it is tied only to new PME, the coefficient of the regression will not capture these costs

[2] *Applied Linear Regression Models*, Kutner, Nachtsheim, and Neter, fourth edition

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Linear approach: Regression-based CER: Concern about the intercept

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- The intercept of a regression equation is "the mean of the probability distribution of Y at $X = 0$"[3]
  - The meaning of the y-intercept can be difficult or even impossible to determine
  - Many statisticians will tell you it has no meaning at all[4]
  - If we needed to estimate the cost of developing a new framework analogous to this one, we could use both the coefficient and the intercept to do so
- However, while the framework is not fully mature, programs integrating into the framework can still "leverage" functionality already in place in the framework
  - If we use the intercept and the coefficient to estimate the costs of a program "plugging into" the framework, we will dramatically overestimate the SE/IT/PM costs

[3] Kutner, et al

[4] For more information, please see "'*To b or not to b': The y-intercept in cost estimation,*" Coleman, Summervile, Braxton, Cullis, and Druker, SCEA 2007

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Linear approach: Simple ratio CER: Analysis

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- For this analysis, the total SE/IT/PM costs over time were summed and divided by the sum of the total PME costs over time
  - This ratio is then used as a linear coefficient to estimate SE/IT/PM from PME
  - This is equivalent to the average of the monthly simple ratios
  - Many analysts do this because of a lack of monthly or quarterly data
    - If the only data available is cumulative data, this may be the only option
  - The CERs in this case came to be much higher than the regression-based CERs
    - This makes sense because we are not accounting for the positive *y*-intercept

CER	Software-intensive program	Hardware-intensive program
Regression-based	**0.52**	**0.83**
Simple ratio	**0.80**	**1.06**

  - However…..What is the statistical basis for this CER?

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Linear approach: Simple ratio CER: Concerns

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- Practically speaking, there is no statistical basis for this CER
  - Intuitively, we believe that there must be a relationship between PME and SE/IT/PM
  - However, this analysis forces a relationship where one may not exist, or may exist in a different form
- However…
  - This method provides a higher CER and therefore more of a cushion to account for costs not captured in the regression-based CER
    - For a program plugging into an immature SOA framework, this could help account for the SE/IT/PM costs associated with reengineering the SOA to accommodate the new program
  - The higher costs are linked to PME, while use of the y-intercept of the regression would not be
  - It's iffy but it's conservative

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Compare and contrast

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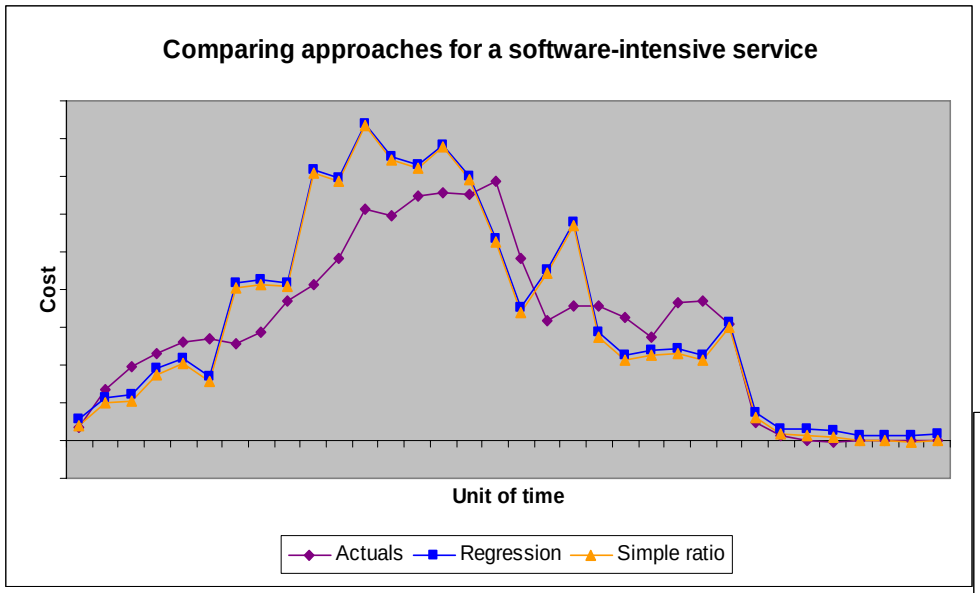
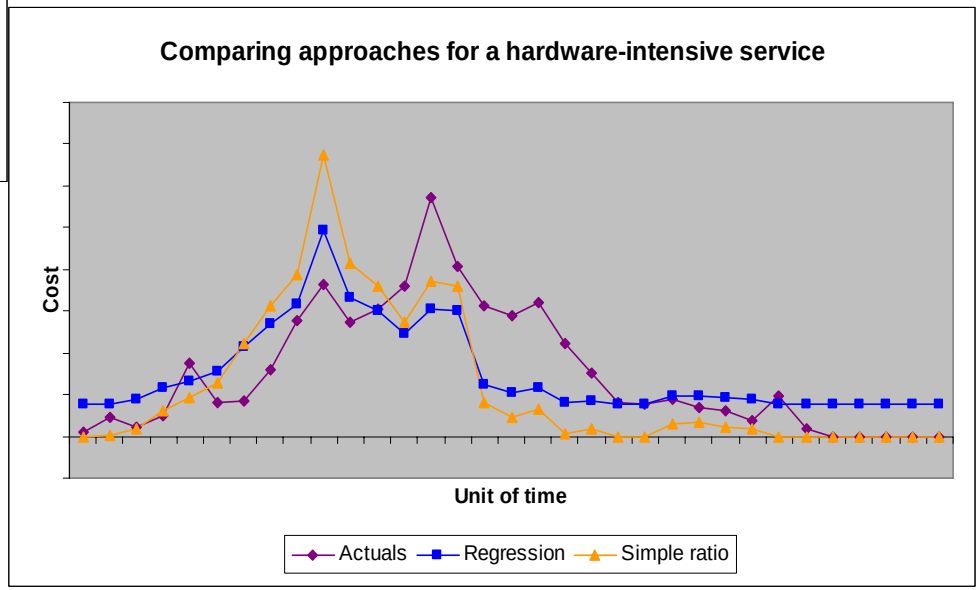
- Comparing the regression analysis and the simple ratio with actuals



The regression-based CER and the simple ratio CER lead to similar costs and spending profiles. Both profiles are similar to the actual expenditures.

The regression-based CER and the simple ratio CER lead to very different spending profiles, both of which are very different from the actual expenditures.



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Nonlinear approach: Time-phasing using Beta curves

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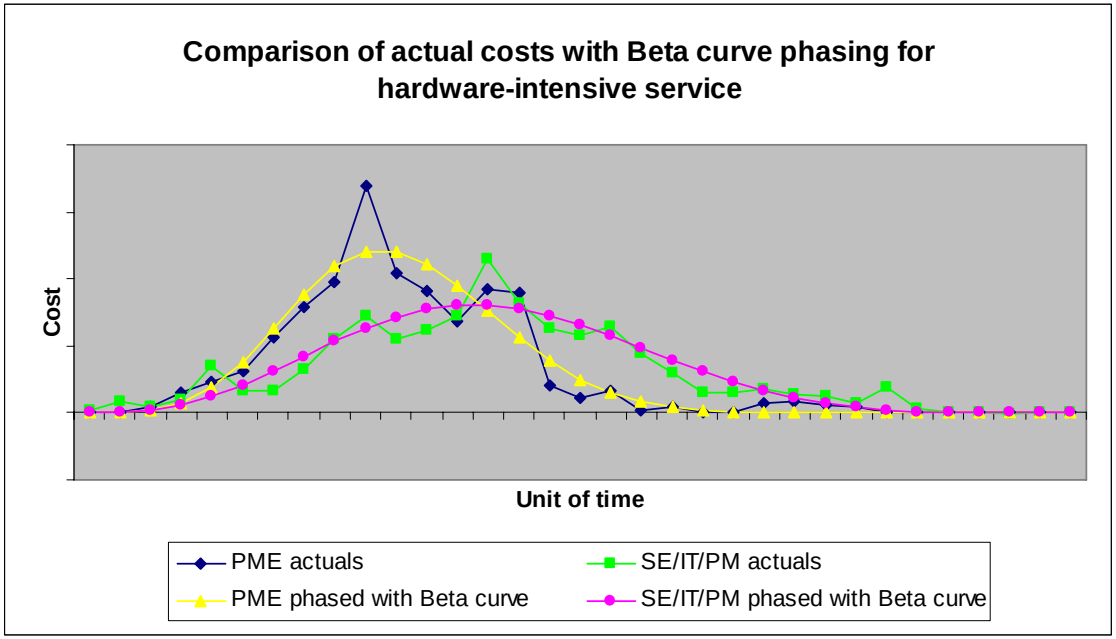
- Because the regression between PME and SE/IT/PM for the hardware-intensive service does not appear very strong, we look again at the profile of the costs.
  - It almost seems as if SE/IT/PM is phased independently of PME
  - The peak of the SE/IT/PM costs lags behind the peak in the PME costs
  - To explore the time-phasing of the two sets of costs, Beta curves were fit to the two time-phased distributions by minimizing the mean squared error of the curve



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Nonlinear approach: Time-phasing using Beta curves

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- Why a Beta curve?
  - Practicality
    - PDF of the beta distribution[5]

$$f(x) = \begin{cases} \dfrac{\Gamma(\alpha+\beta)}{\Gamma(\alpha)\Gamma(\beta)} x^{\alpha-1}(1-x)^{\beta-1}, & 0 < x < 1 \\ 0, & elsewhere \end{cases}$$

    - X is bounded between 0 and 1, so costs can be easily bounded to development period given
    - Easy to use Excel Solver to fit the curve

[5] *Introduction to Mathematical Statistics*, Hogg, McKean, and Craig, sixth edition

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Nonlinear approach: Time-phasing using Beta curves

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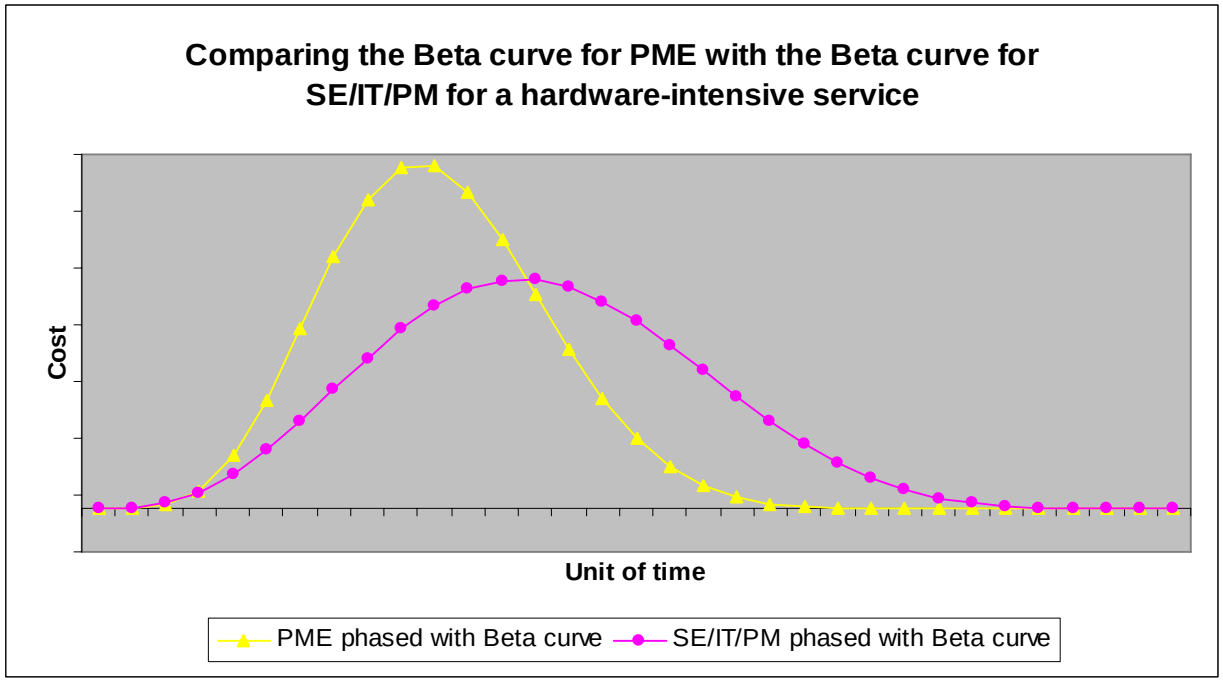
- The peak of the Beta curve for the SE/IT/PM lags behind the peak of the curve for PME, indicating that the relationship is not linear
- The tail behavior indicates that SE/IT/PM costs tail off much more slowly than PME costs, and they may outpace PME in the first few quarters



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Nonlinear approach: Time-phasing using Beta curves

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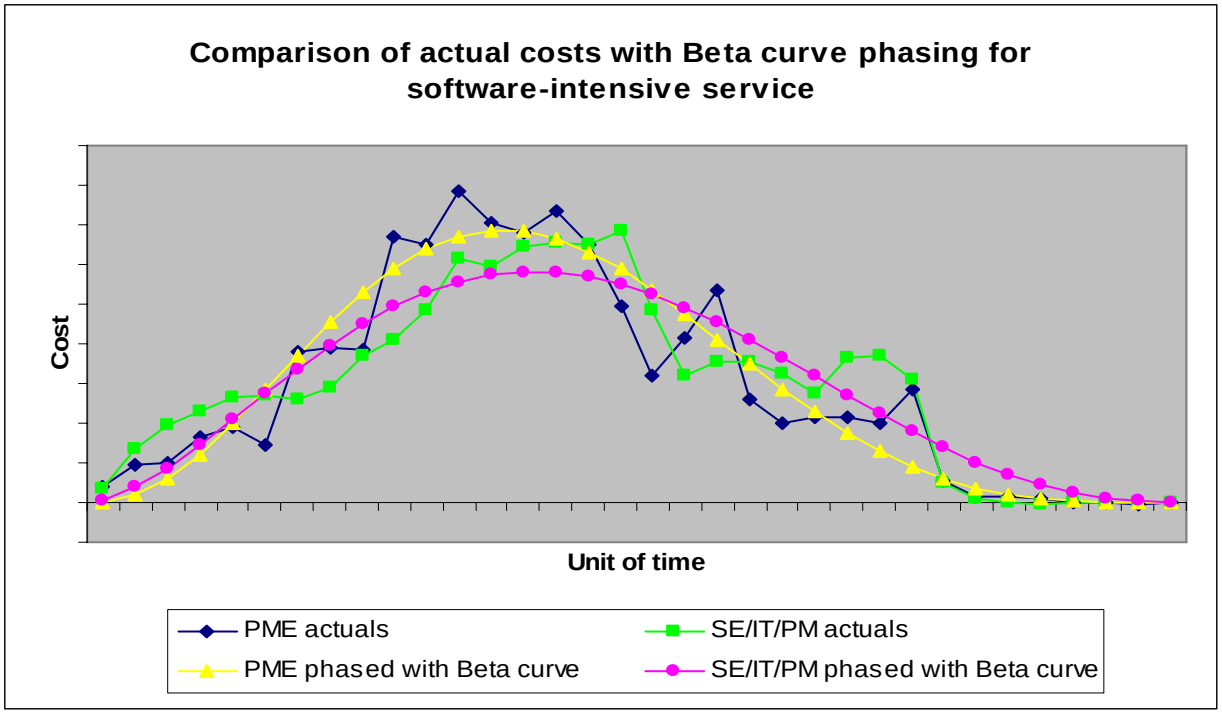
- The same comparison was done for the software-intensive program



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Nonlinear approach: Time-phasing using Beta curves

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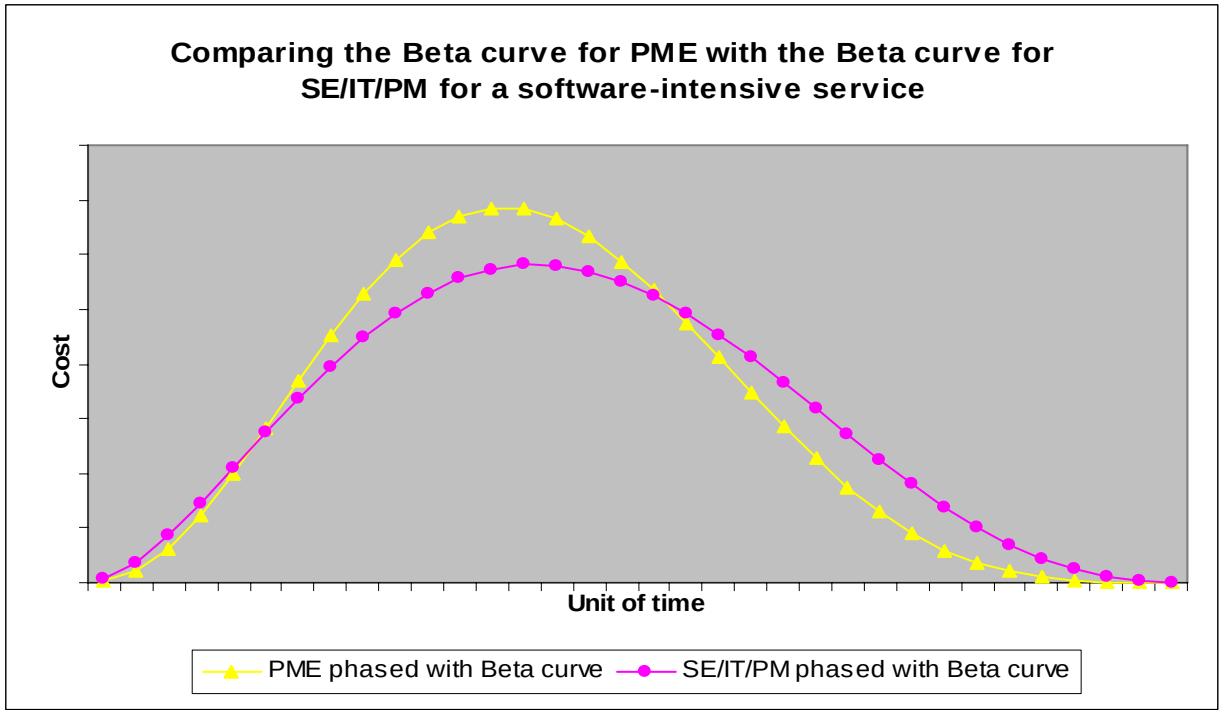
- The same tail behavior seen in the hardware-intensive program was observed here
  - SE/IT/PM ramps up a little faster and tails off more slowly
  - Behavior is not as pronounced as it was for the hardware-intensive function
- However, the peaks of the two curves are more closely aligned, thus reinforcing the idea that SE/IT/PM for the software-intensive service is linearly related to PME



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Nonlinear approach: Time-phasing using Beta curves

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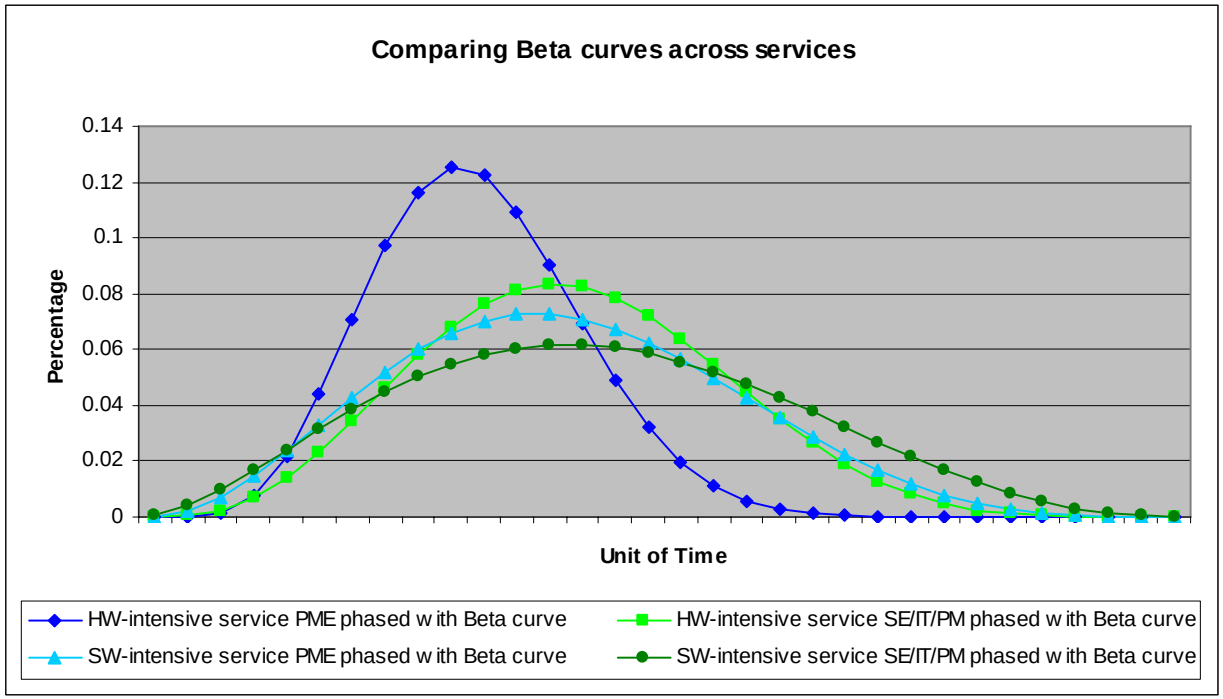
- Points of interest when comparing the four curves
  - Note how close the curves for SE/IT/PM are for the two different services
  - Note how close the curve for PME for the software-intensive service is to the SE/IT/PM curves
  - Why is the PME for the hardware-intensive service so different?



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Nonlinear approach: Potential issues

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- How can the analyst use a nonlinear approach?
  - Setting up the Beta curve phasing is not difficult
    - Estimate the total SE/IT/PM cost
    - Calculate the percentage of SE/IT/PM per time period
    - Multiply
  - However….How does an analyst estimate the total SE/IT/PM cost?
    - Simple ratio approach using PME
      - As mentioned, no statistical basis
    - Other basis?

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Conclusions

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- A regression-based CER for estimating SE/IT/PM based on PME for integrating into an immature SOA will fail to account for SE/IT/PM costs incurred for modifying the SOA to accommodate the new program in the event that the SOA does not have the services the new program requires.
- For a hardware-intensive service, a linear approach to estimating SE/IT/PM costs based in PME costs may not be appropriate.
  - Analysts should remember that regression does not tell the whole story

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Next steps

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- Conduct similar analysis on more data sets
  - Different services
  - Different contracts
- Normalize data to account for bulk buys (i.e. COTS purchases)
- Look for alternatives to PME for basis for SE/IT/PM costs

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Questions?

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