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Measuring Systems Engineering Productivity

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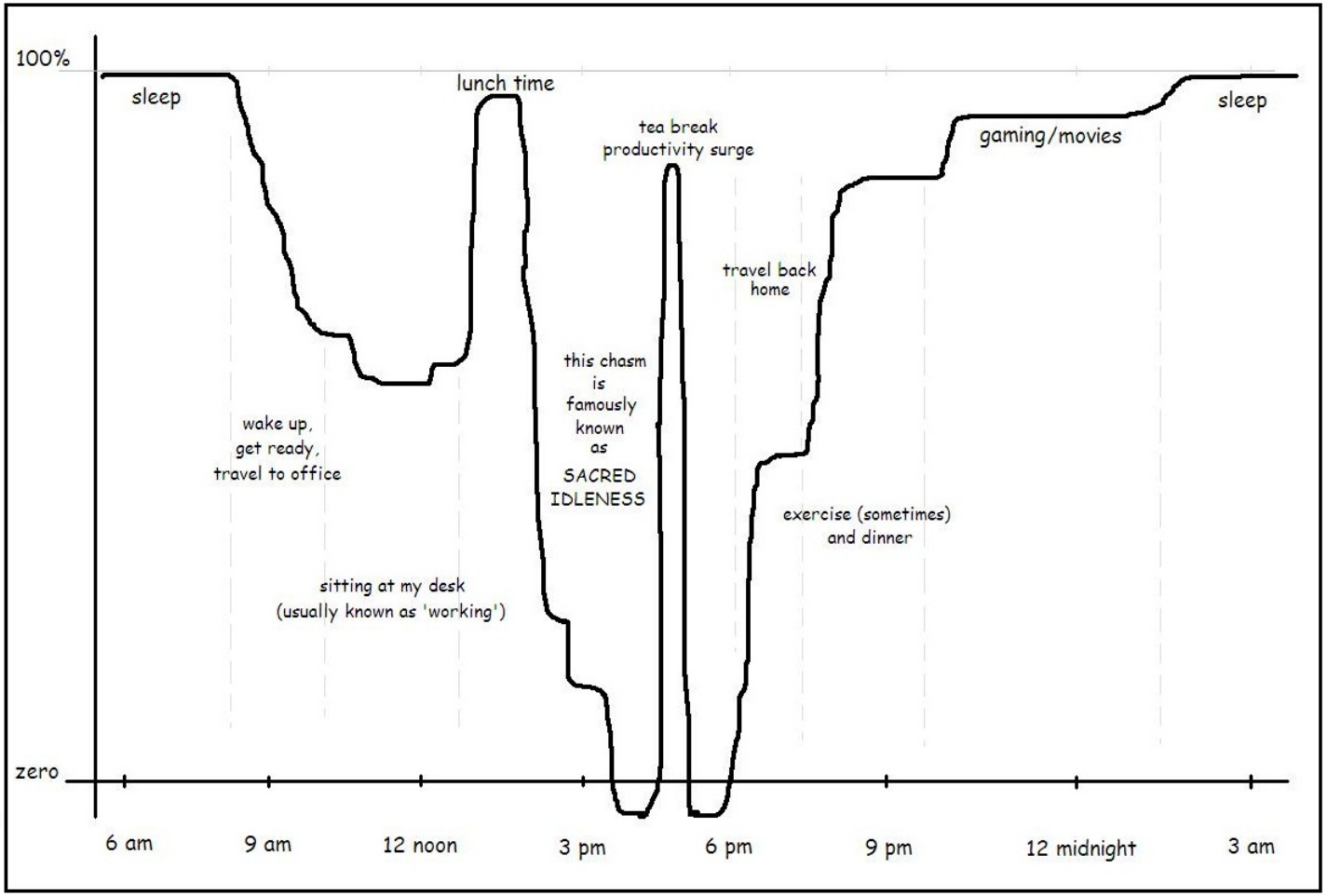
My Productivity Curve



My Productivity curve on a typical workday....

Courtesy: Aditya Kshirsagar

Definitions and Context

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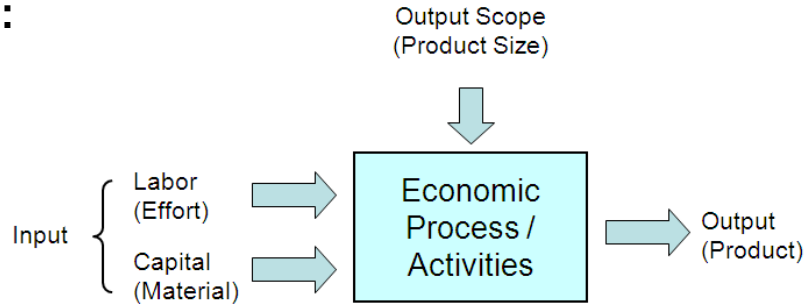
- **Production Model:**



- **Productivity**
  - In general economic terms, **productivity** is the amount of output created (in terms of goods produced or services rendered) per unit input used:

$$Productivity = \frac{Output\ Created}{Input\ Used}$$

  - **Labor productivity** is typically measured as output per worker or output per labor-hour:

$$LP = \frac{\partial Q}{\partial L}$$

- **Efficiency**
  - **Efficiency** is measured by the amount of input required to produce a given output; mathematically reciprocal of productivity
  - **Economic efficiency** is achieved when the cost of producing a given output is as low as possible

Prevalent Use of P&E Measures

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- Some common examples:
  - National Economy: *GDP per Capita*
  - Organization:
    - *$Revenue / employee*
    - *$Income / employee*
    - Gross (Net) Margin
  - Product (Line):
    - Total Productivity = Output in Base Period Price / Cost in Base Period Price
    - Partial Productivity = Output in Base Period Price / Any One Cost in Base Period Price
  - Investment:
    - Return On Asset
    - Return on Invested Capital
    - Profitability = Output Quantity*Price / Input Quantity * Unit Cost
      = Productivity * Price Recovery Factor
  - Software:
    - *Lines of Code / Hour*
    - *Function Points / Hour*
  - Electrical/Mechanical: *Drawings / Hour*
  - *Manufacturing: Units (cars) / Hour*

More Work, More Produced – Right? Right…

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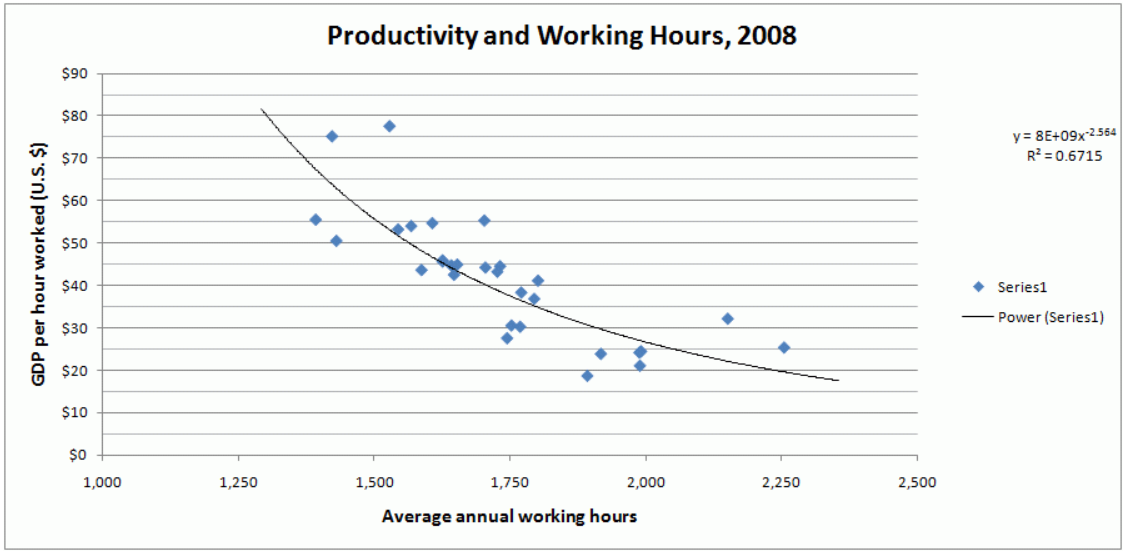

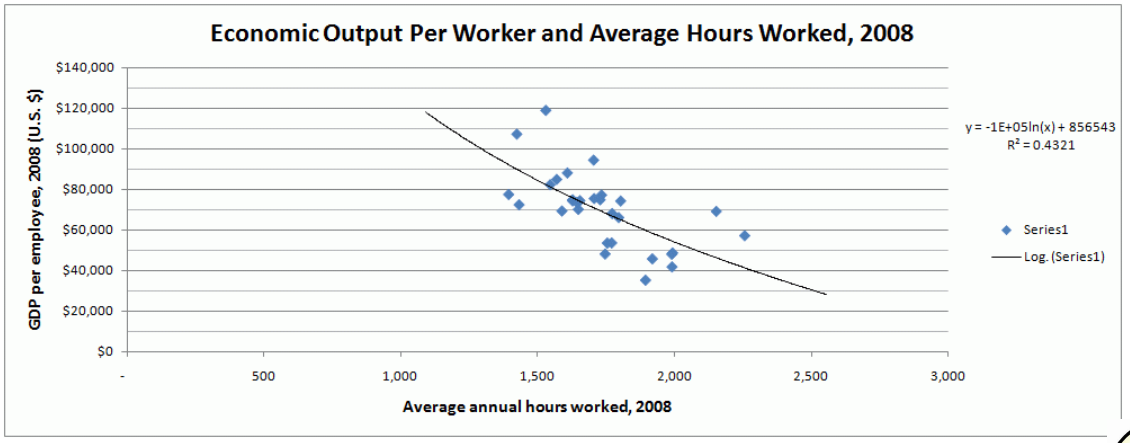

One could argue for shorter work days!

Source: theviewfromseven on Blog at Wordpress.com

What About Systems Engineering?

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- A void so far
  - No commonly accepted P&E metric to date
- Challenges encountered:
  - Difficult to quantify *scope* of work and *size* for SE
    - Choices are many for inputs and outputs*
  - Debates over value added vs. traditional output views
  - Identify crises:
    - What do we systems engineers do?
    - What products do we produce?
    - What are the processes?
- A recent change…
  - Emergence of COSYSMO (and its acceptance) provide an opportunity
  - Model has tried to quantify for SE

* David N. Card

COSYSMO Attempts to Quantify SE

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- ***Size* of System**:

$$System\ Size = \sum_{k}\left(\sum_{r} w_r\left(w_{e,k}\Phi_{e,k} + w_{n,k}\Phi_{n,k} + w_{d,k}\Phi_{d,k}\right)\right)$$

  - Unit of measure: *eReq*
  - From four *Size Drivers*:
    - *Number of System Requirements*
    - *Number of System Interfaces*
    - *Number of System Specific Algorithms*
    - *Number of Operational Scenarios*

- ***Categories of Reuse*** (based on engineering activities)
  - *New*
    - *(Design for Reuse)*
  - *Modified*
    - *Deleted*
  - *Adopted*
    - *Managed*

- ***Levels of Difficulty*** (based on relative effort)
  - *Easy*
  - *Nominal*
  - *Difficult*

Proposed Productivity and Efficiency Measure for Systems Engineering

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- ***SE Productivity***: Productivity for systems engineering is defined as the amount of the system (measured in *eReq*) produced or realized per unit of labor (measured in eng. hour)

$$SE\ \ Productivity = \frac{System\ Size}{Total\ SE\ Hours} \qquad (eReqs/SE\ Hours)$$

- ***SE Efficiency***: Efficiency for systems engineering is defined as the number work hours or effort (measured in eng. hours) required to produce a given unit of system (measured in *eReq*)

$$SE\ \ Efficiency = \frac{Total\ SE\ Hours}{System\ Size} \qquad (SE\ Hours/eReq)$$

Proposed SE Productivity and Efficiency Measure (cont.)

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- ***Normalized SE Productivity***: amount of the system produced or realized per unit of labor, under the *nominal* system complexity and project environment
- Mathematically

$$SE\ \ Productivity_{Norm} = SE\ \ Productivity \cdot CEM$$

$$= \left(\frac{System\ Size}{Total\ SE\ Hours} \right) \cdot CEM$$

Where,

CEM = the composite effort multiplier defined from 14 cost drivers

$$CEM = \left(\prod_{i=1}^{8} AF_i \right)^{1/8} \cdot \left(\prod_{j=1}^{6} TF_j \right)^{1/6}$$

Note: For alternative CEM definition, see Wang, G., et al, *Proposed Modification to COSYSMO Estimating Relationship*, *Proceedings of 18th INCOSE International Symposium*, June 2008

Measurement Approach

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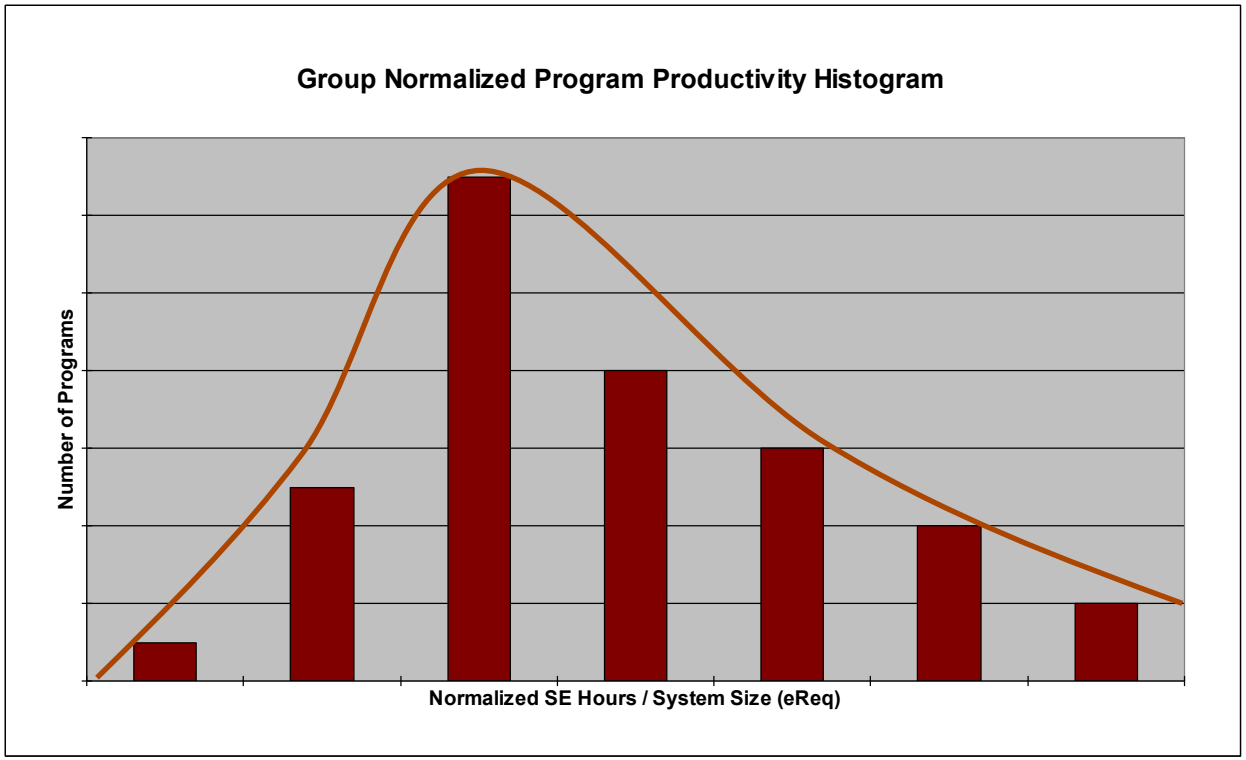
- Apply to historical and on-going projects, periodically for the entire development life cycle
- Measure on a fixed cycle (3 or 6 months) and/or on significant technical milestones (e.g., SRR, PDR, CDR, TRR, etc)
  - Align the project data by milestones
- For on-going projects, use EAC from budget or estimate based on models/methods other than COSYSMO
  - Efficiency = EAC/eReq
- Apply to system development type of projects only
  - For which COSYSMO is better defined
- Compare like project/programs only
  - Different types (e.g., SW-centric or HW-centric) can have different characteristics
- Observe the trend over time, not the absolute P&E values
  - (Absolute values have little practical meaning)

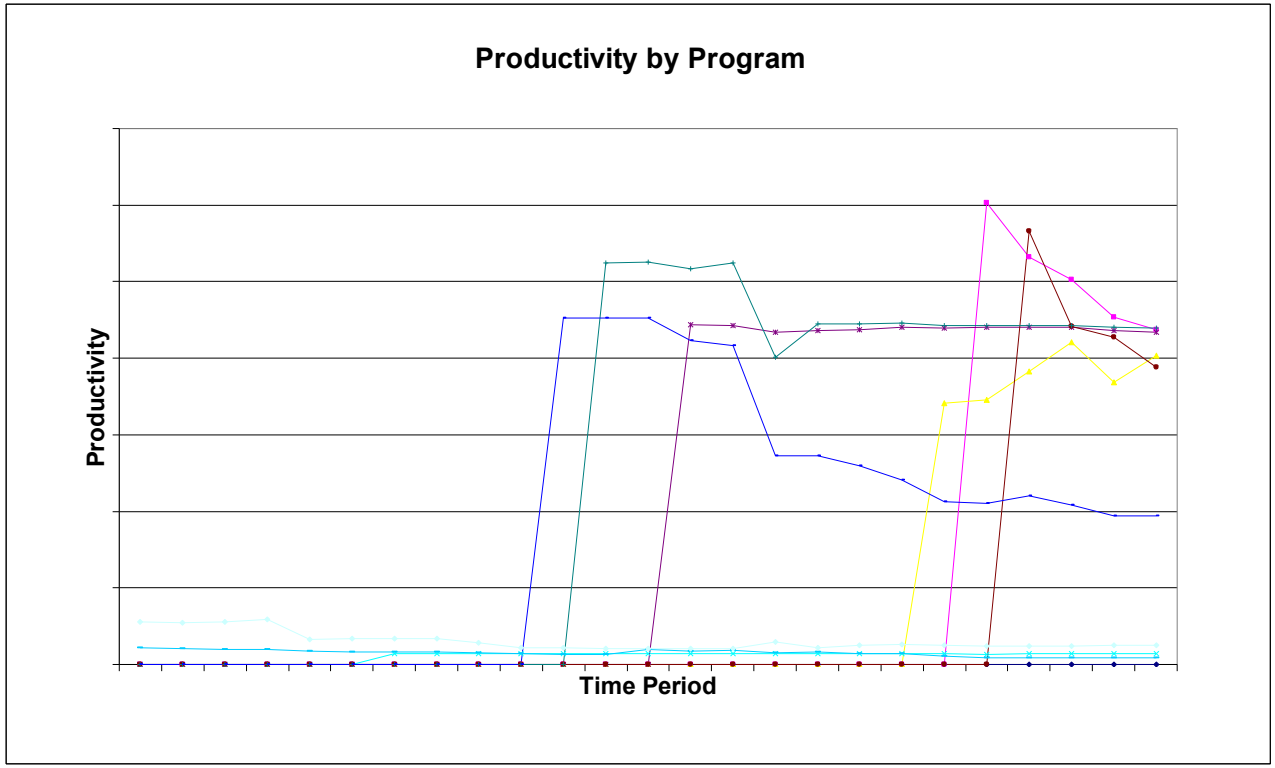
Graphing Techniques

- Histograms are convenient and gives a sense of where the norm is
- Easy to derive quantitative statistics
- Observe the spread and movement of the norm over time
- (You may have to take over the binning from Microsoft…)



Graphing Techniques (cont.)

- Time traces are intuitive and readily show behavior in progress and maturity
- Easy to differences between peer projects; hard to derive group statistics
- Best to align time period (e.g., by technical milestones) for better cross-comparison relative to project maturity



Application of SE P&E Measure

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- Applied to a selected group of projects at BAE Systems
  - Measured quarterly and reported at senior SE management level
  - Drove program behavior
  - Demonstrated improvement over time
- Lessons Learned:
  - Consistency is key in counting COSYSMO cost drivers
    - Apply activity based reuse model
    - Recommend a productivity value for nominal requirement
  - Expect scattering of the data initially but convergence over time
  - Training is important
  - Achieve stakeholder agreement and manage it as a project
    - Expect resistance
  - Avoid “the number” but use the trend
  - Use the measured data constructively to help project improve
    - Use it as catalyst for in-depth casual analysis
    - Do not use it as “label” (e.g., “green”, “yellow”, “red”)
    - Do not use it as a “whip”
  - Start slowly

Conclusion

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- Proposed SE P&E measure based on COSYSMO's *system size* concept
- Recommended measuring approach
- Discussed application strategy and potential pitfalls
- Initial pilot yielded useful and insightful results
- *"If you cannot measure it, you can not manage it"*
  - Same is true for systems engineering…

Questions & Comments

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