

Measuring Systems Engineering Productivity

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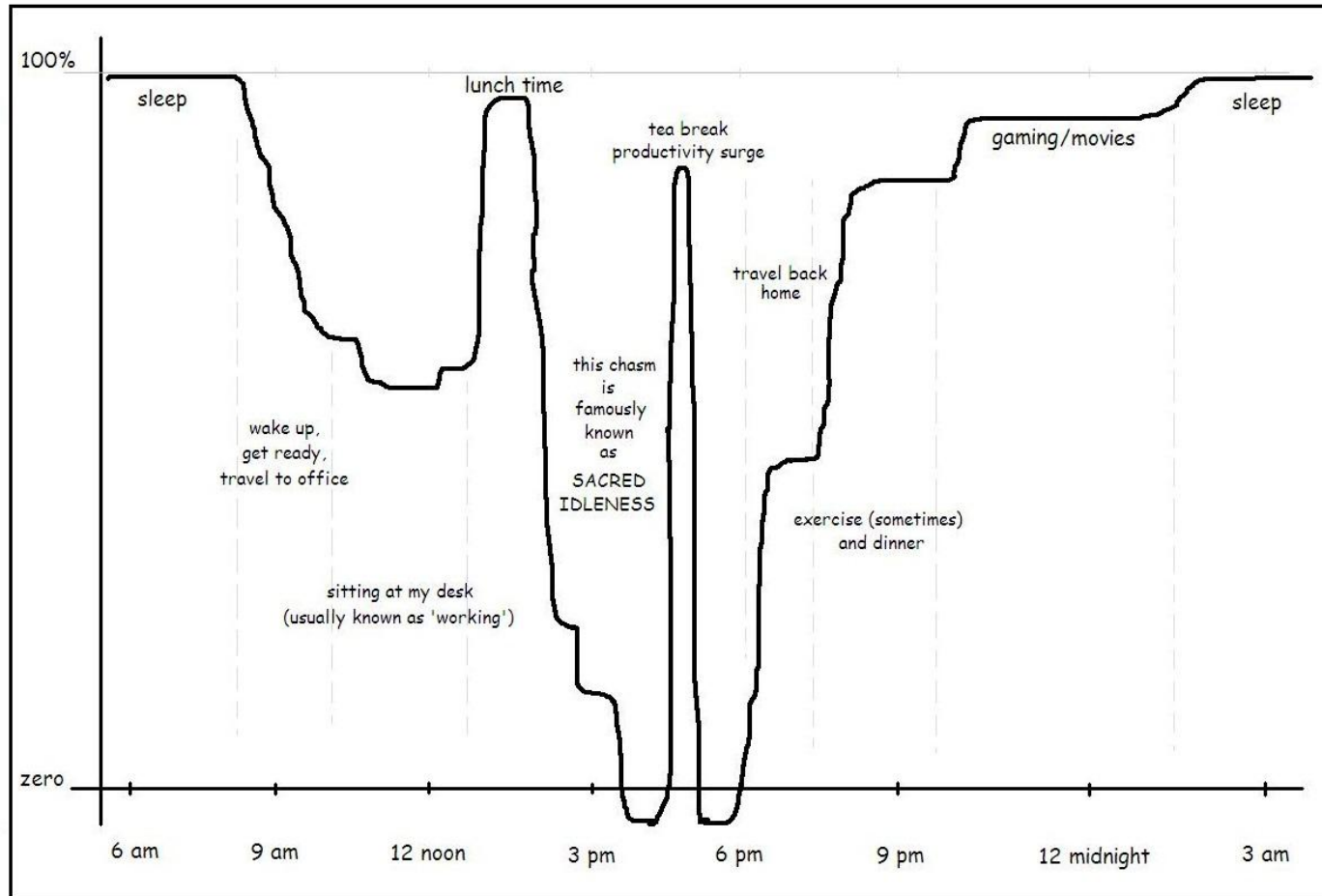
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BAE SYSTEMS

My Productivity Curve

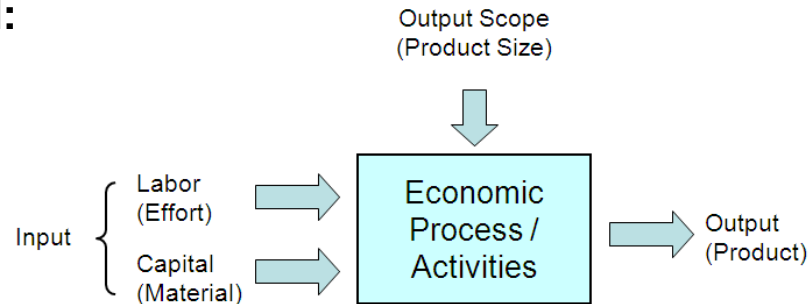


My Productivity curve on a typical workday....

Definitions and Context



➤ 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:

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

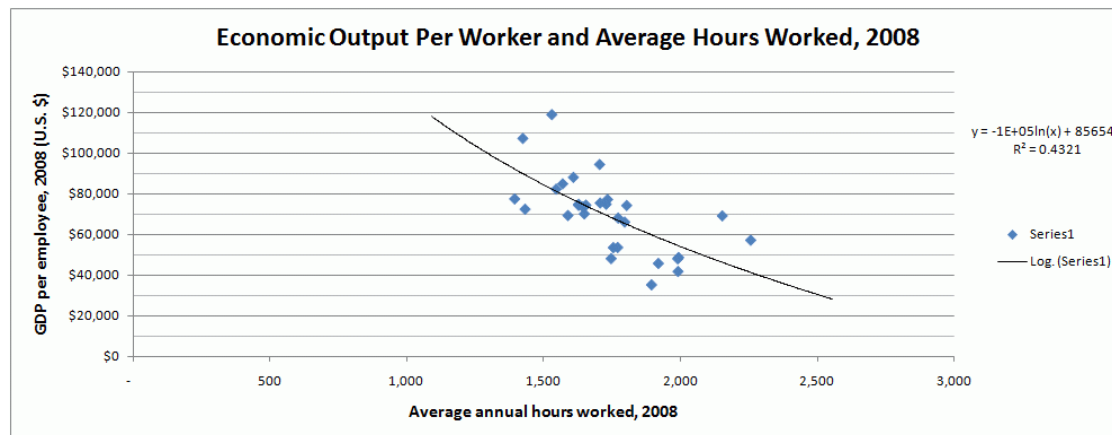
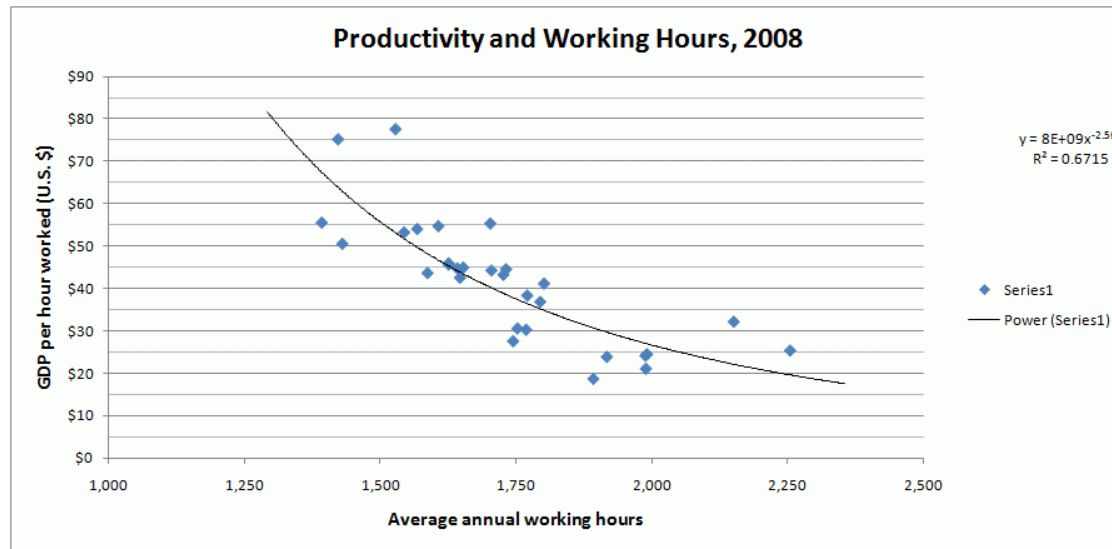
- **Labor productivity** is typically measured as output per worker or output per labor-hour:

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

➤ 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

More Work, More Produced – Right? Right...



One could argue for shorter work days!



Prevalent Use of P&E Measures



- 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*

What About Systems Engineering?



- 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*
 - Arguments 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



- **Size of System:**

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

- 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



- **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)

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

- **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*)

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

Proposed SE Productivity and Efficiency Measure (cont.)



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

$$\begin{aligned} SE\ Productivity_{Norm} &= SE\ Productivity \cdot CEM \\ &= \left(\frac{System\ Size}{Total\ SE\ Hours} \right) \cdot CEM \end{aligned}$$

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

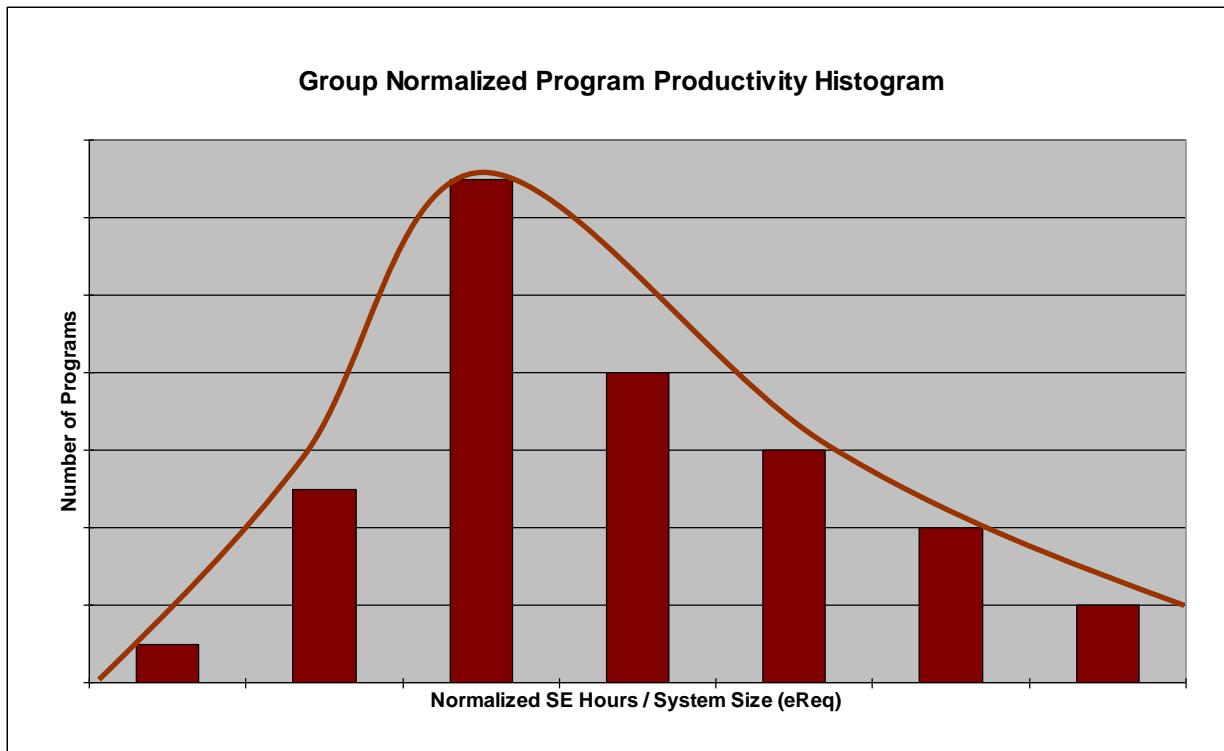
Measurement Approach



- 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)

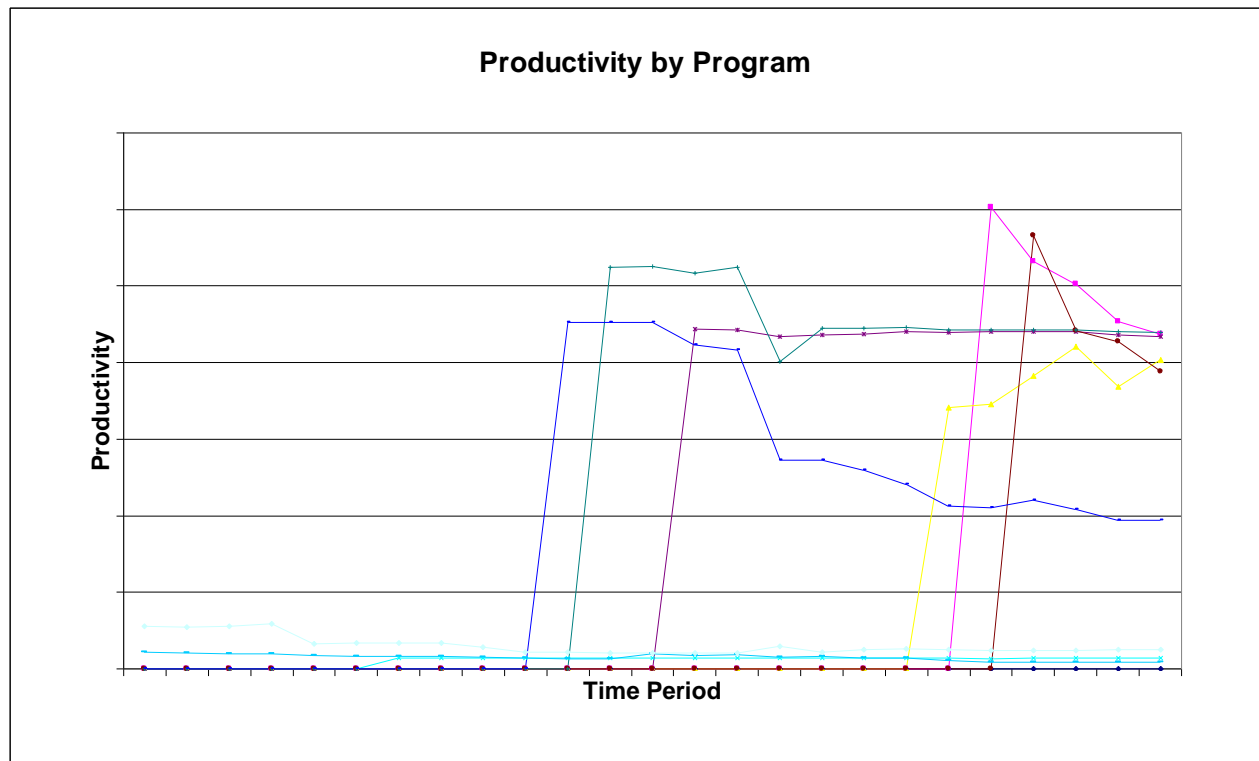
Graphing Techniques

- 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



- 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



- Proposed SE P&E measure based on COSYSMO's *system size* concept
- Recommended measuring approach
- Discussed application strategy and potential pitfalls
- Initial pilot yielded interesting 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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