CENG 6101 Project Management

Engineering Productivity Assessment

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Construction Project Life Cycle

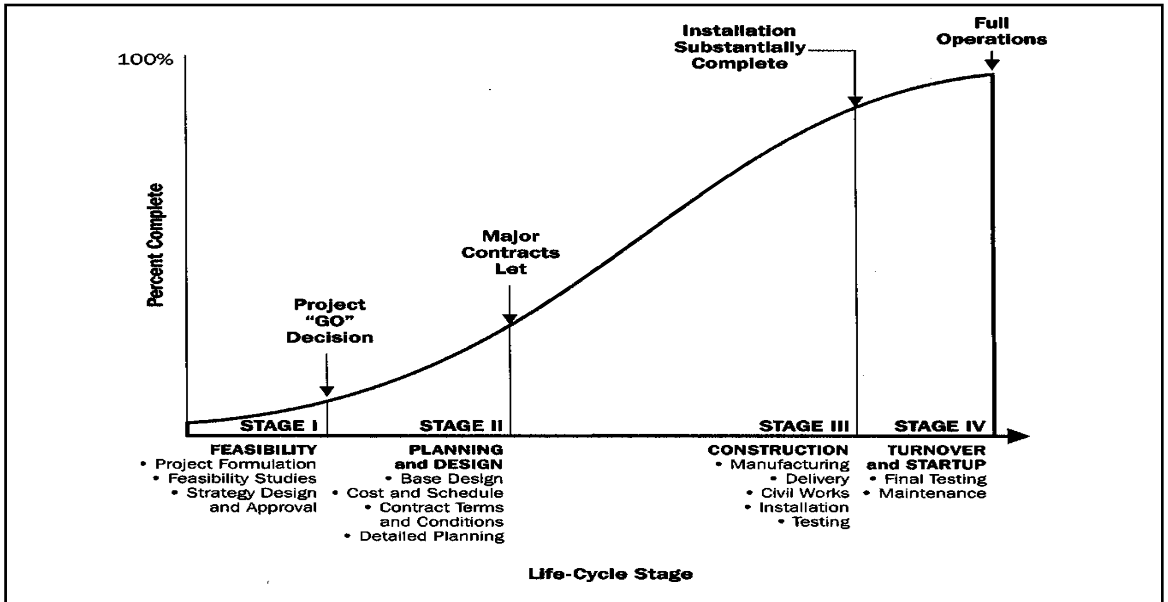
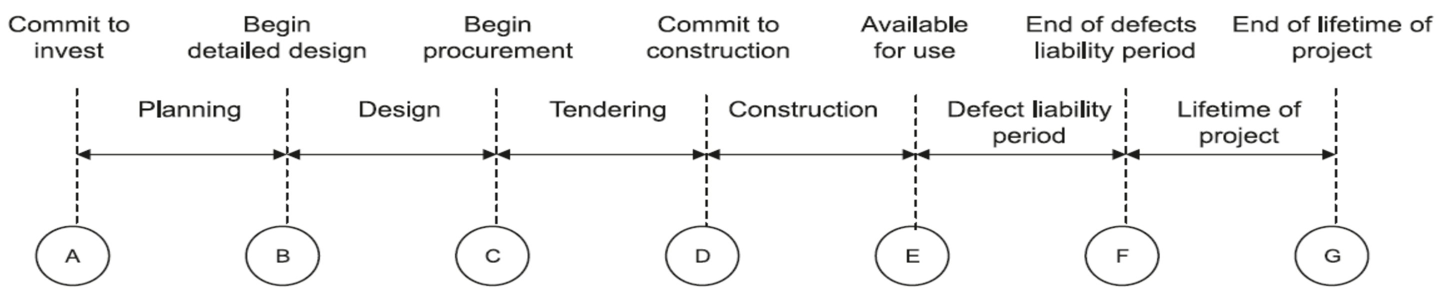


Figure 2–3. Representative Construction Project Life Cycle, per Morris

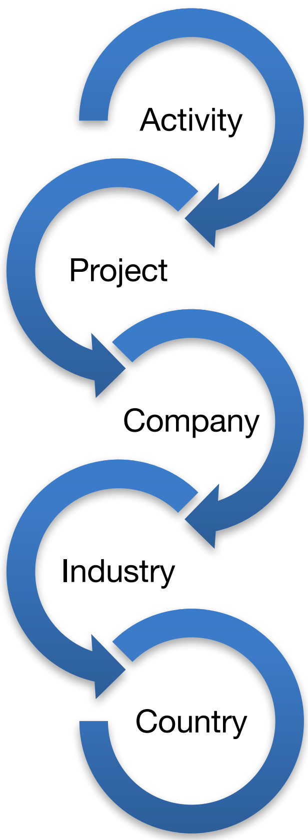
Source: PMBOK (PMI)



Source: Omar (2015)

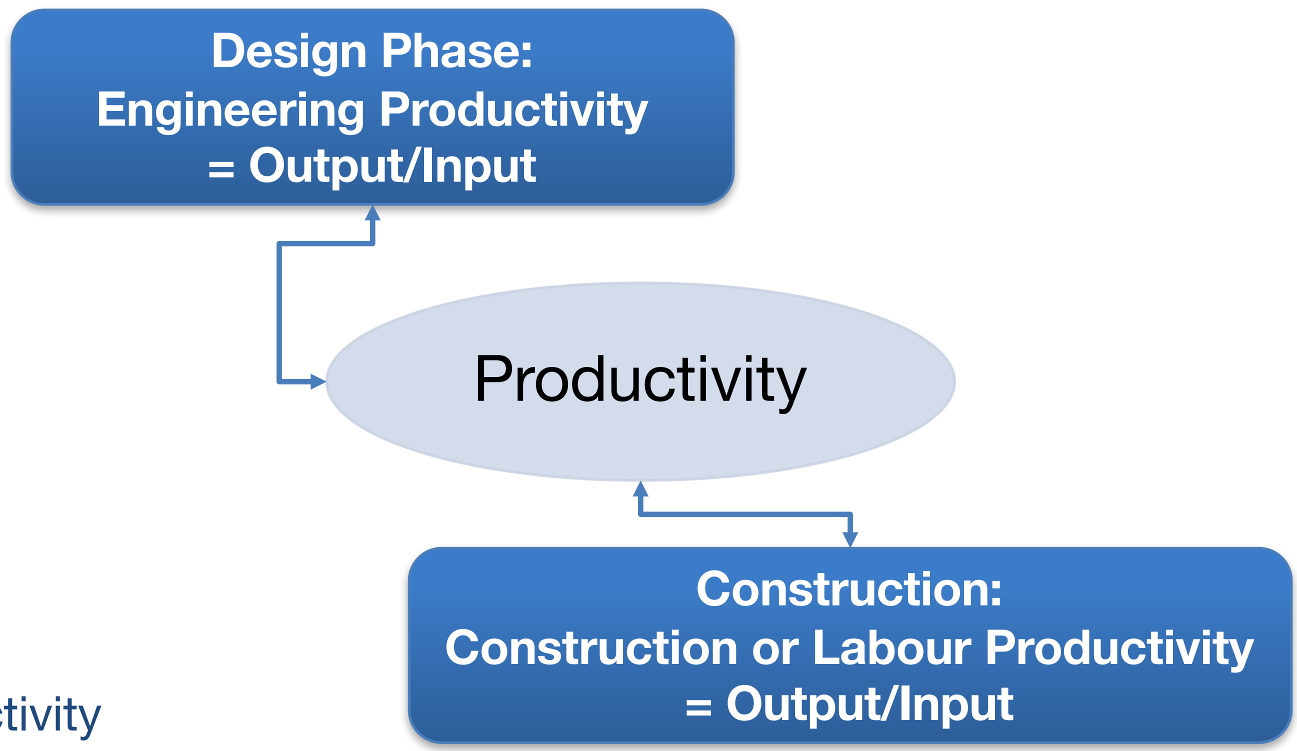
Introduction to Productivity

- Productivity spans several disciplines including economics, operations research, and engineering



Hierarchy and Productivity

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



Introduction to Construction Productivity

Type of Input Measure / Type of Output Measure	Labour	Capital	Capital and Labour	Capital, Labour and Intermediate inputs (energy, materials, services)
Gross Output	Labour productivity (based on gross output)	Capital productivity (based on gross output)	Capital-Labour productivity MFP (based on gross output)	KLEMS productivity
Value Added	Labour productivity (based on value added)	Capital productivity (based on value added)	Capital-Labour productivity MFP (based on value added)	-
Measure	Single Factor Productivity (SFP) measures		Multifactor Productivity (MFP) measures	

Introduction to Construction Productivity

- Construction Labour Productivity (CLP) is defined as activity-level labour productivity, where higher values are desirable:

$$Construction\ Labour\ Productivity = \frac{Output}{Input} = \frac{Units\ of\ output}{Total\ labour\ manhours}$$

Activity	Input			Output	Productivity
	Duration (A)	Crew Size (B)	Total Manhours (C = A * B)	Installed Quantity (D)	Unit (E = D/C)
Concreting	hr	number	mhr	Volume (m^3)	m^3/mhr
Wire pulling	hr	number	mhr	Length (m)	m/mhr
Shield Installation	hr	number	mhr	Number (each)	each/mhr

Total Factor Construction Productivity

Policy Formation	Program Management	Planning/Design	Project Management/ Administration	Site Construction
Policy Definition: - Public works - Defense - Environment - Employment - Conservation - Urban Renewal - Investment incentives - Etc.	Policy Interpretation: - Design control - Quality criteria - Performance standards - Usage goals - Participation goals - Resource allocation - Project selection	Project Interpretation: - Design - Materials - Quality assurance - Budget - Milestone schedule	Project Interpretation: - Supplier selection - Contractor selection - Logistics - Resource utilization - Equipment selection - Labour pool analysis - Detail scheduling	Project Execution: - Labour training - Work rules - Work conditions - Work planning - Supervision
$\frac{\$\,Value\ of\ output}{\$\,cost\ (\$170\ billion)}$	$\frac{\$\,Value\ of\ output}{\$\,cost\ (\$8.9\ billion)}$	$\frac{\$\,Value\ of\ output}{\$\,cost\ (\$546\ million)}$	$\frac{\$\,cost}{project\ unit\ (mile)}$	$\frac{\$\,cost}{work\ unit\ (manhour)}$
____Benefit-Cost-Ratios____ (Take into account all factors-tangible, intangible, social, political, economic, etc.)			____Unit Cost Ratios____	

Kellogg, J., Caroll, J.D. and Green, P.E. (1981). “Hierarchy Model of Construction Productivity.” Journal of Construction Engineering and Management, ASCE, 107 (1), 137-152.

Introduction to Engineering Productivity

- Engineering productivity is less well understood and has received less study than construction productivity
- Many engineering companies measure productivity using intermediate deliverables such as drawings as output.

Design Phase:
Engineering Productivity
= Output/Input

Output:
- **Drawings**
- **Completed Models**
- **Quantity of Designed Work Item**

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Input:
- Design Work Hours

Engineering Productivity Assessment

- Software engineering is a similar industry, where output is measured in terms of Source Lines of Code
- However, as Source Codes vary with language level, therefore, Function Points (FPs) has been defined as the weighted sum of:
  - Number of program inputs, outputs,
  - Number of user inquiries, and
  - Number of files and external interfaces.

  - Engineering Productivity = FP produced per person month

Engineering Productivity Assessment: Studies

- Stull and Tucker (1986) attempted to make a quantitative evaluation of the effectiveness of the design process by studying piping design process:
- Parameters to describe the project's design effectiveness:
  - Accuracy, Usability, Cost of the design, Constructability, Performance against design schedule, Economy of the design, and Ease of start-up.
  - Parameters evaluation:
    - Quantitatively (e.g., Accuracy = number of drawings requiring revision/total number of drawings)
    - Subjectively using a 1 – 10 scale (e.g., Constructability and Usability)

Engineering Productivity Assessment: Studies

- Chang et. Al (2001) stated that majority of engineering firms today measure productivity based upon the number of CAD drawings completed using the earned value method.
  - Weakness: Productivity values can be easily skewed simply by increasing or decreasing the number of drawings delivered for a similar project scope
- CII 156 and Kim (2007) recommended the use of physical quantity based engineering productivity system:

$$Engineering\ Productivity = \frac{Output}{Input} = \frac{IFC\ Quantity\ Designed}{Actual\ Work - Hours}$$

- Driver engineering disciplines for various industries have been identified.

Engineering Productivity Assessment: Studies

Table 2.1 Engineering Productivity Drivers by Industry (Source: CII RR 156-11)

Industry → / Discipline ↓	Light Industrial		Heavy Industrial		Buildings	Infrastructure
	Process	Mech.	Process	Mech.		
Civil/Structural			×	×	×	×
Architectural					×	
Project Mgmt & Controls						
Mechanical (HVAC, Utilities, Vessels)				×		
Piping (Design & Mechanical)	×		×			
Manufacturing Process (Mechanical)		×		×		
Manufacturing Process (Chemical)	×		×			
Electrical						
Instrument/ Controls/ Automation	×	×	×	×		
Other						

Engineering Productivity Assessment: Studies

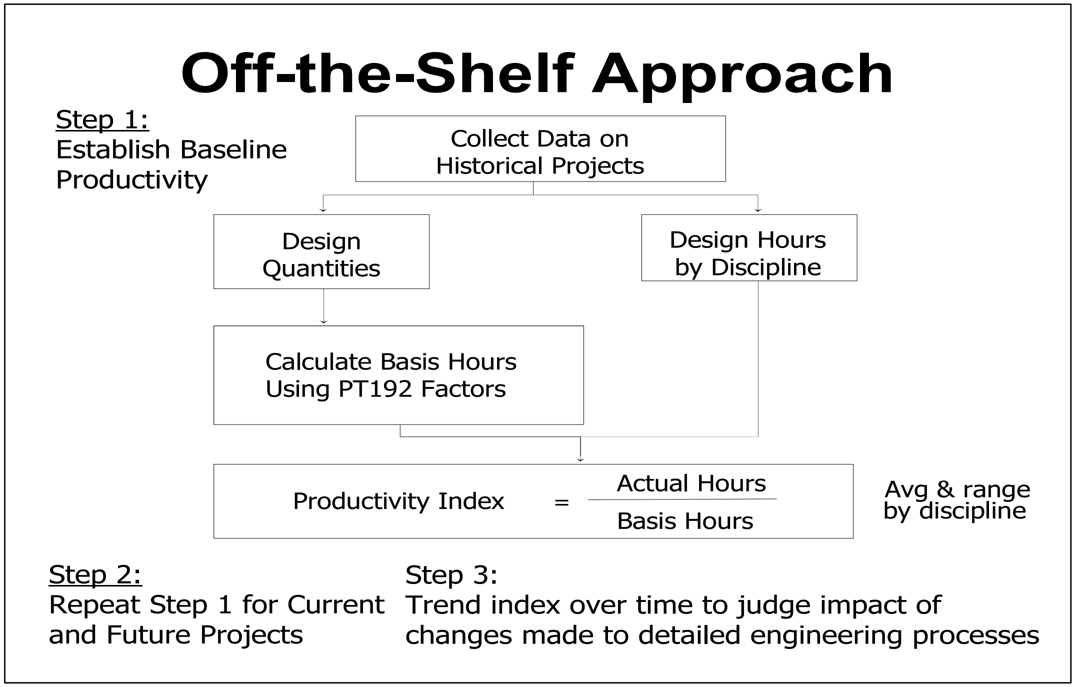
- CII RT 156: Proposed a conceptual model for design engineering productivity based on:
  - Raw Productivity (work-hours per designed quantity)
  - Adjustment factors for:
    - Input Quality Factor: For quality and completeness of the design, PDRI (Project Definition Rating Index) is useful indicator
    - Scope and Complexity Factor: For project complexity and project characteristics
    - Design Effectiveness Factor: For hidden transfer of cost from engineering to other parts of the project. Can be measured using % of field rework as a result of design tested against industry average.

$$Piping\ Design\ Hours\ for\ Feet\ of\ Piping = (0.44985 + 0.00134 * No.of\ Pieces\ of\ Equipment)$$

$$Civil\ or\ Structural\ Hour = (0.0161\ * Square\ Feet\ of\ Building\ Area) + (0.492\ * Cubic\ Yard\ of\ Concrete) + (6.39\ * Tons\ of\ Steel) + (3.5\ * No.of\ Deep\ Foundations)$$

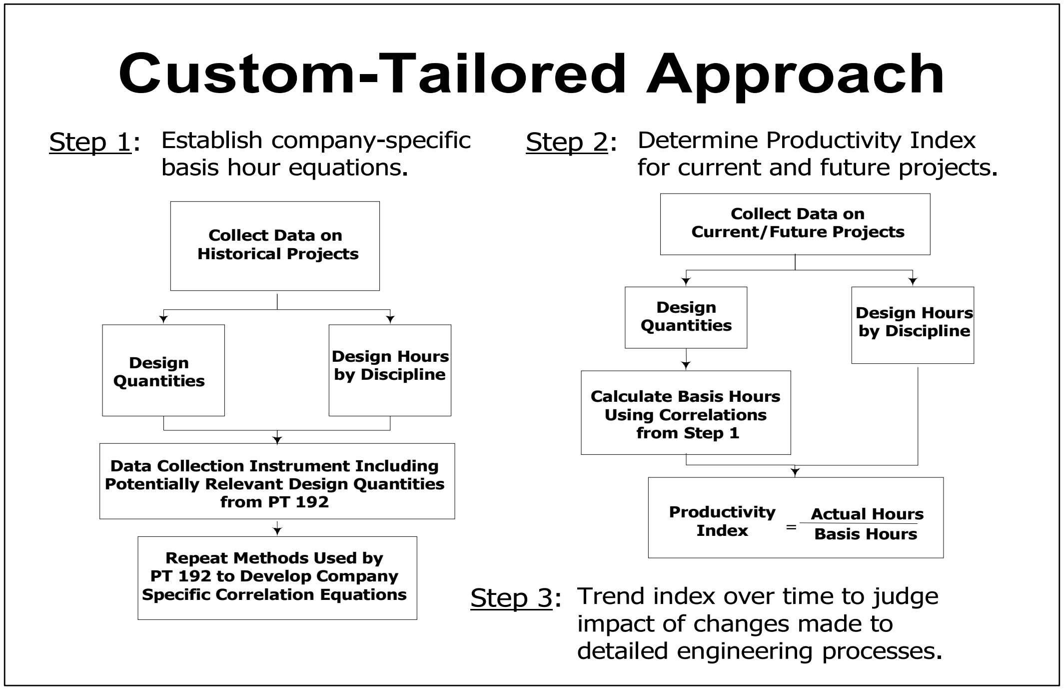
Engineering Productivity Assessment: Studies

- CII RT 156 suggested approaches:
- Off-the-Shelf approach: Using CII equations for establishing baselines



Engineering Productivity Assessment: Studies

- CII RT 156 suggested approaches:
- Custom-Tailored approach: User develops their own basis hour functions or productivity models based on data collected from past projects.



Productivity Models:

- Framework for productivity modeling using historical data

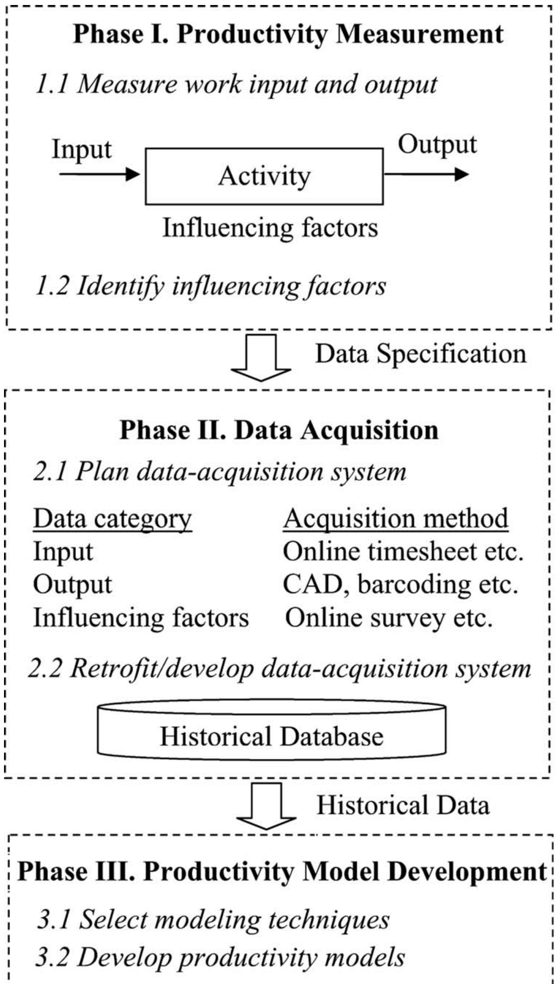


Table 1. Productivity-Influencing Factors for Steel Drafting

Number	Factor	Description
1	Project type	Structural/plate work/both
2	Work scope	Supply only/supply and erect
3	Contract type	Lump sum/unit price
4	Piece cloning	Percentages of unique pieces over all pieces
5	Dynamic structure	Yes/no
6	Fireproofing	Yes/no
7	Special fall arrest provision	Yes/no
8	Overall complexity	1 very high, 3 average, 5 very low
9	Draftsperson qualification	1 very low, 3 average, 5 very high
10	Crew size	1–2, 3–5, 5+
11	Client	Index derived from historical data
12	Engineer firm	Index derived from historical data
13	Engineering standards	1 very low, 3 average, 5 very high
14	Administration	Percentages of administration hours over total hours
15	Overtime	Percentages of overtime hours over total hours
16	Subcontract	Percentages of subcontracts
17	Total work quantity	Quantity in drafting unit

Modeling techniques: Regression, Expert Systems, Neural Networks, Self-Organizing Maps, System Dynamics, Fuzzy Rule-Based Systems

References:

- Kim, I. Development and Implementation of an Engineering Productivity Measurement System (EPMS) for Benchmarking. PhD Thesis, University of Texas at Austin, 2007.
- Song, L. and AbouRizk, S. M. (2008). "Measuring and Modeling Labor Productivity Using Historical Data." *Journal of Construction Engineering and Management*, ASCE, 134 (10), 786 – 794.
- Kellogg, J., Caroll, J.D., and Green, P.E. (1981). "Hierarchy Model of Construction Productivity." *Journal of Construction Engineering and Management*, ASCE, 107 (1), 137-152.