A Systematic Approach to Estimate the Life Cycle Cost and Effort of Project Management for Technology Centric Systems Development Projects

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Agenda Overview

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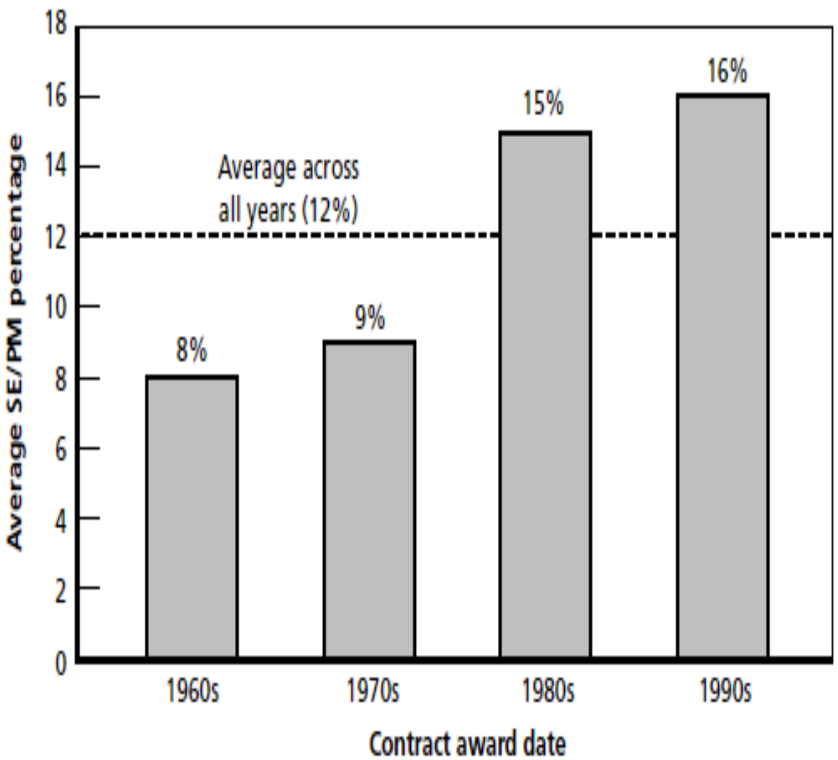
- General View of Systems Costs
- The Cost of Management: Systems Engineering (SE) & Project Management (PM)
- The Cost of Project Management Services
- The Relationship between SE & PM: Similarities & Differences
- Current Research Effort: PM Cost Estimating Model
- Current Research Status & Next Steps

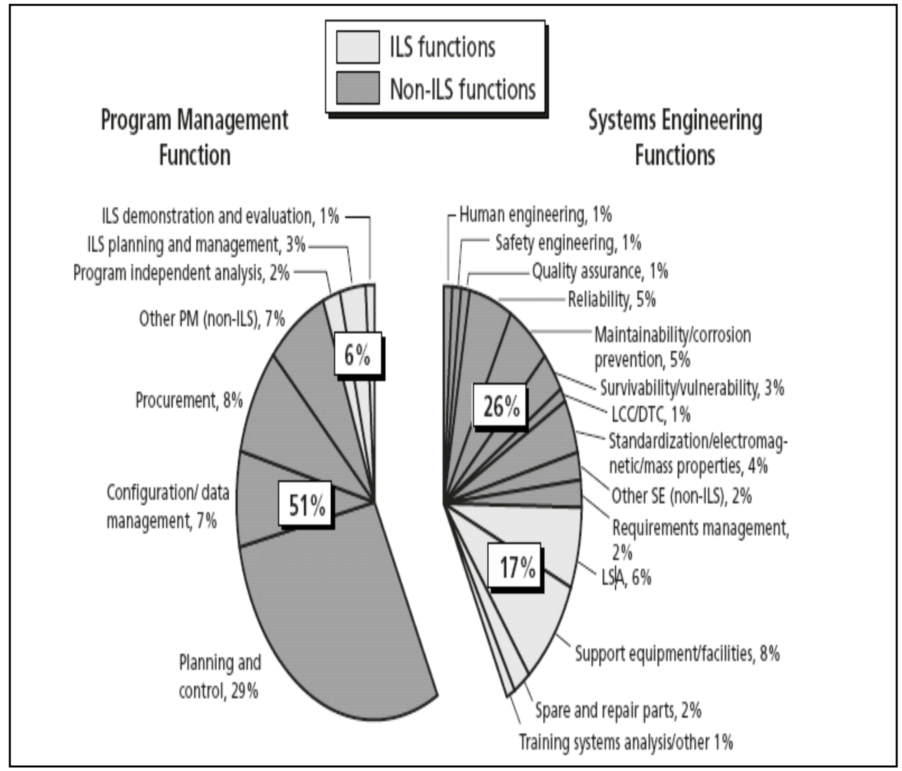
General View of Systems Costs

- Simplest Form & Subcategories
  - 4 Major Systemic Elements
    - Hardware, Software
      - Mature, e.g. the Constructive Cost Model (COCOMO suite)
    - Integration
      - Emerging area – difficult to estimate, e.g. the Constructive System of Systems Integration Cost Model (COSOSIMO)
    - Management
      - Development Management = Systems Engineering (SE) & Project Management (PM)
      - e.g. Defense Industry, USAF Programs (Stem et al., 2006)
        - » Development Management (100/%) = SE (50%) + PM (50%)
        - » SE/PM costs doubled since 1960s

General View of Systems Costs



Aircraft SE/PM Costs as a Percentage of Total Development Cost for All Development Programs, 1960s–1990s (Stem, et al., 2006)



SE/PM as a function of Integrated Logistics Support (ILS) for a typical Air Force program (Stem, et al., 2006)

Systems Engineering (SE) & Project Management (PM)

- **SE Costs** – significant amount of research has been conducted
  - –The International Council on Systems Engineering (INCOSE) surveyed (Honour, 2004):
    - •52% of systems projects spent 5% or less of total systems development cost on SE tasks
  - –The Constructive Systems Engineering Cost Model (COSYSMO)
    - •As a SE cost estimating tool used by systems engineering, systems cost estimators, etc (Valerdi, 2006)
- PM Cost Estimating Methodology and Tools?

PM Services Costs

- Literature – limited information on PM related expenditures or costs
- Organizations often ***do not*** identify or measure PM costs, and a survey led by UC Berkley (Ibbs and Kwak, 2000a, 2000b) shows:
  - 80% of companies surveyed spend less than 10% of total project cost (TPC) for PM services
  - Average = 6% of TPC, Range = 0.3% ~ 15% of TPC
  - Another survey indicated the average = 10% of TPC (Ibbs and Reginato, 2002)
- Evidently, PM costs varies among organizations
  - Influential PM Cost Factors: project type, size, # of projects, PM maturity level (Archibald, 2003)

Systems Engineering (SE) & Project Management (PM): Similarities & Differences

- SE is *"a methodical, disciplined approach for the design, realization, technical management, operations, and retirement of a system. SE is the art and science of developing an operable system capable of meeting requirements within often opposed constraints. Systems engineering is a holistic,* ***integrative discipline****, wherein the contributions of structural engineers, electrical engineers, mechanism designers, power engineers, human factors engineers, and many more disciplines are evaluated and balanced, one against another, to produce a coherent whole that is not dominated by the perspective of a single discipline*." (NASA, 2007)

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Systems Engineering (SE) & Project Management (PM): Similarities & Differences

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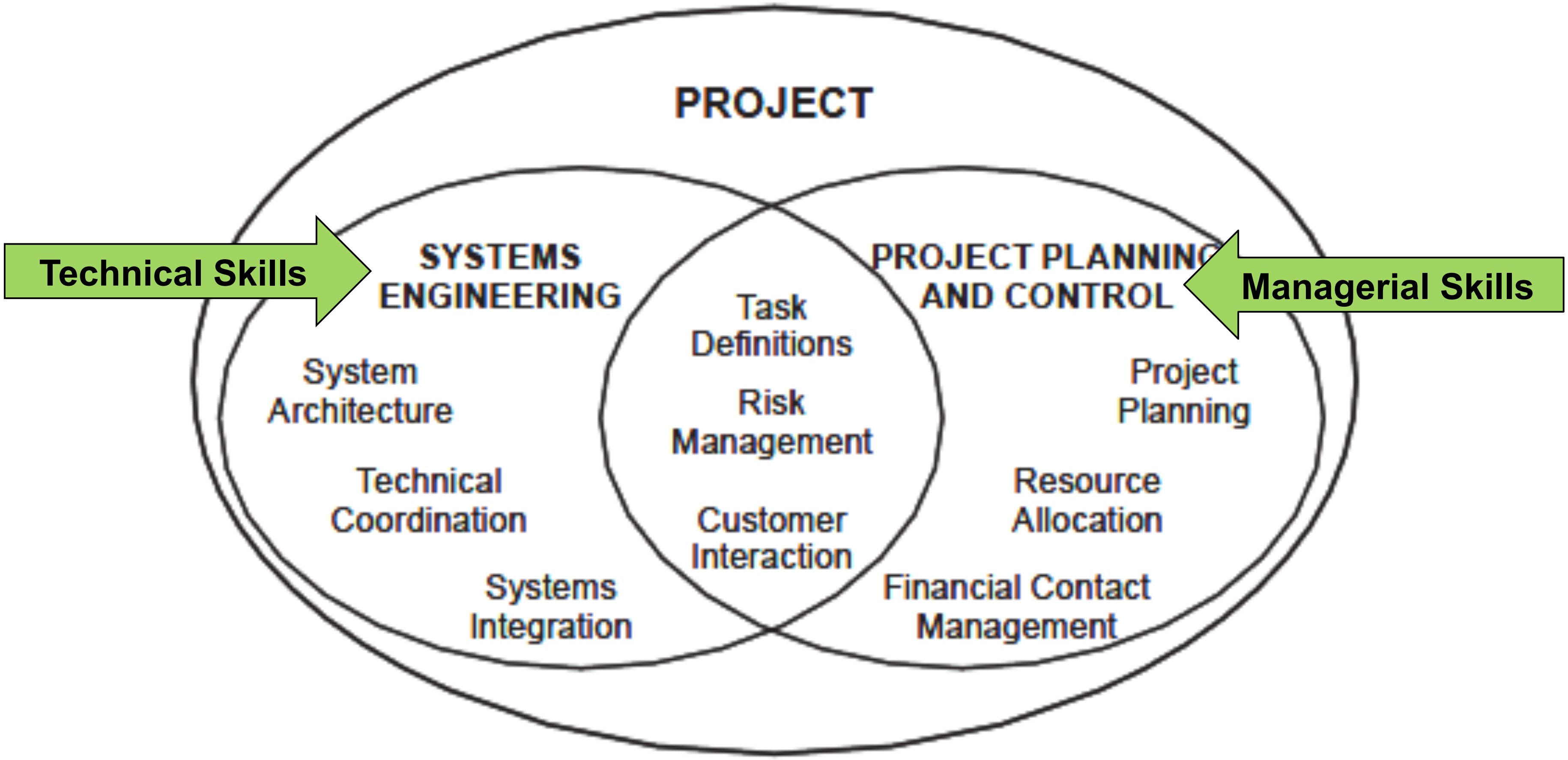
- Project Management Institute (PMI) - Project Management Body of Knowledge (PMBOK) guidebook defines PM as "*the application of knowledge, skills, tools and techniques to project activities in order to meet or exceed stakeholder needs and expectations from a project*" (PMI, 2004)

- NASA defines PM as "*the function of planning, overseeing, and directing the numerous activities required to achieve the requirements, goals, and objectives of the customer and other stakeholders within specified cost, quality, and schedule constraints*" (NASA, 2007, 2010)

Systems Engineering (SE) & Project Management (PM): Similarities & Differences



The Overlapping Areas of SE & PM in a Project

(Kossiakoff and Sweet, 2003)

Systems Engineering (SE) & Project Management (PM): Similarities & Differences

Technical Management Processes	Technical Processes
Decision Analysis	Stakeholders Requirements Definition
Technical Planning	Requirements Analysis
Technical Assessment	Architectural Design
Requirements Management	Implementation
Risk Management	Integration
Configuration Management	Verification
Technical Data Management	Validation
Interface Management	Transition

The Roles of Program/Project Manager and Systems Engineer in the Defense Systems Project Life Cycle Processes

(DOD, 2010)

Systems Engineering (SE) & Project Management (PM): Similarities & Differences

Life-cycle Processes	Program Manager	Chief / Systems Engineer
Stakeholder Management	Primary	Support
Technical Planning	Support	Primary
Decision Analysis	Primary	Support
Technical Assessment (Includes Program Status: Technical Progress, Schedule & Cost Management)	Shared	Shared
Configuration Management	Primary	Support
Data Management	Primary	Support
Requirements Management	Support	Primary
Contract Management	Primary	Support
Requirements Analysis	Support	Primary
Architecture Design	Support	Primary
Implementation	Support	Primary
Risk Management	Primary	Support
Interface Management	Support	Primary
Integration	Support	Primary
Verification	Support	Primary
Validation	Shared	Shared

The Responsibility of Program/Project Manager and Systems Engineer in the Defense Systems Project Life Cycle Processes

(DOD, 2010)

Systems Engineering (SE) & Project Management (PM): Similarities & Differences

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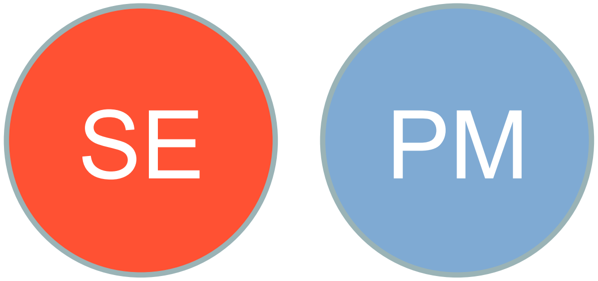
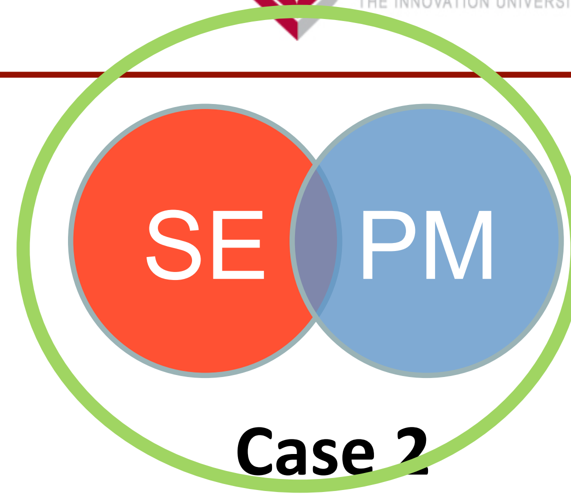


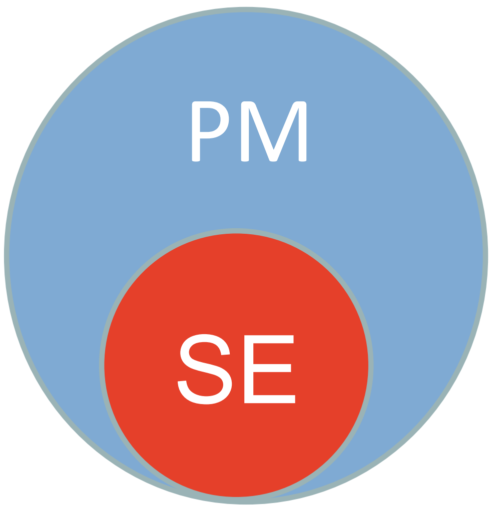
Case 1



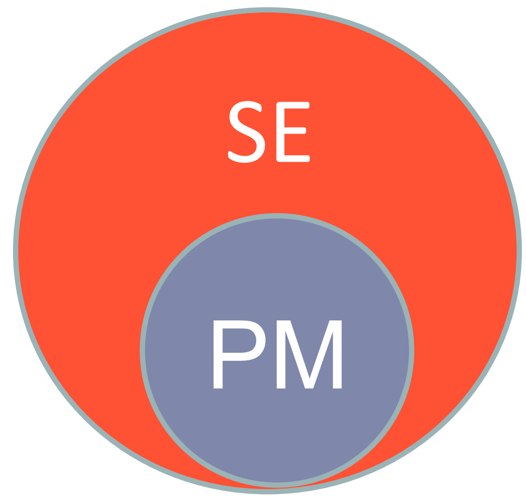
Case 2

Case A: PM = f(SE);

Case B: PM ≠ f(SE)



Case 3



Case 4

Research Model: PM Cost Estimating Model

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Synthesized via COSYSMO (Valerdi, 2005)

$$PM_{NS} = A \cdot \left(\sum_k (w_{e,k}\Phi_{e,k} + w_{n,k}\Phi_{n,k} + w_{d,k}\Phi_{d,k}) \right)^E \cdot \prod_{j=1}^{14} EM_j$$

Where,

PM_{NS} = effort in Person Months (Nominal Schedule)

A = calibration constant derived from historical project data

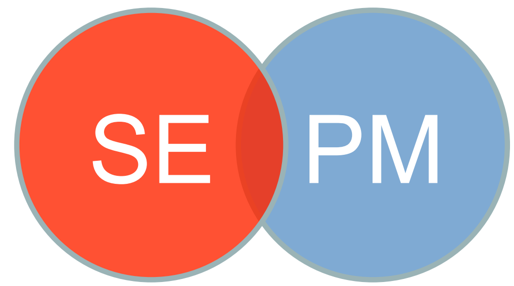
k = {REQ, IF, ALG, SCN}

w_k = weight for “easy”, “nominal”, or “difficult” size driver

Φ_k = quantity of “k” size driver

E = represents diseconomies of scale

EM = effort multiplier for the *j*th cost driver. The geometric product results in an overall effort adjustment factor to the nominal effort.



Case A: PM = f(SE)

Research Model: PM Cost Estimating Model

Potential model parameters were predetermined through various knowledge sources (e.g. books, scholar publications, research whitepapers, dissertations, professional and government publications, etc.)

- Aerospace Engineering
- Civil Engineering
- Computer Science
- Construction Engineering and Management
- Defense/Military
- Engineering Management
- Government
- Information Technology
- Management Information Systems
- Professional Societies
- Project Management
- Risk Management
- Software Engineering
- Systems Engineering

Research Model: PM Cost Estimating Model

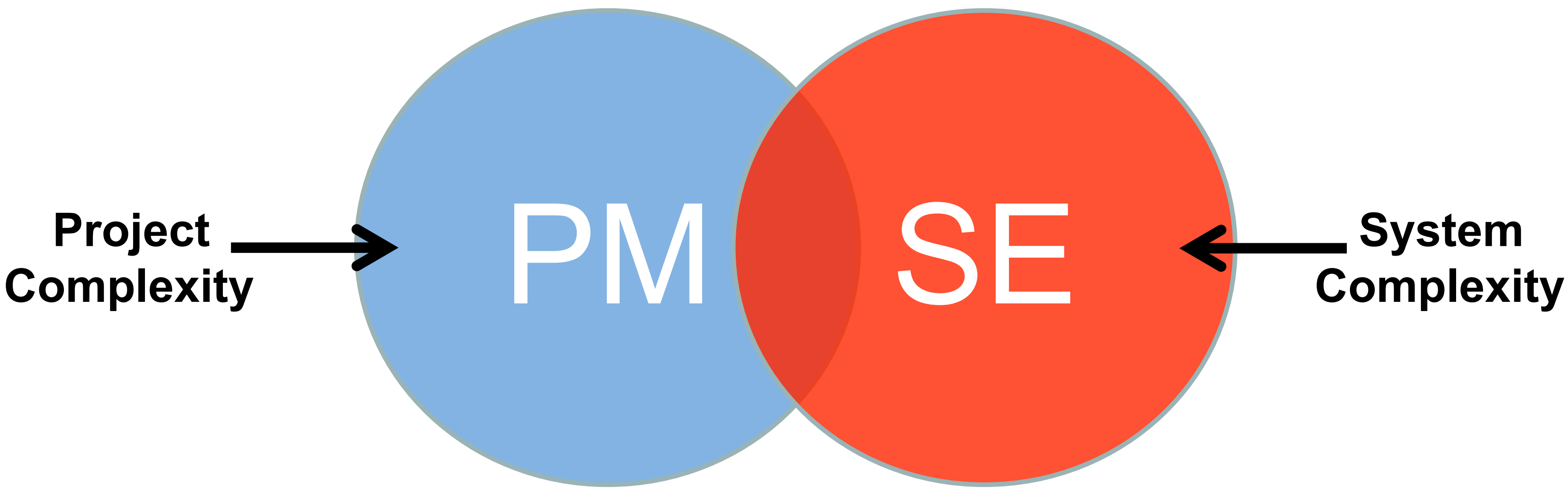
The initial 18 PM effort multipliers are listed as following:

- Scope Understanding
- Scope Volatility
- Scope Growth
- Requirements Volatility
- Requirements Growth
- Budget Constraints
- Schedule Span
- Project Complexities
- Systems Complexities
- Documentation Level
- Level of Service Requirements
- Stakeholder Cohesion
- Project Management Maturity
- Project Management Experience/Continuity
- Process Capability
- Technology Maturity and Risk
- Tool Support
- Multisite Coordination

These initial PM cost indicators were determined to be possibly correlated to factors that have effects on SE/PM cost adjustment factors (Akintoye, 2000; Anderson and Brown, 2004; Crawford et al., 2005; de Wit, 1988; Hamaker and Componation, 2005; Hartman and Ashrafi, 2002; Honour, 2010; NASA, 2010; Valerdi, 2005)

Research Model: PM Cost Estimating Model

Is PM effort proportional to SE effort?



What if PM ≠ f(SE) ?

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Research Model: PM Cost Estimating Model

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Synthesized via COSYSMO (Valerdi, 2005)

$$PM_{NS} = A \cdot \left(\sum_{k} (w_{e,k}\Phi_{e,k} + w_{n,k}\Phi_{n,k} + w_{d,k}\Phi_{d,k}) \right)^{E} \cdot \prod_{j=1}^{5} EM_{j}$$

Where,

PM_{NS} = effort in Person Months (Nominal Schedule)

A = calibration constant derived from historical project data

k = {**REQ, PCR, CST, SCM, DCL**}

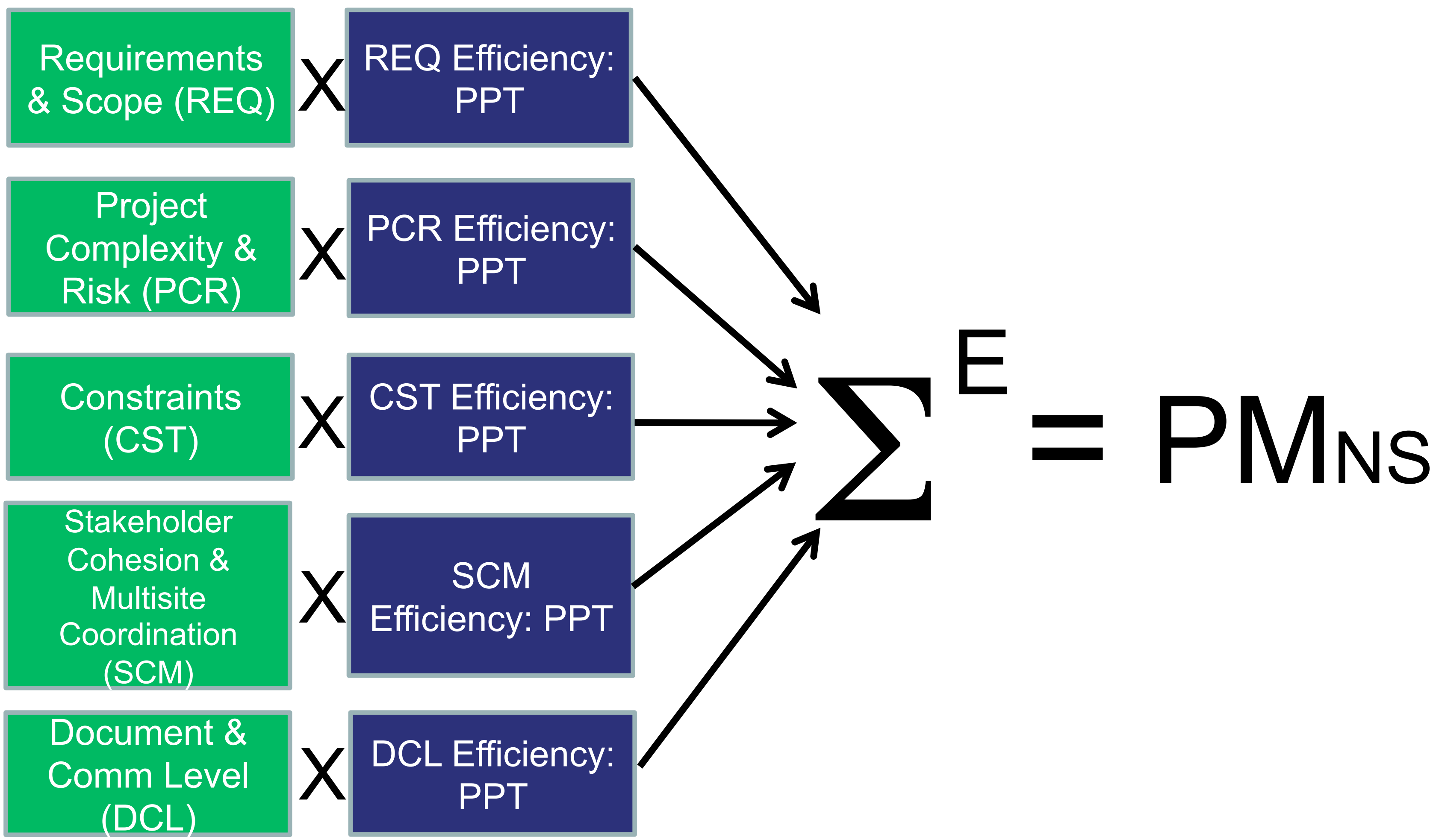
w_k = weight for "easy", "nominal", "difficult", or "**low**", "**medium**", "**high**" size driver

Φ_k = quantity of "k" size driver

E = represents diseconomies of scale

EM = **project management *efficiency* multiplier** for the *j*th cost driver. The geometric product results in an overall effort adjustment factor to the nominal effort.

Research Model: PM Cost Estimating Model



PPT = Project Management Capability & Maturity of People, Process & Tools

Research Model: PM Cost Estimating Model

Consolidated 5 Cost Categories

REQ: Requirements & Scope – How well understood is the project?

- Scope of requirements
- Number of requirements
- How well defined (e.g. Statement of Work (SOW), Work Breakdown Structure (WBS), etc
- Volatility/Rate at which they are changing

PCR: Project Complexity & Risk – How much risk is there?

- What is the level of risk for the project
- How difficult is it to assess the risk
- Number of known project complexity & risks

CST: Constraints – How tight are the constraints?

- Schedule Span – Time constraints
- Budget Constraints – Money constraints
- Resources Constraints – Human resources constraints
- Function/feature – Minimum acceptable features
- Quality – Minimum acceptance by customers

Research Model: PM Cost Estimating Model

Consolidated 5 Cost Categories (cont'd)

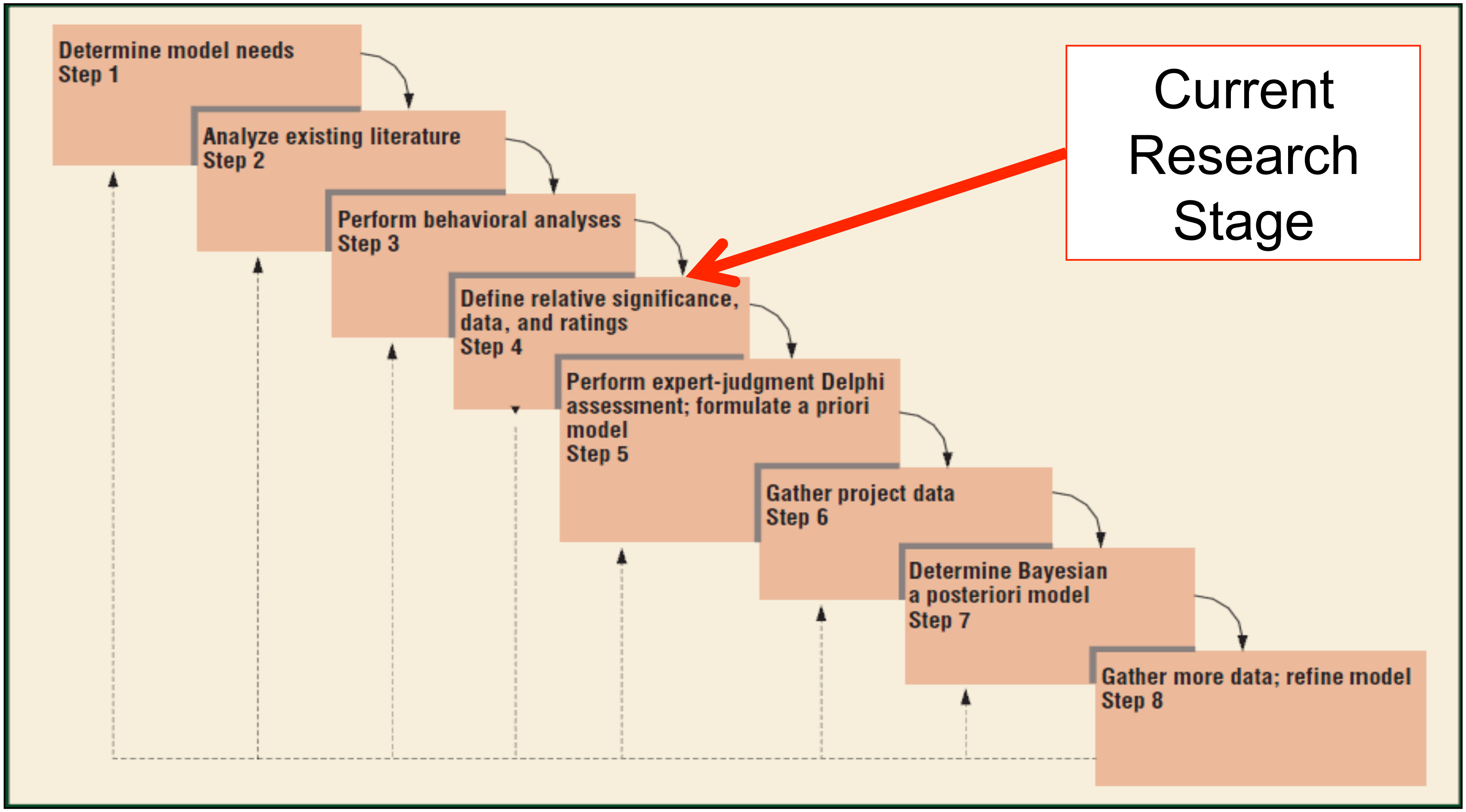
SCM: Stakeholder Cohesion & Multisite Coordination

- o Number of stakeholders
- o Diversity of stakeholders (e.g., have opposing goals/objectives, have different world views)
- o Communication challenges (external clients, internal clients, contractors, languages, time zone difference, etc)

DCL: Documentation & Communication Level – Amount of PM work to be done

- o Amount and complexity of required documentation (e.g., project plan, resource management plan, status reports, etc)
- o Amount and complexity of required communications (number, length, occurrence of meetings, etc)

Current Research Stage



USC CSSE Cost Estimation Model Development Methodology

(Boehm and Valerdi, 2008)

Next Steps

- Utilize recommendations/suggestions from practitioners & subject matter experts (SME) to update the proposed PM cost model
- COSYSMO workshop
  - Thursday, Nov 4th, 2010
  - Develop an approach to generate PM Efficiency (PPT) cost driver weight factors
- Facilitate the industry outreach to reach agreement on data-sharing
  - United States Army - Armament Research, Development and Engineering Center (ARDEC)

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Questions?

- Suggestions?
- Comments?

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COSYSMO Workshop

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Thursday, Nov 4th, 2010

The University of Southern California (USC)

<u>Section</u>

Systems Engineering and Project Management:

Similarities and Difference for Cost Estimation