Systems Engineers' Perceptions on the Adequacy of Project Management Methods for Systems Engineering Management

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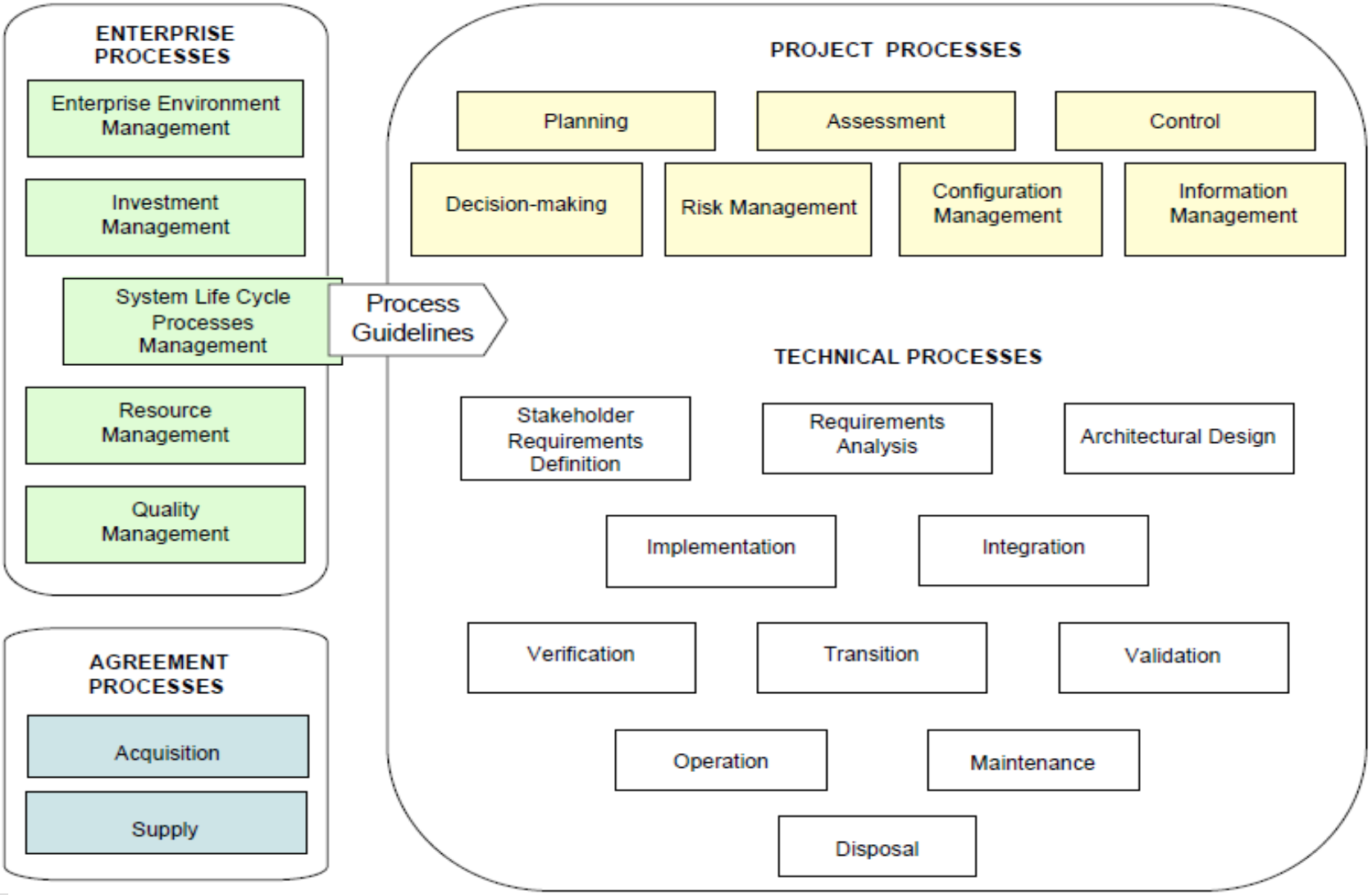
Project Management and Systems Engineering Competencies

INCOSE International Symposium

INCOSE Systems Engineering Handbook V3



Project Management and Systems Engineering Competencies

PROJECT MANAGEMENT AND SYSTEM ENGINEERING HANDBOOK NASA MSFC-HDBK-3173, May 30, 2001:

“Today’s political and economic environment is substantially different from that of the Apollo/Saturn era. Cost along with schedule and technical performance are solid anchoring factors in the project management and systems engineering concept. This suggests that managers and systems engineers of future projects will have to do adequate up-front planning, to successfully achieve the projects’ goal in today’s faster, better and cheaper environment”.
“Previously, project management principles and systems engineering practices were documented in separate documents. This handbook combines the project management and systems engineering principles and practices”

Project Management and Systems Engineering Competencies

The NASA Project Management and Systems Engineering Competency

PROJECT MANAGEMENT AND SYSTEM ENGINEERING HANDBOOK

in

combines the project management and systems engineering principles and practices."

Each competency area describes, in broad terms, what is expected of NASA Project Management and Systems Engineering personnel in terms of particular components or functions of the job.

Project Management and Systems Engineering Competencies

The *Defense Acquisition Guidebook* (DAG), Department of Defense, 15 June 2009

Contains eleven chapters, each dealing with a separate subject of program management, from which Chapter 4, devoted to systems engineering in acquisition programs, presents generic systems engineering processes, grouped in two categories:

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

Project Management and Systems Engineering Competencies

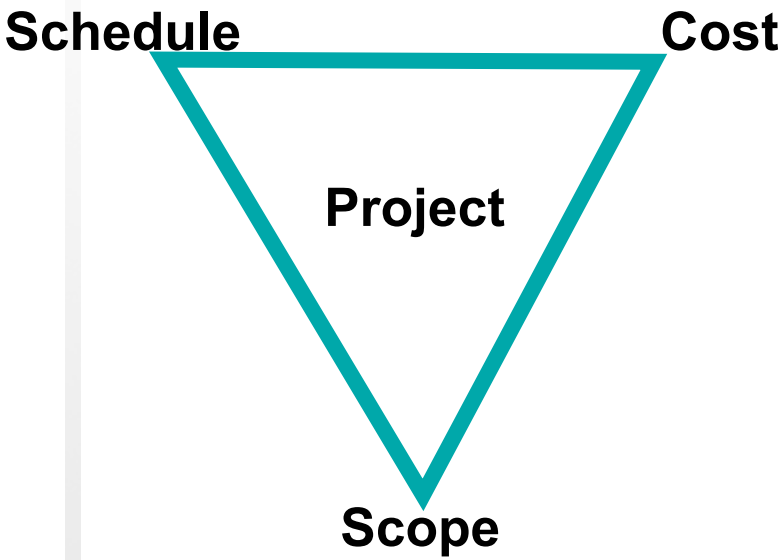
The *Defense Acquisition Guidebook* (DAG), Department of Defense, 15 June 2009

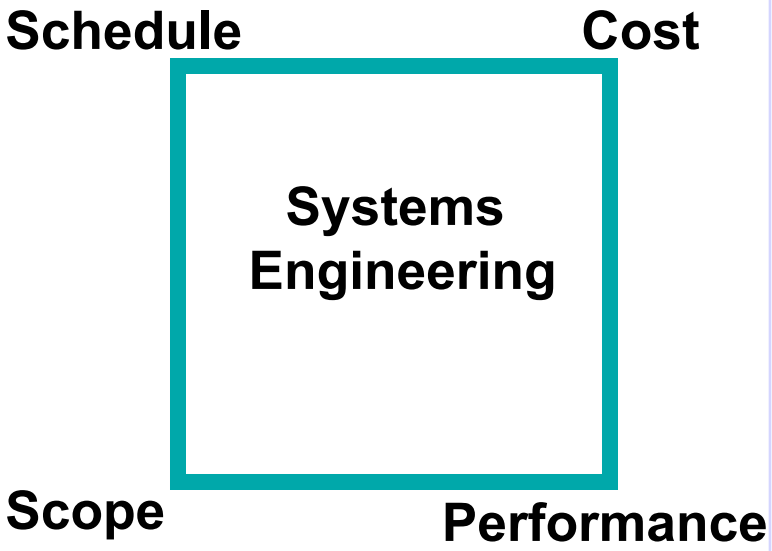
Contains eleven chapters, each dealing with a separate subject of program management, from which Chapter 4, devoted to systems engineering in acquisition programs, presents generic systems engineering processes, grouped in two categories.

The chapter on systems engineering describes systems engineering techniques and tools for management, oversight, and analysis and provides some general knowledge management resources, including:

- Systems Engineering Plan (SEP)
- Integrated Master Plan (IMP)
- Integrated Master Schedule (IMS)
- Earned Value Management (EVM)
- Work Breakdown Structure (WBS).

Project Management vs. Systems Engineering Management





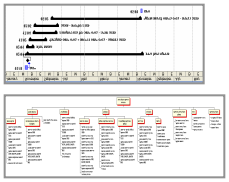
Arsenal:
Gantt, PERT,
CPM, DSM,
EVM, SD…..

→

Arsenal:
Gantt, PERT,
CPM, DSM,
EVM, SD…..

Technical requirements,
Functionality,
Architecture,
Verification

Building a combined plan iteratively while creating the product-project model



Project

Preliminary Project Scope and Project Plan

Further Development of the basic concept

Product

Basic Concept

Elaborated Concept

Traceability & Coverage Maintained !

Detailed Decomposition

Detailed Decomposition

The Overall Research Goal

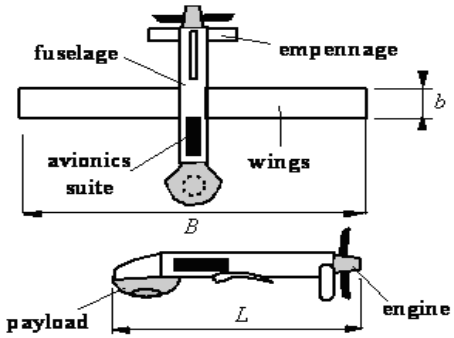
To develop a combined project-product methodology and conceptual model, containing both domains, linked with explicit relationships.

Research Questions 1 & 2

#	Topic	Questions	Research Method	Notes
1, 2	Application of Project Management Methods within Systems Engineering Management	(1) While conducting the systems engineering management, to what extent do practitioners perceive a notion of a project-domain, a product-domain, and a combined project-product domain? (2) How do systems engineers perceive the extent to which the common PM methods support SEM?	Structured questionnaires 	focus is put on seven PM methods 24 participants

Method for Research Question 4
Stages (1) +(2)

Given
UAV Specification



UAV concept, Specifications:
L=2000 mm, B=3500 mm, b=500 mm

23 activities specified with relationships

Gantt Model
created by
participants

Project-Product OPM
Model
created by participants

Comparison of Gantt model versus OPM model
based on the five roles of Deliverables in the OPM project plan

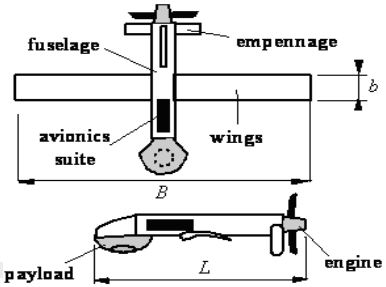
Method for Research Questions 1 & 2

The seven investigated project management methods

Project management method – short name	System Dynamics	Program Evaluation and Reviewing Technique	Critical Path Method	Design Structure Matrix	Earned Value Method	Gantt chart	Object Process Methodology
Project management method – full name	SD	PERT	CPM	DSM	EVM	Gantt	OPM
Homework assignment	HW1	HW2	HW2	HW3	HW4	HW5	HW5
Number of 3-hour sessions devoted to method	6	1	1	2	1	Reviewed prior to MBPP	Reviewed prior to MBPP

* The MBPP approach was presented during 1.5 sessions (4.5 hours).

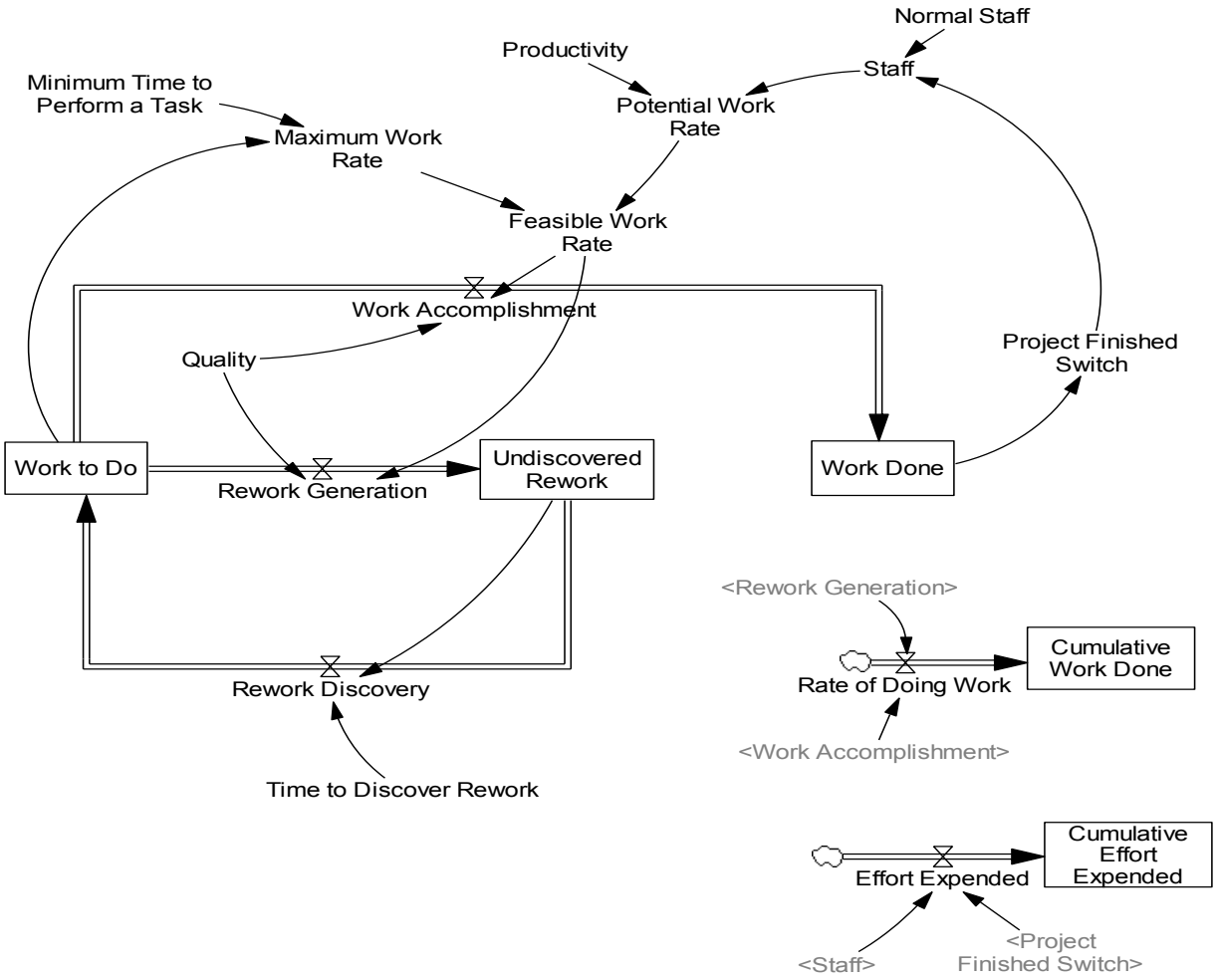
Given UAV Specification
23 activities specified with relationships



UAV concept, Specifications:
L=2000 mm, B=3500 mm, b=500 mm

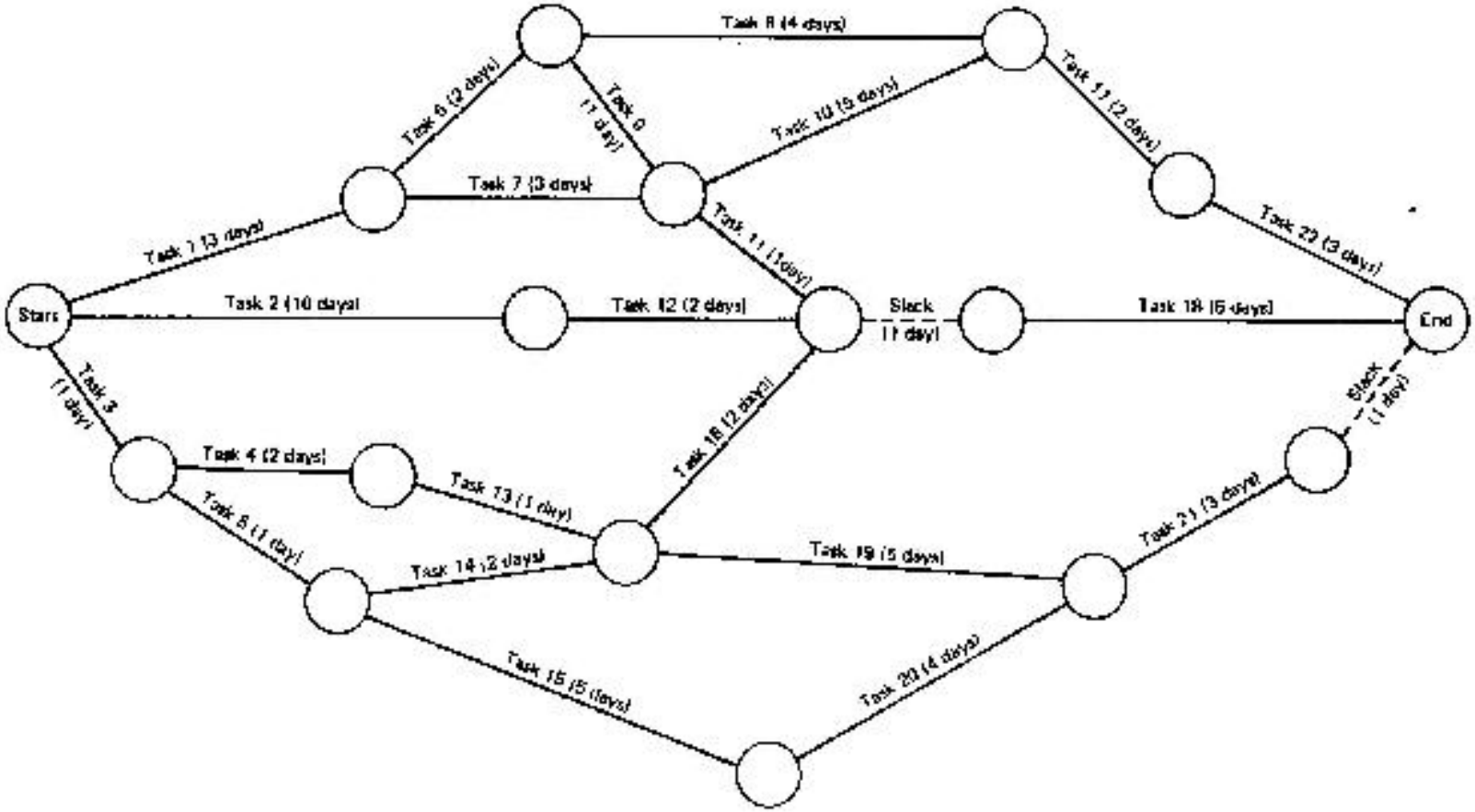
System Dynamics

- SD



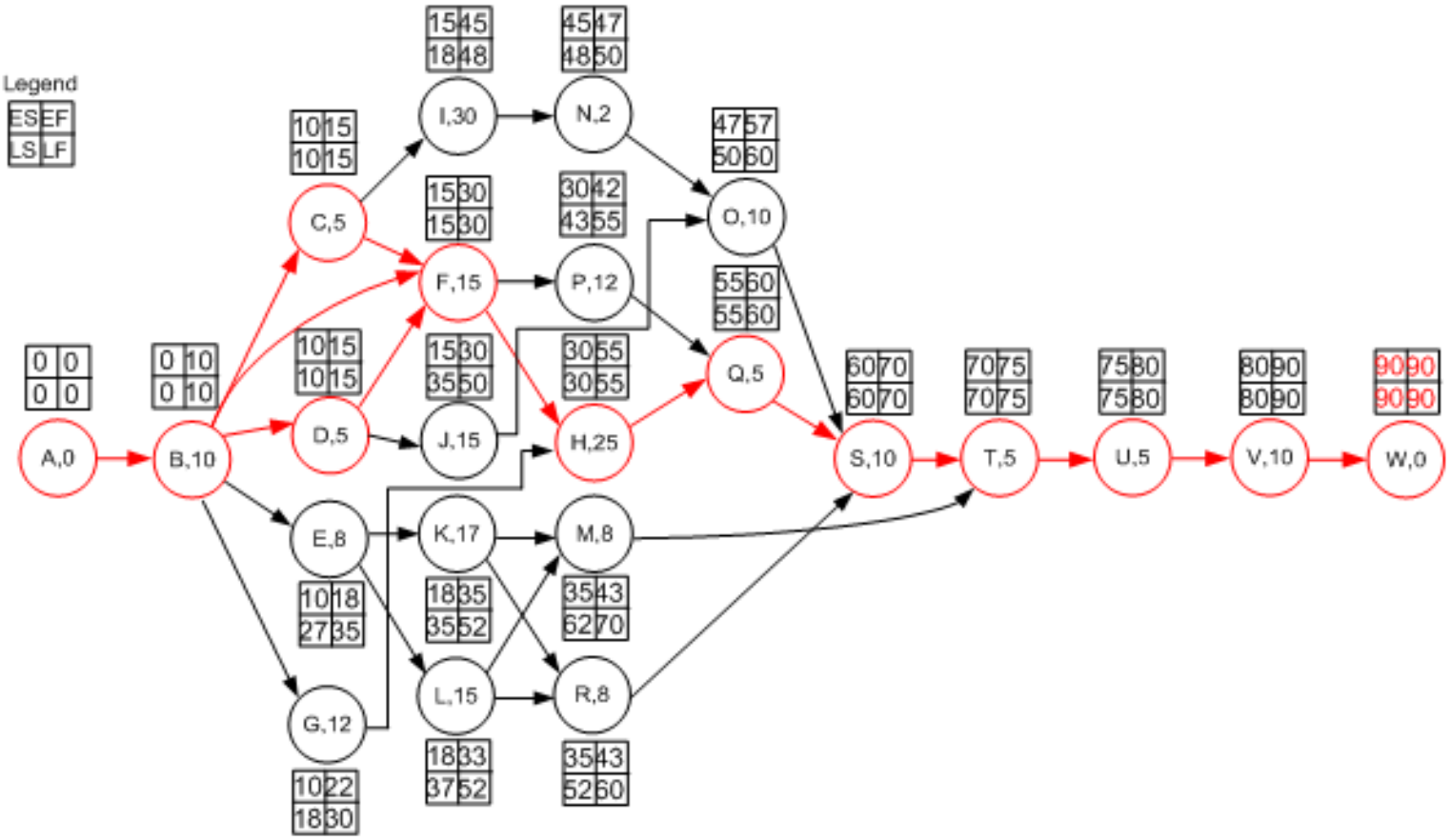
Program Evaluation and Reviewing Technique

- PERT



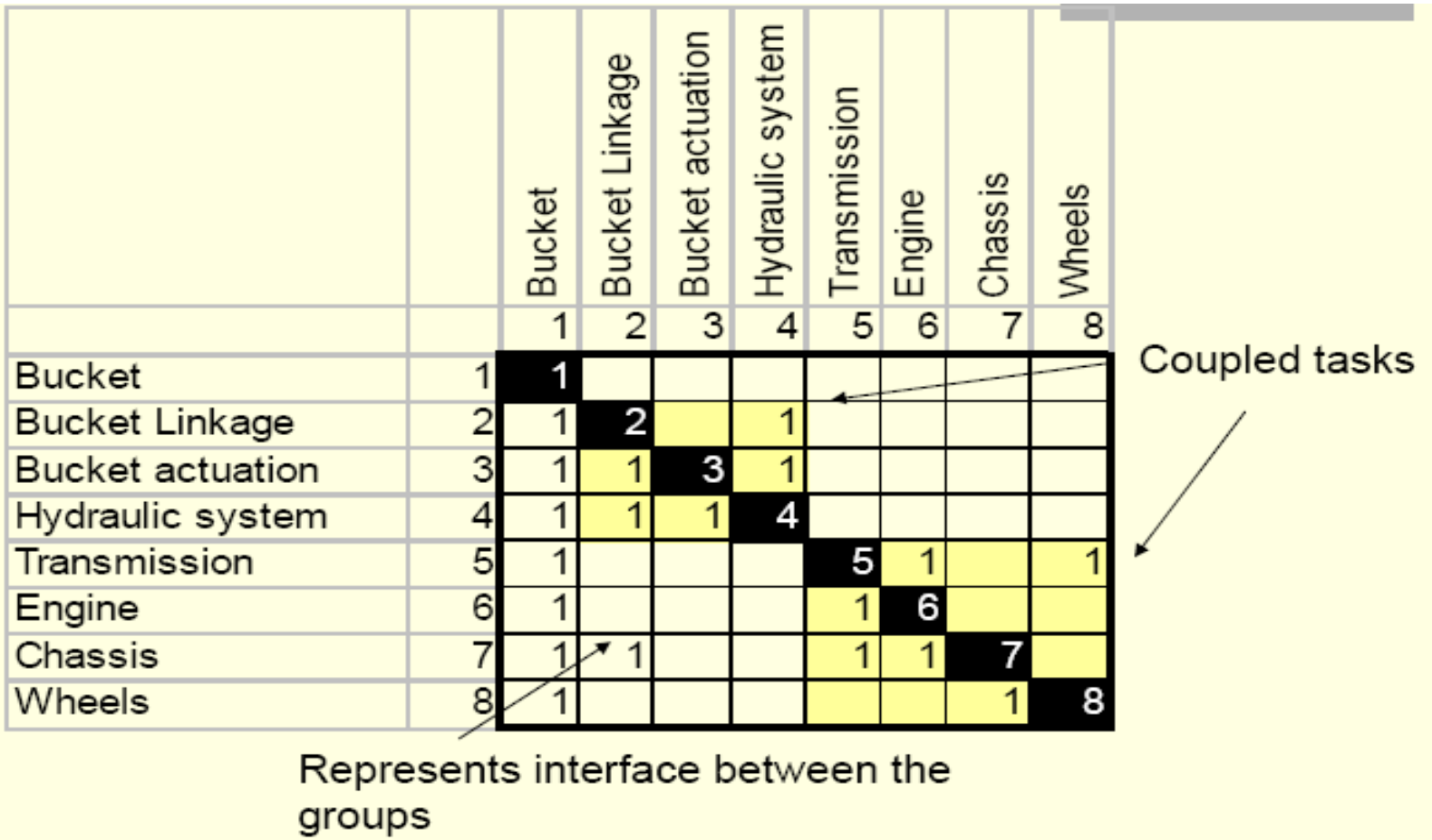
Critical Path Method

- CPM



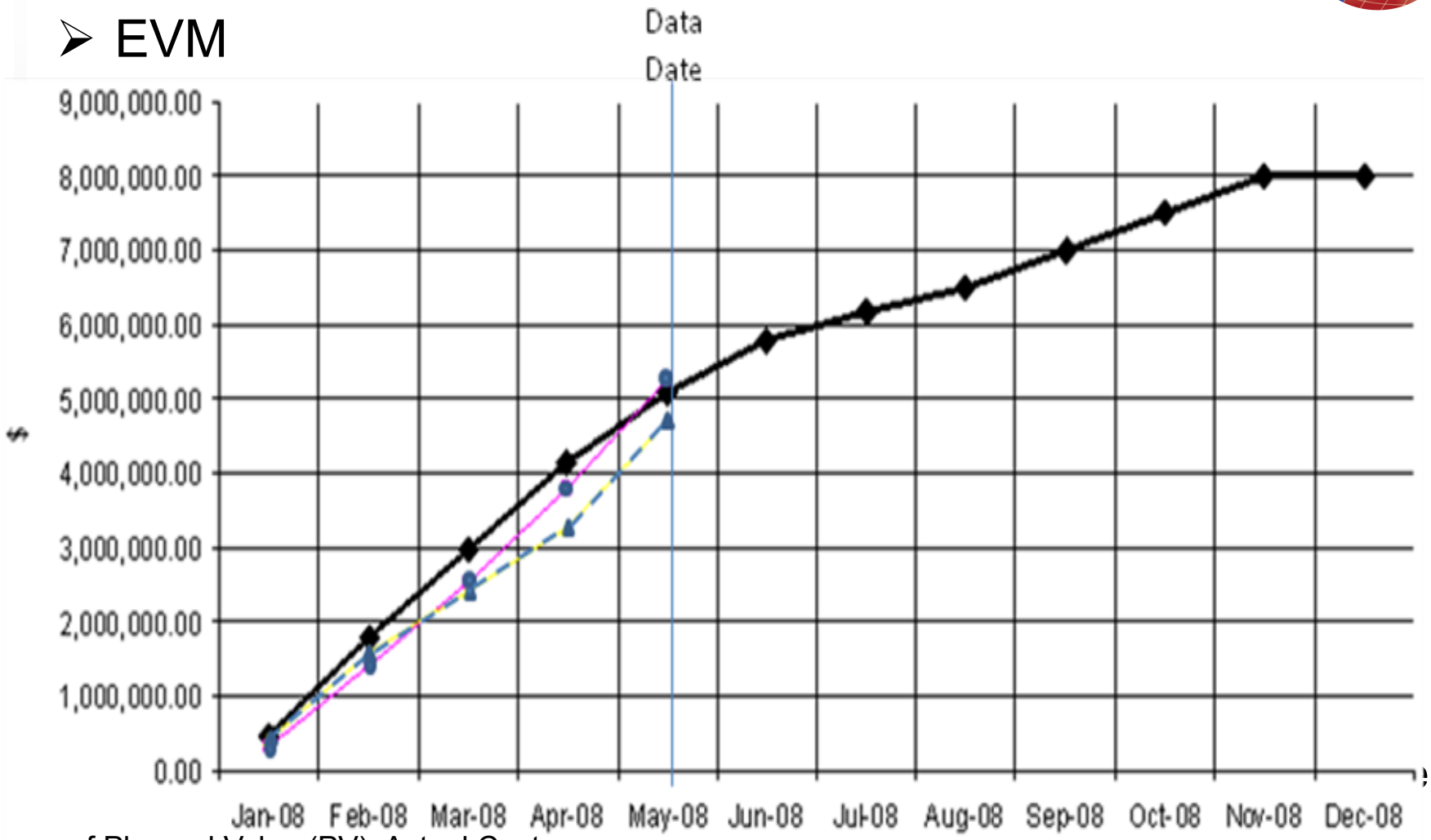
Design Structure Matrix

- DSM



Earned Value Method

- EVM

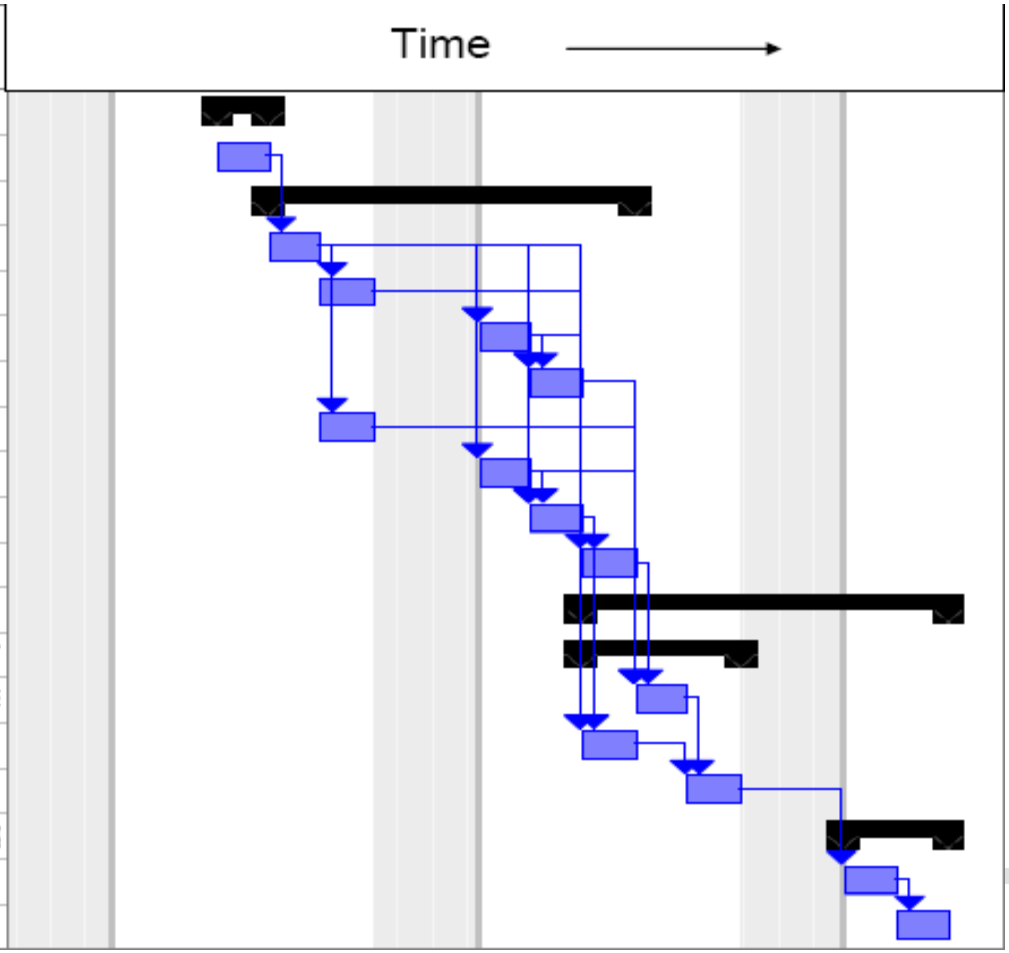


Curves of Planned Value (PV), Actual Cost (AC), and Earned Value (EV) against each other from the beginning of the project till the "Data Date" time point.

Gantt chart

- Gantt

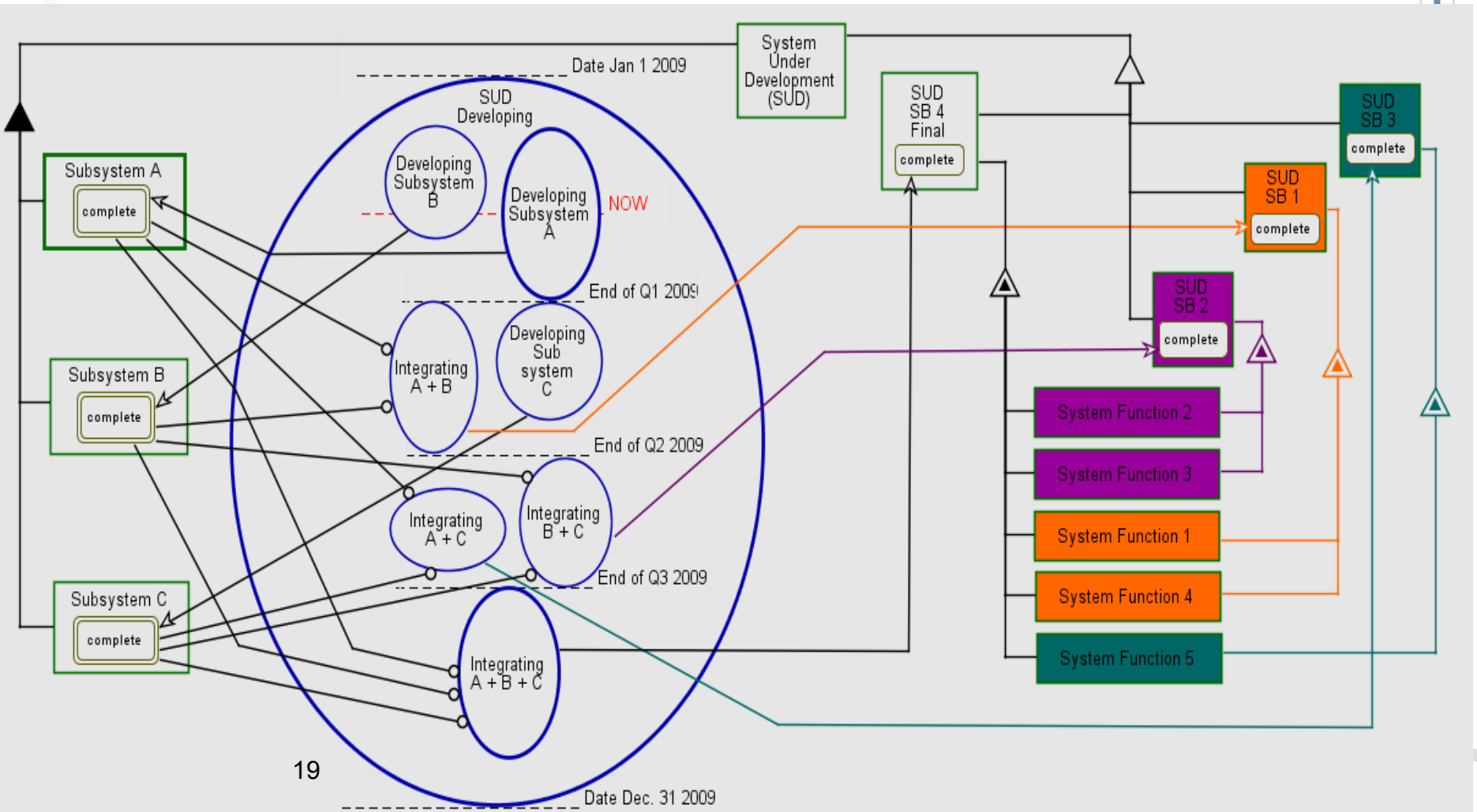
ID	Task Name
1	**Preliminary Design**
2	Design iteration
3	**Detail Design**
4	Bucket
5	Bucket Linkage
6	Bucket actuation
7	Hydraulic system
8	Transmission
9	Engine
10	Chassis
11	Wheels
12	**Testing and refinement**
13	**Prototype Manufacturir**
14	By parts and subsys
15	Manufacturing
16	Assmbly
17	**Evaluation and Redesi**
18	Testing
19	Redesign



OPM

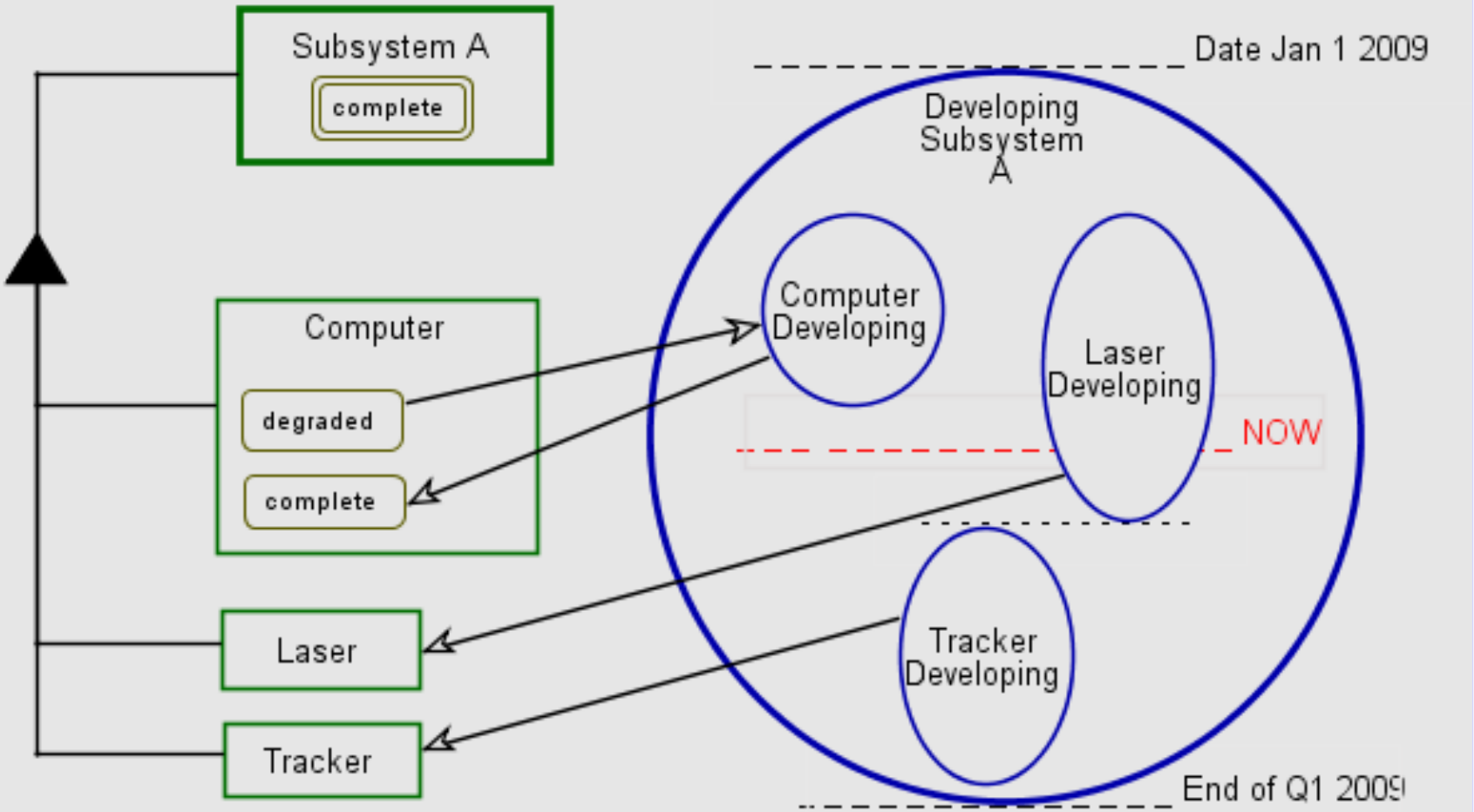
with extended time notations: early start, early finish, … floating start

PPLM model of a SUD Developing process



Zooming into Developing Subsystem A

PPLM plan of Developing Subsystem A



PPLM Generic Plan Construct (GPC)

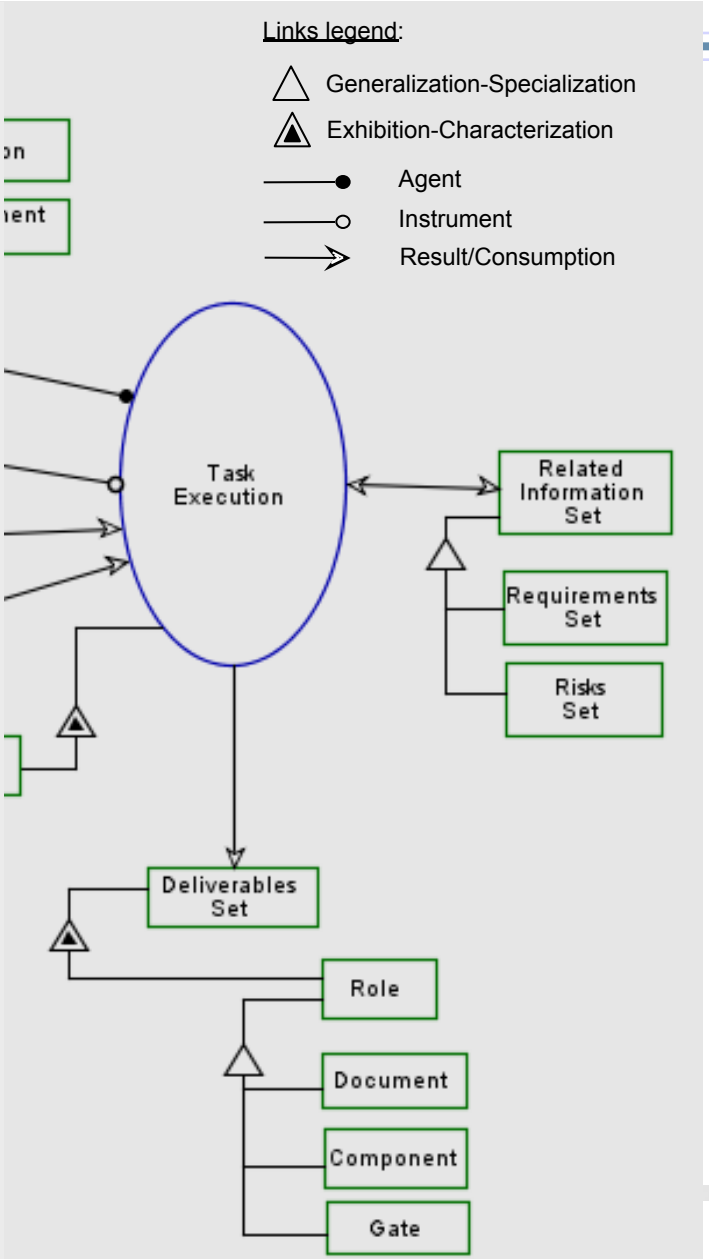
Task Execution exhibits Duration.
Duration exhibits Minimum Activation Time, Maximum Activation Time, and Units.

Task Execution affects Related Information Set.
Requirements Set is a Related Information Set.
Risks Set is a Related Information Set.

Task Execution requires Instruments Set.
Task Execution consumes Budget and Consumables Set.
Task Execution yields Deliverables Set.
Deliverables Set exhibits Role.
Document is a Role.
Component is a Role.
Gate is a Role.

Resources Set exhibits Utilization.
Utilization exhibits Measurement Units.
Agents Set is a Resources Set.
Instruments Set is a Resources Set.
Budget is a Resources Set.
Consumables Set is a Resources Set.

Agents Set handles Task Execution.
Agents Set is physical.
Instruments Set is physical.



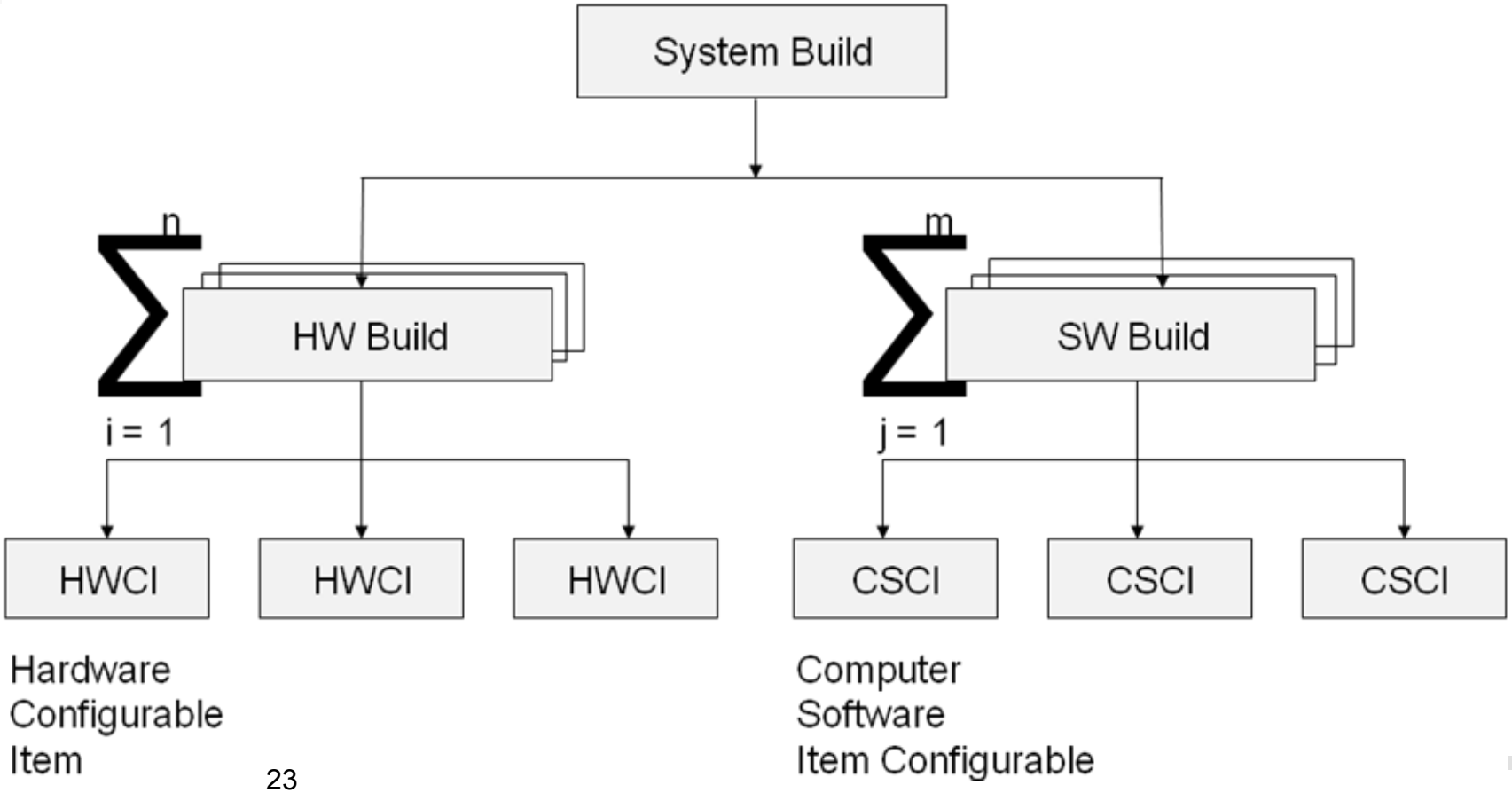
PPLM Objects typology

The roles of objects in the OPM-based combined plan

Symbol			Description	Examples
Deliverables (Roles)		D	Document – a recorded definition of anything related to the product or the project delivering it expressed via an informatical object	Requirements Document, , Design Document, Engineering Drawing, Testing Procedure Document
		G	Gate for required approval	Approval of a key document or a physical artifact, often related to a milestone, such as a requirements document, a design document, a prototype
		C	Component	System or product part: Engine, Payload, Software
Resources	Inputs	R	Budget	
			Consumables Set	Raw materials, Energy, Utilities, Un-saved data
	Enablers	A	Agent – a human enabler	System Engineer, Software Engineer, Engine Designer, Test Engineer, Technician, Programmer, Team Leader
		I	Instrument – a non-human enabler	Design Tool, CAD System, Telemetry Equipment, Laboratory

Planning to Systems Builds (SBs)

The combined product-project model System Build (SB) hierarchy



Automatic Extraction of Coherent common Project Views

PPLM Model

Model-Based Systems Engineering Management (MBSEM)

A single source for all common management views

ANP PERT/CPM Gantt DSM WBS MBS Combined views

Coherent !

Method for Research Questions 1 & 2

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Method for Research Questions 1,2

The 14 Systems Engineering Management Factors

SEM Factor		Dimension
1	Budget/Schedule measurement/tracking	Project
2	Budget/Schedule forecasting	Project
3	Inter-relationships (process & product)	Project-Product
4	Resource management	Project
5	Stakeholders/agents tracking	Project-Product
6	Performance quality	Product
7	Product quality	Product
8	Product planning	Product
9	Product measurement/tracking	Product
10	Risk management	Project-Product
11	Iterations management	Project
12	Information resolution level	Project-Product
13	Ease of communication	Project-Product
14	Change management	Project-Product

Method for Research Questions 1,2

The 14 Systems Engineering Management Factors

$$D_{SEM} = \{F_1, F_2, \ldots, F_{14}\}$$

$$D_{project} = \{F_1, F_2, F_4, F_{11}\}$$

$$D_{product} = \{F_6, F_7, F_8, F_9\}$$

$$D_{project-product} = \{F_3, F_5, F_{10}, F_{12}, F_{13}, F_{14}\}$$

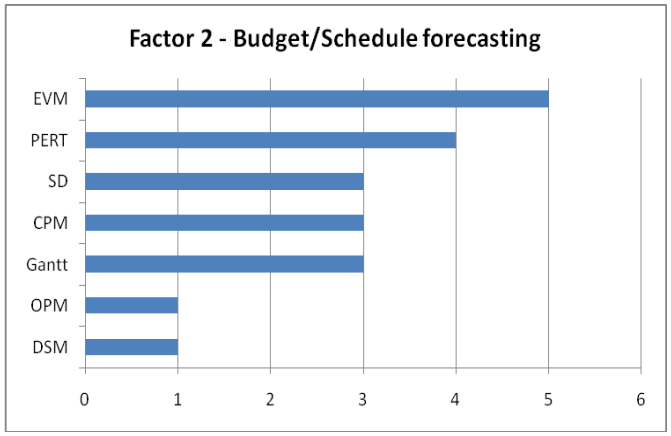
Results for Research Questions 1 & 2

All Factors Set Reliability

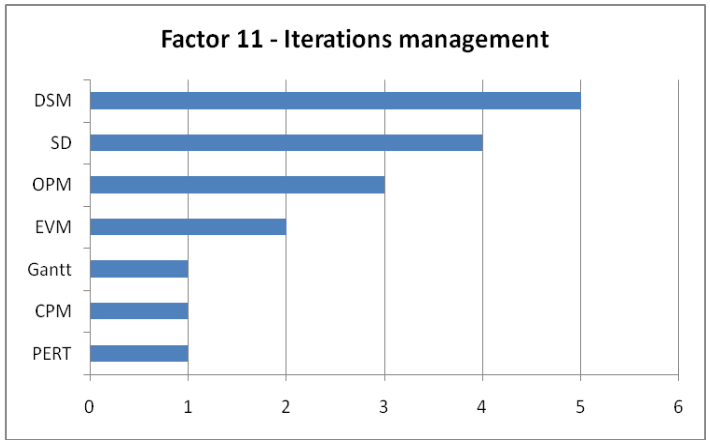
Project Management Method	SD	PERT	CPM	DSM	EVM	Gantt	OPM
Full name	System Dynamics	Program Evaluation and Reviewing Technique	Critical Path Method	Design Structure Matrix	Earned Value Method	Gantt Chart	Object Process Methodology
Cronbach's Alpha	**.743**	**.793**	**.754**	**.640**	**.757**	**.760**	**.855**
Best Improved	-	-	-	**.702**(1)	-	-	-

(1) Improved by deletion of factor 12 – Information Resolution Level and factor 3 - Inter-relationships (process & product)

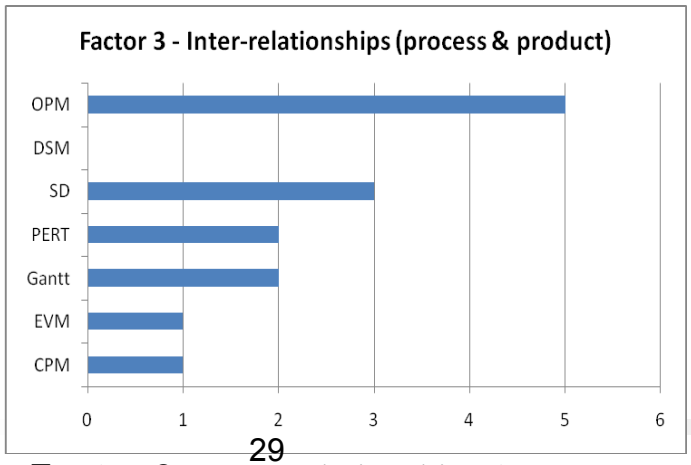
The suitability of each one of the seven PM methods to handle four of the 14 factors



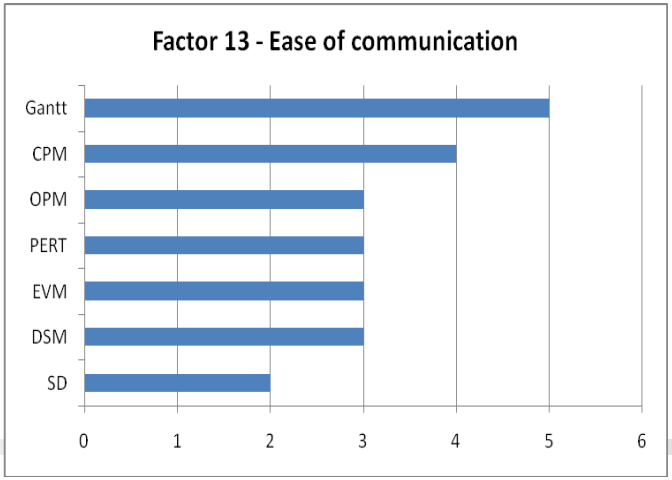
Factor 2 - Budget/Schedule forecasting



Factor 11 - Iterations management

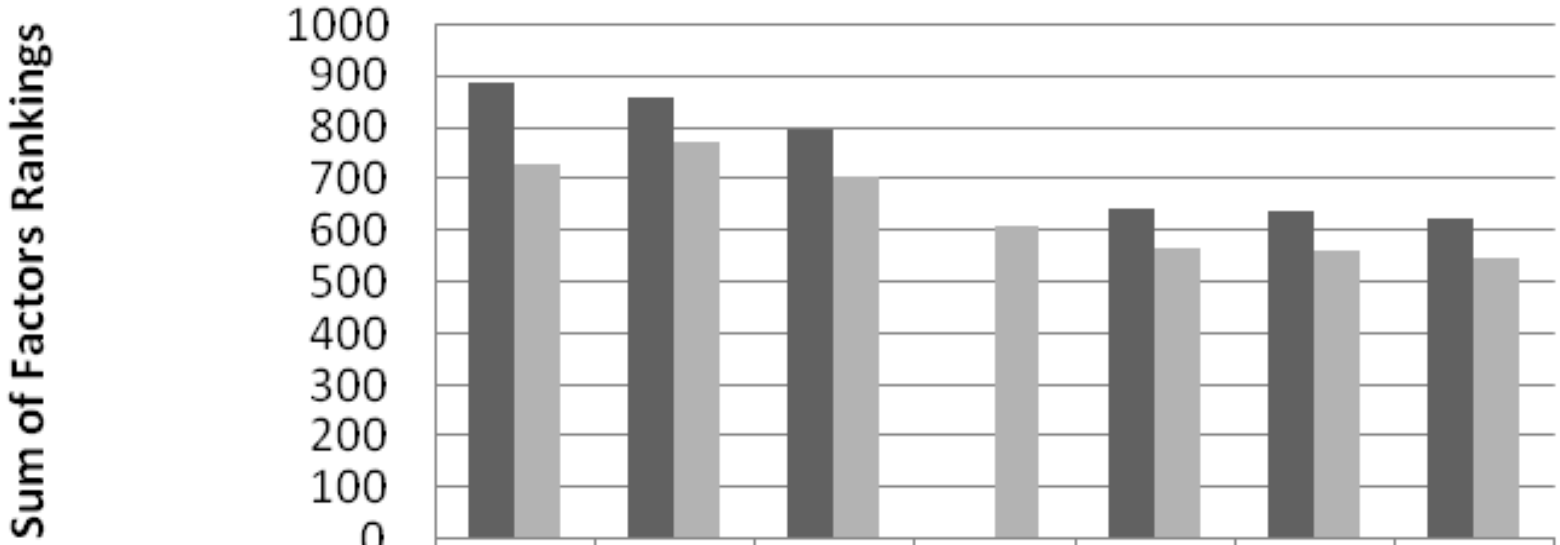


Factor 3 - Inter-relationships (process & product)



Factor 13 - Ease of communication

Project management Methods Comparison by Sum of Factors Rankings

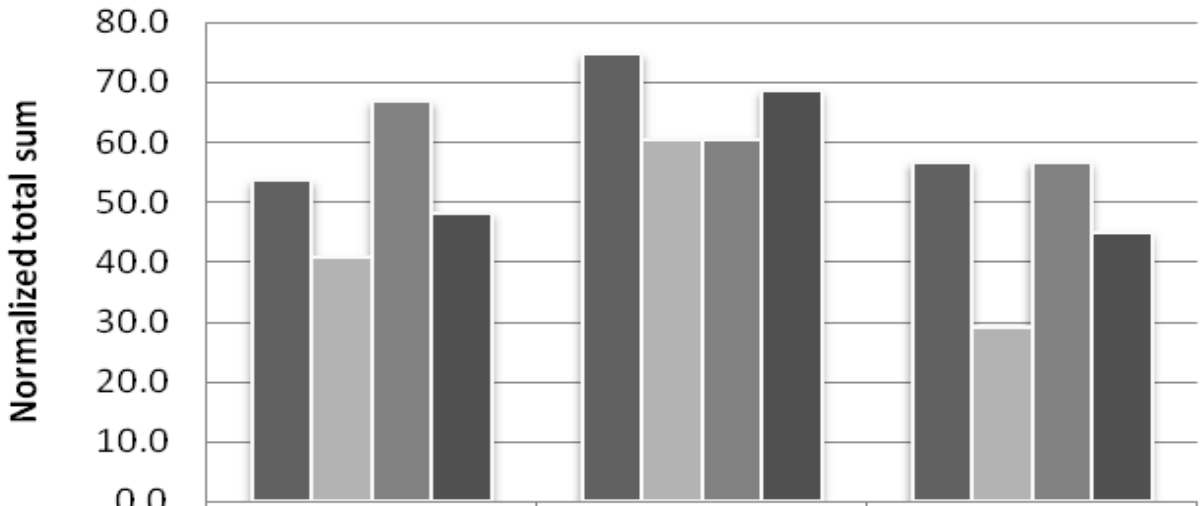


	OPM	SD	EVM	DSM	Gantt	CPM	PERT
Toatl of all Fourteen Factors	885	858	795		642	637	620
Total Without Factors 3 and 12	726	769	702	609	566	560	544

Research Questions 1 & 2: Findings for the defined dimensions

Project Management Method	SD	PERT	CPM	DSM	EVM	Gantt	OPM
Full name	System Dynamics	Program Evaluation and Reviewing Technique	Critical Path Method	Design Structure Matrix	Earned Value Method		Object Process Methodology
Project Dimension	ν	ν	-	ν	-	-	ν
Product Dimension	ν	-	-	ν	-	-	ν
Project-Product Dimension	-	-	-	-	ν	-	ν
Combined Project-Product Dimension	ν	ν	-	ν	-	-	ν

Project management methods comparison by dimensions



	SD	OPM	DSM
Project (sum of factors 1, 2, 4, and 11)	53.5	74.8	56.5
Product (sum of factors 6, 7, and 9; without 8)	40.7	60.3	29.0
Project-Product (sum of factors 5, 10, 13, and 14; Without 3 and 12)	66.8	60.5	56.5
Combined Project-Product (sum of factors 1, 2, 4, 11 and 6, 7, 9)	48.0	68.6	44.7

Research Questions 1 & 2

#	Topic	Questions	Research Method	Notes
1, 2	Application of Project Management Methods within Systems Engineering Management	(1) While conducting the systems engineering management, do practitioners perceive a notion of a project-domain, a product-domain, and a combined project-product domain? (2) How do systems engineers perceive the extent to which the common PM methods support SEM?	Structured questionnaires	focus is put on seven PM methods 24 participants

Encouraging…

Research Question 3

#	Topic	Questions	Research Method	Notes
3	Perceived Characteristics of SE Tools and Methods	How do systems engineers perceive systems engineering methods and tools?	Qualitative Research – Interviews, inspections and analysis of artifacts	focus is put on ten systems engineers in a large enterprise