Project Management

Basic Definitions: Project and Project Plan

- **Software Project:**
  - All *technical* and *managerial* activities required to deliver the deliverables to the client.
  - A software project has a specific duration, consumes resources and produces *work products*.
  - Management categories to complete a software project:
    - Tasks, Activities, Functions

- **Software Project Management Plan:**
  - The controlling document for a software project.
  - Specifies the technical and managerial approaches to develop the software product.
  - Companion document to requirements analysis document:
    - Changes in either document may imply changes in the other document.
  - The SPMP *may* be part of the project agreement.
Components of a Project

A More Complex Model
States of a Project

Capability Maturity Model

- Model produced by the Software Engineering Institute to rate an organization’s software development process

- Level 1: Initial - Lowest level, chaotic
- Level 2: Repeatable – Project tracking of costs, schedule, and functionality. Able to repeat earlier successes.
- Level 3: Defined – A documented and standardized software process. All development accomplished using the standard processes.
- Level 4: Managed – Quantitatively manages the process and products.
- Level 5: Optimizing – Uses the quantitative information to continuously improve and manage the software process.
Personal Software Process

• Can use the CMM idea and apply it to an individual software developer. Watts Humphrey developed PSP in 1997.
  – Use personal time logs to measure productivity; errors timed and recorded

<table>
<thead>
<tr>
<th>Date</th>
<th>Start</th>
<th>Stop</th>
<th>Delta</th>
<th>Interrupt</th>
<th>Task</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/1</td>
<td>09:00</td>
<td>15:30</td>
<td>360</td>
<td>30 lunch</td>
<td>50 LOC</td>
</tr>
<tr>
<td>1/3</td>
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<td>14:00</td>
<td>270</td>
<td>30 lunch</td>
<td>60 LOC</td>
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<tr>
<td>1/4</td>
<td>09:00</td>
<td>11:30</td>
<td>150</td>
<td></td>
<td>50 LOC</td>
</tr>
<tr>
<td>1/5</td>
<td>12:00</td>
<td>02:00</td>
<td>120</td>
<td></td>
<td>Testing</td>
</tr>
</tbody>
</table>

900 minutes to write/test a program of 160 LOC. Assuming 5 hrs/day this is 3 days to write/test 160 LOC. Productivity = 53 LOC/day

Earned Value Analysis

• Basic measures to calculate how much has been accomplished
  – Percent of the estimated time that has been completed

• Basic Measures
  – Budgeted Cost of Work (BCW)
    • The estimated effort for each work task
  – Budgeted Cost of Work Scheduled (BCWS)
    • The sum of the estimated effort for each work task that was scheduled to be completed by the specified time
  – Budget at Completion (BAC)
    • The total of the BCWS and thus the estimate of the total effort of the project
Earned Value Analysis

• Basic Measures
  – Planned Value (PV)
    • PV = BCW/BAC
    • The percentage of the total estimated effort assigned to a particular work task
  – Budgeted Cost of Work Performed (BCWP)
    • The sum of the estimated efforts for the work tasks completed by the specified time
  – Actual Cost of Work Performed (ACWP)
    • Sum of the actual efforts for the work tasks that have been computed

• Progress Indicators
  – Earned Value (EV) or Percent Complete (PC)
    • EV = BCWP/BAC
    • The sum of the Planned Value for all completed work tasks
  – Schedule Performance Index (SPI)
    • SPI = BCWP / BCWS
    • 100% = perfect schedule
  – Schedule Variance (SV)
    • SV = BCWP – BCWS
    • Negative is behind schedule, Positive ahead
Earned Value Analysis

- **Progress Indicators**
  - **Cost Performance Index (CPI)**
    - $\text{CPI} = \frac{\text{BCWP}}{\text{ACWP}}$
    - 100% = perfect cost
  - **Cost Variance (CV)**
    - $\text{CV} = \text{BCWP} - \text{ACWP}$
    - Negative is behind on cost, positive ahead on cost

### Earned Value Analysis Example

<table>
<thead>
<tr>
<th>Task</th>
<th>Estimated Effort (days)</th>
<th>Actual Effort To Date</th>
<th>Estimated Completion</th>
<th>Actual Completion</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5</td>
<td>10</td>
<td>1/25</td>
<td>2/1</td>
</tr>
<tr>
<td>2</td>
<td>25</td>
<td>20</td>
<td>2/15</td>
<td>2/15</td>
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<tr>
<td>3</td>
<td>120</td>
<td>80</td>
<td>5/15</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>40</td>
<td>50</td>
<td>4/15</td>
<td>4/1</td>
</tr>
<tr>
<td>5</td>
<td>60</td>
<td>50</td>
<td>7/1</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>80</td>
<td>70</td>
<td>9/1</td>
<td></td>
</tr>
</tbody>
</table>

Today is 4/1

- **BAC** = sum of estimations = $5 + 25 + 120 + \ldots = 330$ days
- **BCWP** = estimate of completed work = $5 + 25 + 40 = 70$ days
- **EV or PC** = $\frac{70}{330} = 21.2\%$
- **BCWS** = sum of estimates scheduled to be done = $5+25 = 30$
- **SPI** = $\frac{\text{BCWP}}{\text{BCWS}} = \frac{70}{30} = 233\%$
- **SV** = 70 – 30 = 40 days (ahead)
- **ACWP** = sum of actual work done = 10+20+50 = 80
- **CPI** = $\frac{\text{BCWP}}{\text{ACWP}} = \frac{70}{80} = 87.5\%$
- **CV** = $\text{BCWP} - \text{ACWP} = 70-80 = -10$ programmer days (behind)
Track Status Over Time

- Comparison of planned costs against actual costs allows the manager to assess the health of the project

Other Measurement Tools

- Error Tracking
  - We generally expect error rates to go down over time
- Postmortem Reviews
  - Assemble key people to discuss quality, schedule, software process. Results should not be sanitized.
Project Management Concepts

• Follow critical / best practices
• Divide and conquer approach generally taken to decompose work into smaller, more manageable pieces
• Key Tasks
  – Hierarchical representation of all the tasks in a project called the Work Breakdown Structure (WBS)
  – Task model or Network model
  – Mapping of the task model to the project schedule
  – Development of a Software Project Management Plan (SPMP)

Work Packages

• Work packages are assignment to participants to do the work
  – Small work package: an action item
  – Larger work packages:
    • Create the object model
    • Class diagram
    • Etc.
  – Any work product delivered to the customer is a deliverable; All other work products are internal work products
Work Breakdown Structure

• Simple hierarchical model of the work to be performed; uses aggregation only

Creating Work Breakdown Structures

• Two major philosophies
  – Activity-oriented decomposition ("Functional decomposition")
    • Write the book
    • Get it reviewed
    • Do the suggested changes
    • Get it published
  – Result-oriented ("Object-oriented decomposition")
    • Chapter 1
    • Chapter 2
    • Chapter 3

• Which one is best for managing? Depends on project type:
  – Development of a prototype
  – Development of a product
  – Project team consist of many unexperienced beginners
  – Project team has many experienced developers
Estimates for establishing WBS

• Establishing a WBS in terms of percentage of total effort:
  – Small project (7 person-month): at least 7% or 0.5 PM
  – Medium project (300 person-month): at least 1% or 3 PMs
  – Large project (7000 person-month): at least 0.2 % or 15 PMs
  – (From Barry Boehm, Software Economics)

Example: Let‘s Build a House

• What are the activities that are needed to build a house?
Typical activities when building a house

- Surveying
- Excavation
- Request Permits
- Buy Material
- Lay foundation
- Build Outside Wall
- Install Exterior Plumbing
- Install Exterior Electrical
- Install Interior Plumbing
- Install Interior Electrical
- Install Wallboard
- Paint Interior
- Install Interior Doors
- Install Floor
- Install Roof
- Install Exterior Doors
- Paint Exterior
- Install Exterior Siding
- Buy Pizza

Finding these activities is a brainstorming activity. It requires similar activities used during requirements analysis.

Hierarchical organization of the activities

- Building the house consists of
  - Prepare the building site
  - Building the Exterior
  - Building the Interior

- Preparing the building site consists of
  - Surveying
  - Excavation
  - Buying of material
  - Laying of the foundation
  - Requesting permits
Partial Work Breakdown Structure

Build House:WBS
  ➔ Build Structure
  ➔ Install Plumbing
  ➔ Install Heating
  ➔ Install Electric

  ➔ Build Foundation
  ➔ Build Walls
  ➔ Build Roof
  ➔ Install Sewer Pipes
  ➔ Install Cold & Hot Water Pipes
  ➔ Install Tubs & Sinks

From the WBS to the Dependency Graph

- The work breakdown structure does not show any temporal dependence among the activities/tasks
  - Can we excavate before getting the permit?
  - How much time does the whole project need if I know the individual times?
    - What can be done in parallel?
  - Are there any critical activities, that can slow down the project significantly?

- Temporal dependencies are shown in the dependency graph
  - Nodes are activities
  - Lines represent temporal dependencies
Building a House (Dependency Graph)

The activity "Buy Material" must Precede the activity "Lay foundation"

Map tasks onto time

- Estimate starting times and durations for each of the activities in the dependency graph
- Compute the longest path through the graph: This is the estimated duration of your project
PERT

- PERT = Program Evaluation and Review Technique
- Developed in the 50s to plan the Polaris weapon system in the USA.
- PERT allows the manager to assign optimistic, pessimistic and most likely estimates for the span times of each activity.
- You can then compute the probability to determine the likelihood that overall project duration will fall within specified limits.

PERT Diagram Notation

A Node is either an event or an activity.
Distinction: Events have span time 0

Event (Milestone or Deliverable)

Activity

Event (Milestone or Deliverable)

Milestone boxes are often highlighted by double-lines
What do we do with these diagrams?

- Compute the project duration
- Determine activities that are critical to ensure a timely delivery

- Analyze the diagrams
  - to find ways to shorten the project duration
  - To find ways to do activities in parallel

- 2 techniques are used
  - Forward pass (determine critical paths)
  - Backward pass (determine slack time)
Definitions: Critical Path and Slack Time

• Critical path:
  – A sequence of activities that take the longest time to complete
  – The length of the critical path(s) defines how long your project will take to complete.

• Noncritical path:
  – A sequence of activities that you can delay and still finish the project in the shortest time possible.

• Slack time:
  – The maximum amount of time that you can delay an activity and still finish your project in the shortest time possible.

Example of a critical path

Critical path in bold face
Definitions: Start and Finish Dates

• Earliest start date:
  – The earliest date you can start an activity

• Earliest finish date:
  – The earliest date you can finish an activity

• Latest start date:
  – The latest date you can start an activity and still finish the project in the shortest time.

• Latest finish date:
  – The latest date you can finish an activity and still finish the project in the shortest time.

2 Ways to Analyze Dependency Diagrams

• Forward pass: Goal is the determination of critical paths
  – Compute earliest start and finish dates for each activity
  – Start at the beginning of the project and determine how fast you can complete the activities along each path until you reach the final project milestone.

• Backward pass: Goal the determination of slack times
  – Compute latest start and finish dates activity
  – Start at the end of your project, figure out for each activity how late it can be started so that you still finish the project at the earliest possible date.

• To compute start and finish times, we apply 2 rules
  – Rule 1: After a node is finished, we can proceed to the next node(s) that is reachable via a transition from the current node.
  – Rule 2: To start a node all nodes must be complete from which transitions to that node are possible.
Forward Path Example

Project Duration = 7

<table>
<thead>
<tr>
<th>Activity</th>
<th>Earliest Start(ES)</th>
<th>Earliest Finish(EF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>Start of week 1</td>
<td>End of week 5</td>
</tr>
<tr>
<td>A2</td>
<td>Start of week 6</td>
<td>End of week 6</td>
</tr>
<tr>
<td>A3</td>
<td>Start of week 1</td>
<td>End of week 1</td>
</tr>
<tr>
<td>A4</td>
<td>Start of week 2</td>
<td>End of week 4</td>
</tr>
<tr>
<td>A5</td>
<td>Start of week 6</td>
<td>End of week 7</td>
</tr>
</tbody>
</table>

Backward Path Example

Project Duration = 7

<table>
<thead>
<tr>
<th>Activity</th>
<th>Latest Start(LS)</th>
<th>Latest Finish(LF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>Start of week 1</td>
<td>End of week 5</td>
</tr>
<tr>
<td>A2</td>
<td>Start of week 7</td>
<td>End of week 7</td>
</tr>
<tr>
<td>A3</td>
<td>Start of week 2</td>
<td>End of week 2</td>
</tr>
<tr>
<td>A4</td>
<td>Start of week 3</td>
<td>End of week 5</td>
</tr>
<tr>
<td>A5</td>
<td>Start of week 6</td>
<td>End of week 7</td>
</tr>
</tbody>
</table>
Computation of slack times

- Slack time \( ST_A \) of an activity \( A \):
  - \( ST_A = LS_A - ES_A \)
  - Subtract the earliest start date from the latest start date for each activity

Example: \( ST_{A4} = 3 - 2 = 1 \)

Slack times on the same path influence each other.
Example: When Activity 3 is delayed by one week, activity 4 slack time becomes zero weeks.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Slack time</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>0</td>
</tr>
<tr>
<td>A2</td>
<td>1</td>
</tr>
<tr>
<td>A3</td>
<td>1</td>
</tr>
<tr>
<td>A4</td>
<td>1</td>
</tr>
<tr>
<td>A5</td>
<td>0</td>
</tr>
</tbody>
</table>

Building a House (PERT Chart)

Each Activity has a start time and an estimated duration

- Determination of total project time
- Determination of the critical path
- Determination of slack times
Gantt Chart

Time (in weeks after start)

Activity 1
Activity 2
Activity 3
Activity 4
Activity 5

Easy to read

Gantt Chart with Milestones

Project Start
Activity 1
Activity 2
Activity 3
Design Review
Activity 4
Activity 5
Project Finish

Time (in weeks after start)

Good for reviews.
Two Types of Gantt Charts

- **Person-Centered View**
  - To determine people’s load

- **Activity-Centered View**
  - To identify teams working together on the same tasks

Choose one view, stay with it. Usually base the view on the WBS structure.

Managing Experienced Teams: Person-centered view
Managing Beginners: Activity oriented view

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Heuristics for WBS

- The project manager may find the following heuristics useful to create the work breakdown structure
  - Reuse an existing WBS
    - Consult people who have worked on similar projects
  - Involve key developers
    - Developers with knowledge in the solution domain should participate in the development
    - If they join after the WBS is developed they should be able to review and critique it
  - Identify work gaps.
    - All work to be performed must be mapped onto tasks
    - Work associated with an activity must be addressed by at least one task
  - Identify work overlaps
    - The same task should not be included in more than one activity
Creating the Initial Schedule

• Impossible to generate a precise schedule for the entire project at the beginning of the project
• One solution: initial schedule with deadlines mutually agreed by the client and project manager
• Detailed for the first few weeks of the project
  – Kick-off meetings
  – Initial team meetings
  – Tutorials
  – Individual teams could start working on a revision of the initial schedule after the initial team meetings

Organizing the Project

• The project manager needs to address the communication infrastructure
  – Scheduled modes of communication
    • Planned milestones, review, team meetings, inspections, etc.
    • Best supported by face-to-face communications
  – Event-based modes of communication
    • Problem reports, change requests, etc.
    • Usually arise from unforeseen problems or issues
    • E-mail, groupware, web databases the best mechanisms
Identifying Skills

• Skills for a software development project
  – Application domain skills
  – Communication skills
  – Technical skills
  – Quality skills
  – Management skills
• Assign management, technical roles
• 3-5 team members the best size for a group

Kick-off Meeting

• Project manager, team leaders, and the client officially start the project in a kick-off meeting with all developers present
• Purpose: Share information about the scope of the project, communication infrastructure, and responsibilities of each team
• Presentation split between client and project manager
  – Client: Requirements and scope of the project
  – Project manager: Project infrastructure, top-level design, and team responsibilities
Project Agreement

- Document that formally defines the scope, duration, cost, and deliverables
  - Contract or statement of work, business plan, or charter
  - Typically finalized after the analysis model is stabilized
- Should contain
  - List of deliverables
  - Criteria for demonstrations of functional requirements
  - Criteria for demonstration of nonfunctional requirements
  - Criteria for acceptance
- Represents the baseline of the client acceptance test
- Changes in the functionality, deadlines, or budget requires renegotiation of the project agreement

Controlling the Project

- The project manager must collect information to make effective decisions in the steady state phase of the project
- Tools to collect information
  - Meetings
    - Periodic status meetings, milestones, project reviews, code inspections, prototype demonstrations
  - Metrics
    - Lines of code, branching points, modularity
    - Defects, mean time between failures
Software Cost Estimation

• How many resources to complete the project?
  – For big projects, expressed in Programmer Months
  – Older approach: LOC estimation
  – Newer approach: Counting Function Points

LOC Estimation

• Estimate number of lines of code in the finished project
  – Use prior experience, similar products, etc.

• Standard approach:
  – For each piece i, estimate the max size, min size, and best guess. The estimate for the each piece is $1/6*(\text{max} + 4*\text{guess} + \text{min})$

<table>
<thead>
<tr>
<th>Part</th>
<th>Min</th>
<th>Guess</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>20</td>
<td>30</td>
<td>50</td>
</tr>
<tr>
<td>2</td>
<td>10</td>
<td>15</td>
<td>25</td>
</tr>
<tr>
<td>3</td>
<td>25</td>
<td>30</td>
<td>45</td>
</tr>
</tbody>
</table>

Whole = \frac{(20+4*30+50)/6 + (10+4*15+25)/6 + (25+4*30+45)/6}{6}
= 79 LOC
COCOMO

- COCOMO = Constructive Cost Model, developed by Boehm in the 70's
  - Used thousands of delivered lines of code to determine a relationship between size and cost in Programmer Months (PM)
  - App Programs: PM = $2.4 \times (\text{KLOC})^{1.05}$
  - Utility Programs: PM = $3.0 \times (\text{KLOC})^{1.12}$
  - Systems Programs: PM = $3.6 \times (\text{KLOC})^{1.20}$

General LOC Estimation

In general: $\text{Cost} = A \times \text{KLOC}^B + C$ where $A, B, C$ are constants

Can determine these values regressively if you measure your own efforts:

<table>
<thead>
<tr>
<th>Project</th>
<th>KLOC</th>
<th>Effort (PM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>50</td>
<td>120</td>
</tr>
<tr>
<td>2</td>
<td>80</td>
<td>192</td>
</tr>
<tr>
<td>3</td>
<td>40</td>
<td>96</td>
</tr>
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<td>4</td>
<td>10</td>
<td>24</td>
</tr>
<tr>
<td>5</td>
<td>20</td>
<td>48</td>
</tr>
</tbody>
</table>
Function Point Analysis

• Identify and quantify the functionality required for the project. Some possibilities, but no standards for what is considered a function point:
  – Inputs
    • Logical input, not individual fields
  – Outputs
    • Displays of application data
  – Inquiries
    • Request/response pairs
  – Internal files
    • Number of logical files
  – External interfaces
    • Data shared with other programs

Function Point Analysis

• Individual function points classified as simple, average, or complex, and weights are summed

<table>
<thead>
<tr>
<th></th>
<th>Simple</th>
<th>Average</th>
<th>Complex</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outputs</td>
<td>4</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>Inquiries</td>
<td>3</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>Inputs</td>
<td>3</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>Files</td>
<td>7</td>
<td>10</td>
<td>15</td>
</tr>
<tr>
<td>Interfaces</td>
<td>5</td>
<td>7</td>
<td>10</td>
</tr>
</tbody>
</table>

• Correlate total with PM; can capture effort for hidden items (e.g. one output, lots of internal work)
Conclusion

• Software Project Managers have a lot of challenging work that shouldn’t be ignored
  – Unlike the Pointy Haired Boss
  – Must deal with project outcomes, schedules, work products, work breakdown schedule, and resources
  – Development of a Software Project Management Plan
  – Much of this built into the Agile Development process in a simple way

• Project managers can deal with project complexity the same way developers deal with system complexity
  – Modeling of the domain
  – Communication
  – Analysis
  – Planning