Object-Oriented Software Engineering
Using UML, Patterns, and Java

Work Breakdown Structures

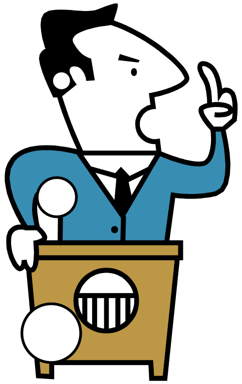
Outline of today's class

- Determining Work and Tasks Sizes
- Work Breakdown Structure (WBS)
- Different Approaches for developing WBSs
- Notations for Work Breakdown Structures
- Heuristics and examples for WBS
  - Starting with templates
  - How to identify work
  - What do you do with risky tasks?
- Using WBS in large projects
  - How detailed should a WBS be?
  - How can you plan the tasks of a long project when things are unknown or changing all the time?

What is the problem?

- Your boss: "How long will this take?"

You: "Between 1 and 6 months."



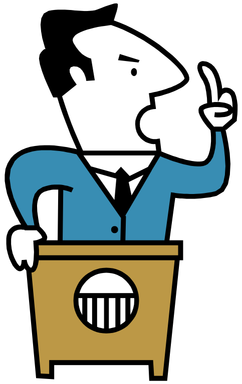
"As long as I can do it within 6 months, I keep my promise."

"With hard work, he can do it in 1 month."

What is the problem?

- Your boss: “How long will this take?”

You: “Between 1 and 6 months.”



“I have not the slightest clue, if it is possible at all.”

“Even if it is possible, I don’t know, how long it will take.”

Solution: Use divide and conquer

To give a good answer you have to break the work down into activities for which you try to get timing estimates

Only if you can get good estimates can you compute the estimated project duration

Let‘s Build a House

What are the activities that are needed to build a house?

First Step: Identify the work to be done

- 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

Initially finding these tasks is a brainstorming activity.

Similar to activities used during requirements engineering and analysis

Second Step: Hierarchically organize the tasks

- 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

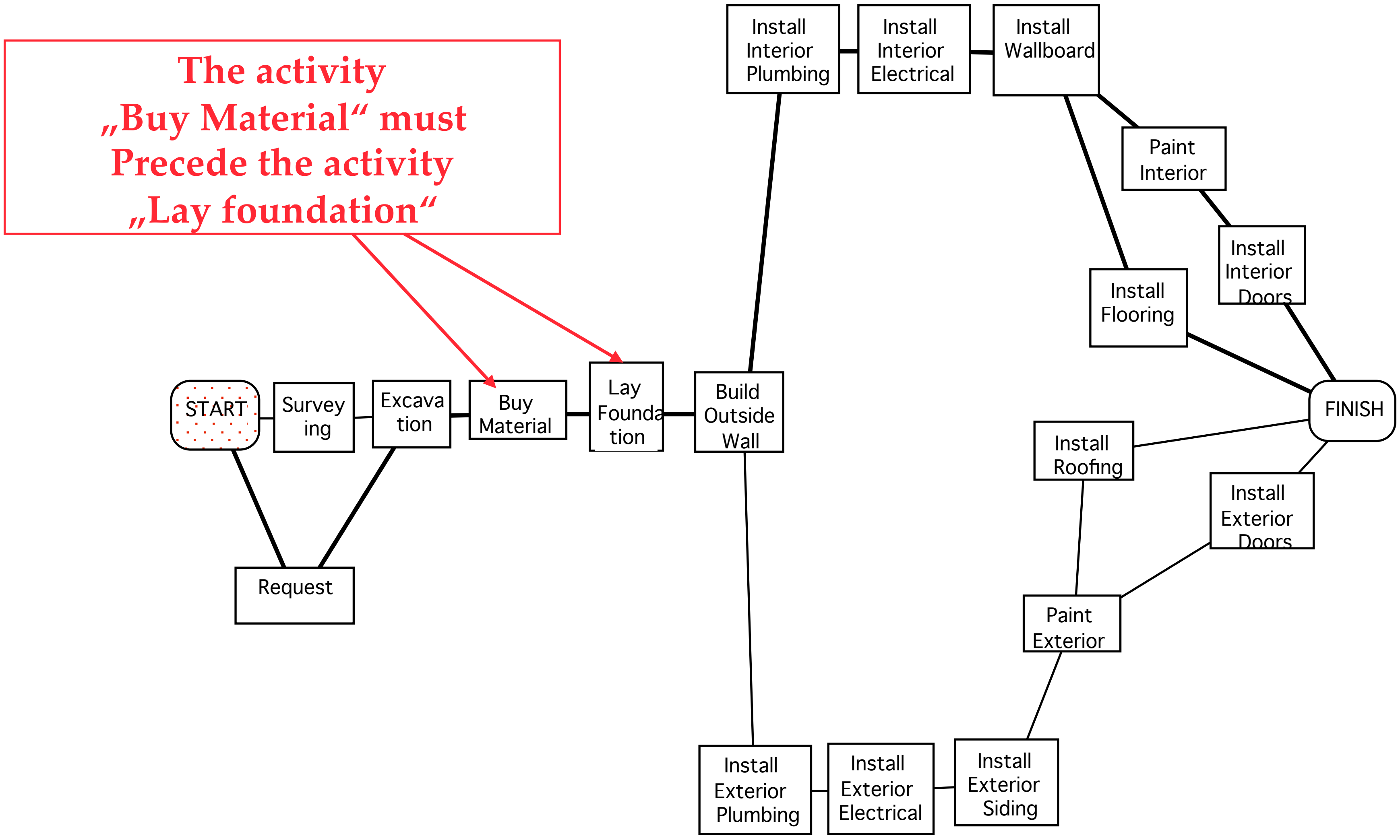
Finding this organization involves categorization and refinement.

Good after brainstorming, not during brainstorming

Third Step: Identify dependencies between tasks

- **The work breakdown structure does not show any 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 actitivites, that can slow down the project significantly?**
- **Dependencies like these are shown in the dependency graph**
  - Nodes are activities
  - Lines represent temporal dependencies

Building a House (Dependency Graph)



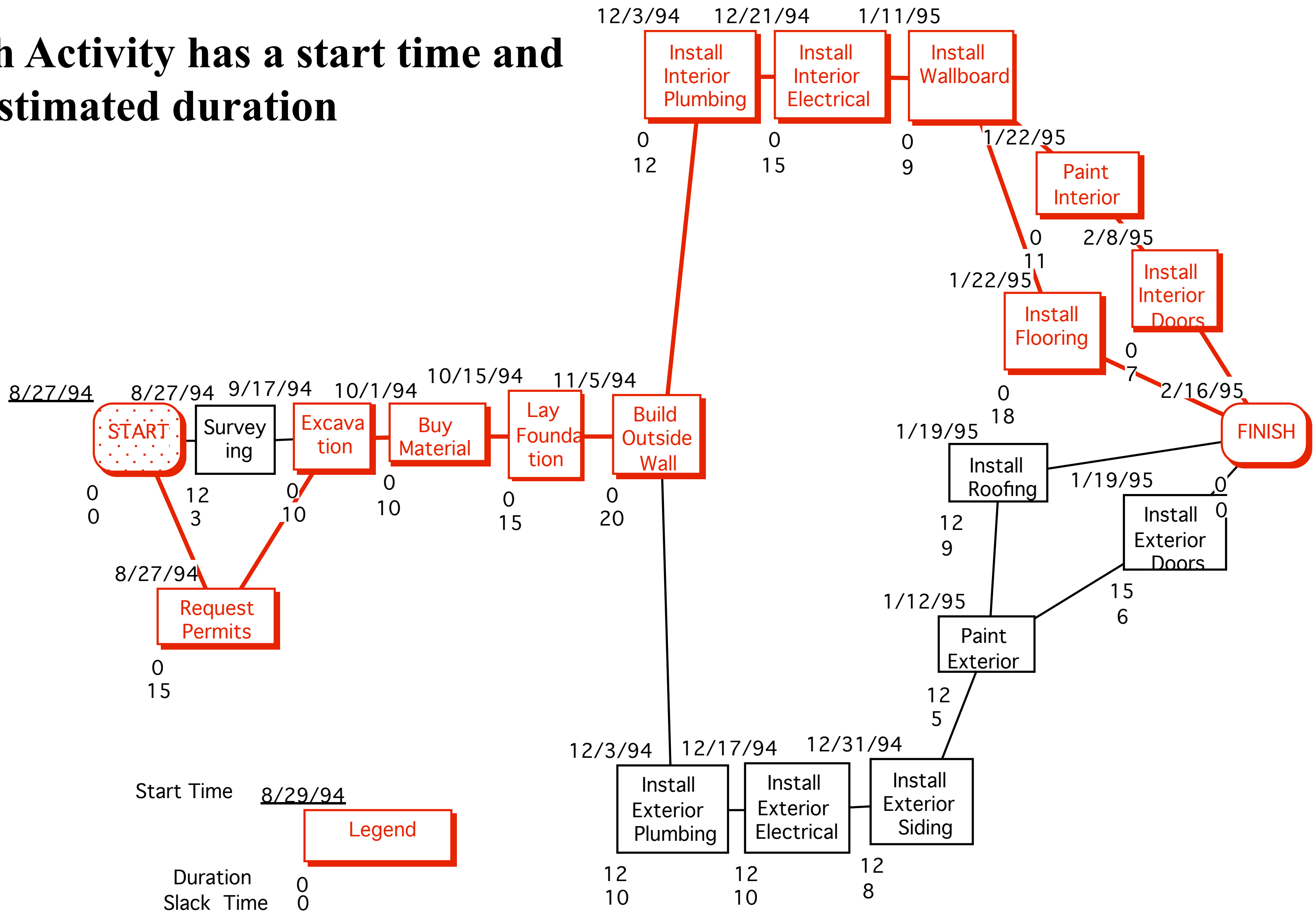
The activity „Buy Material“ must Precede the activity „Lay foundation“

Fourth step: 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**

Building a House (Schedule, PERT Chart)

Each Activity has a start time and an estimated duration



8/27/94 START 0 0

8/27/94 Surveying 12 3

8/27/94 Request Permits 0 15

9/17/94 Excavation 0 10

10/1/94 Buy Material 0 10

10/15/94 Lay Foundation 0 15

11/5/94 Build Outside Wall 0 20

12/3/94 Install Interior Plumbing 0 12

12/21/94 Install Interior Electrical 0 15

1/11/95 Install Wallboard 0 9

1/22/95 Paint Interior 0 11

2/8/95 Install Interior Doors 0 7

1/22/95 Install Flooring 0 18

12/3/94 Install Exterior Plumbing 12 10

12/17/94 Install Exterior Electrical 12 10

12/31/94 Install Exterior Siding 12 8

1/12/95 Paint Exterior 12 5

1/19/95 Install Roofing 12 9

1/19/95 Install Exterior Doors 15 6

2/16/95 FINISH 0 0

Start Time 8/29/94

Legend

Duration 0

Slack Time 0

How do we get good estimate times?

- **Estimation of starting times and durations is crucial for setting up a plan.**
- **In the lecture on Scheduling we will discuss methods and heuristics on how to do it and how to establish a software project schedule.**

Recall Definitions from Lecture 1

- Project:
  - A Project has a duration and consists of functions, activities and tasks
- Work Package:
  - A description of the work to be accomplished in an activity or task
- Work Product:
  - Any tangible item that results from a project function, activity or task.
- Project Baseline:
  - A work product that has been formally reviewed and agreed upon.
  - A project baselines can only be changed through a formal change procedure
- Project Deliverable:
  - A work product to be delivered to the customer

Activities, Tasks and Functions

- Activity: A a major unit of work with precise dates that consists of smaller activities or tasks. It culminates in a project milestone.
- Task: Smallest unit of work subject to management. Small enough for adequate planning and tracking. Large enough to avoid micro management
- Project Function: An activity or set of activities that span the duration of the project

Tasks

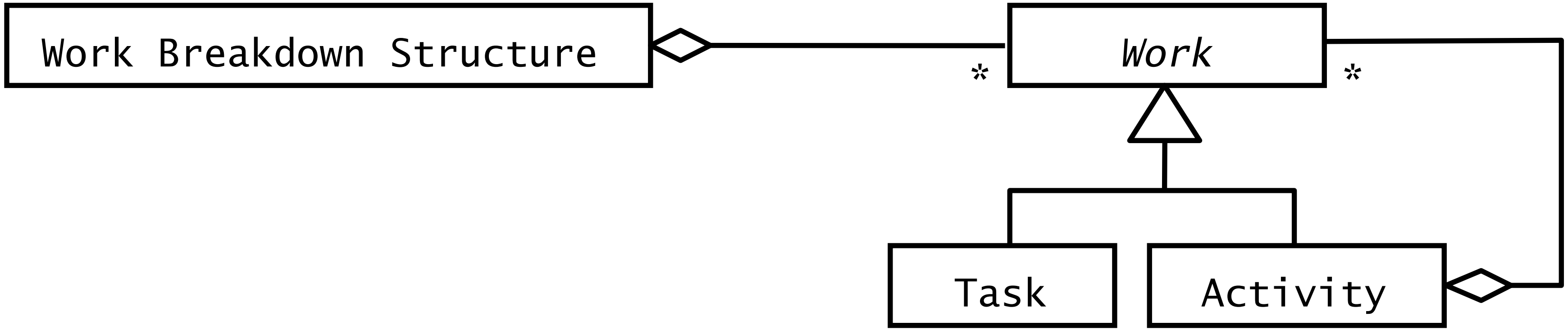
- Smallest unit of management accountability
  - Atomic unit of planning and tracking
  - Tasks have finite duration, need resources, produce tangible result (documents, code)
- The description of a task is done in a work package
  - Name, description of work to be done
  - Preconditions for starting, duration, required resources
    - Other work packages that need to be completed before this task can be started.
  - Work products to be produced, acceptance criteria for it
  - Risk involved
- Completion criteria
  - Includes the acceptance criteria for the work products (deliverables) produced by the task.

Determining Task Sizes

- Finding the appropriate task size is problematic
  - Todo lists and templates from previous projects
  - During initial planning a task is necessarily large
  - You may not know how to decompose the problem into tasks at first
  - Each software development activitity identifies more tasks and modifies existing ones

- Tasks must be decomposed into sizes that allow monitoring
  - Depends on nature of work and how well task is understood.
  - Work package usually corresponds to well defined work assignment for one worker for a week or two.
  - Work assignments are also called action items

Work Breakdown Structure



Work Breakdown Structure: The aggregation of all the work to be performed in a project. Often called WBS

Approaches to Develop Work Breakdown Structures

Product component approach

Structure the work based on the work products

Examples: Design documents, manuals, the delivered system,…

Functional approach

Structure the work based on development activities and project functions

Examples: Analysis, design, implementation, integration,…

Geographical area approach

Structure the work based on geographical location

Examples: Munich team, Pittsburgh team, off-shore team,…

Organizational approach

Structure the work based on the organizational structure

Example: R&D department, predevelopment, product development, marketing, sales,…

When to use what Approach

- The teams are distributed over the continent:
  - Geographical area approach
- The teams consist of experienced developers:
  - Product component approach
- The project has mostly beginners or an unexperienced project manager:
  - Functional approach
- The project is a continuation of a previously successful project, there are no changes in the requirements and no new technology enablers
  - Organizational approach

Whatever approach you choose, stick with it to prevent possible overlap in categories

Mixing different Approaches is bad

- Consider the WBS for an activity „Prepare report"
- Functional approach:
  - Write draft report
  - Have draft report reviewed
  - Write final report
- Product component approach:
  - Chapter 1
  - Chapter 2
  - Chapter 3
- Mixed approach:
  - Chapter 1
  - Chapter 2
  - Chapter 3
  - Have draft report reviewed
  - Write final report

Why is this bad?

How do you develop a good WBS?

- **Top down approach**:
  - Start at the highest, top level activities and systematically develop increasing levels of detail for all activities.
- **Bottom up approach ("Brainstorming"):**
  - Generate all activities you can think of that will have to be done and then group them into categories.
- Which one you use depends on
  - how familiar you and your team are with the project,
  - whether similar projects have successfully been performed in the past, and
  - how many new methods and technologies will be used.

The Top Down WBS Development

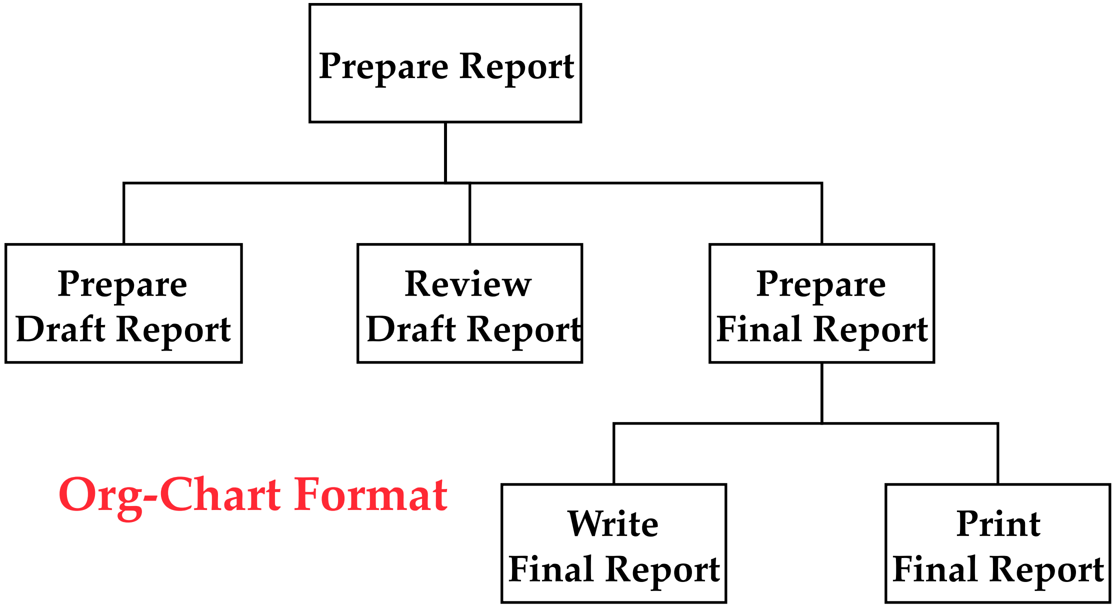
- Specify all activities required for the entire project to be finished
- Determine all tasks required to complete each activity
- If necessary, specify sub-activities required to complete each task
- Continue in this way until you have adequately detailed your project.
- **Approach is good if**
  - You are familiar with the problem (or your team)
  - You have successfully managed a similar project in the past
  - You are not introducing new methodologies, methods or tools

The Brainstorming WBS Development

- On a single list, write any activities you think will have to be performed for your project.
- Brainstorming means you
  - Don’t worry about overlap or level of detail
  - Don’t discuss activity wordings or other details
  - Don’t make any judgements
  - Write everything down
- Then study the list and group activities into a few major categories with common characteristics
- If appropriate, group identified activities into higher level activities
- Consider each category you have created and use the ***top-down WBS development*** to determine any additional activities you may have overlooked.

Displaying Work Breakdown Structures

- Three different formats are usually used
- Organization-chart format
  - Effectively portrays an overview of your project and the hierarchical relationships of different activities and tasks.
- Outline format
  - Subactivities and tasks are indented
- Bubble format
  - The bubble in the center represents your project
  - Lines from the center bubble lead to activities
  - Lines from activities lead to tasks



Org-Chart Format

Prepare Report

1.0 Prepare draft report

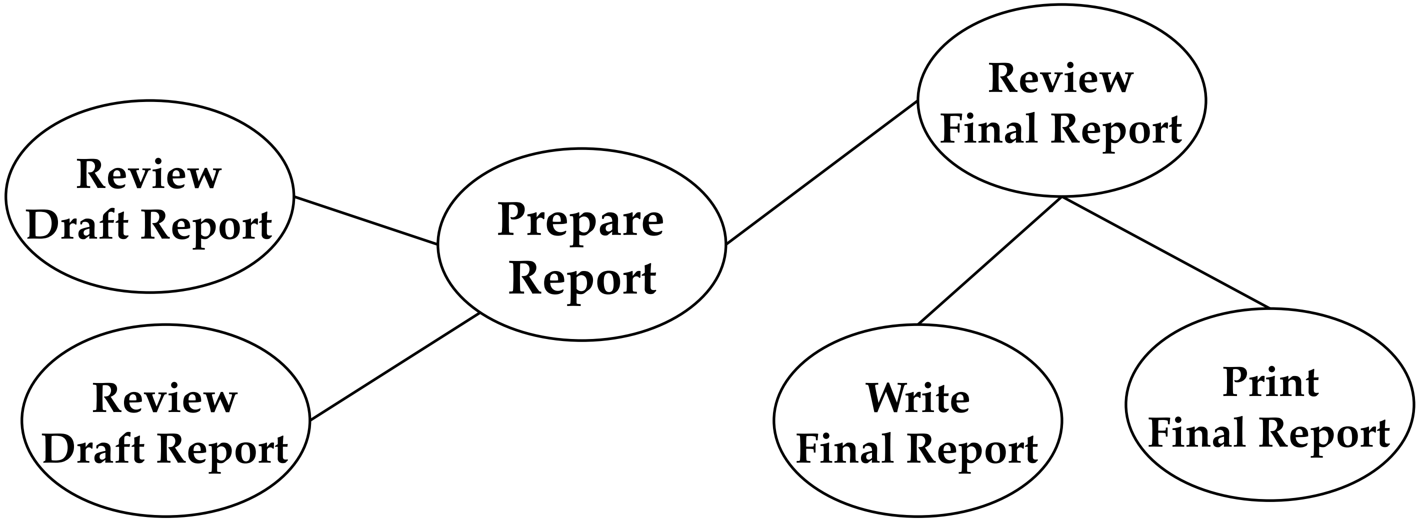
2.0 Review draft report

3.0 Prepare final report

 3.1 Write final report

 3.2 Print final report

Outline Format



Bubble Format

What is the best display format for WBS?

- Organization-chart format:
  - Often good for a “bird view” of the project (executive summaries,...)
  - Less effective for displaying large numbers of activities
- Outline format:
  - Easier to read and understand if WBS contains many activities
- Bubble format:
  - Effective for supporting brainstorming
  - Not so good for displaying work breakdown structures to audiences who are not familiar with the project.
- In large projects:
  - Use bubble format to develop the WBS, then turn it into Organization-chart or Outline format.
  - Display activities in Organization-chart format,
  - Display subactivities and tasks in Outline format

Heuristics for developing high quality WBS

- Involve the people who will be doing the work in the development of the WBS
    - In particular involve the developers
- Review and include information from work breakdown structures that were developed for similar projects
    - Use a project template if possible

Use more than one WBS approach

Do project component and functional approach simultaneously

This allows you often to identify overlooked activities

Make assumptions regarding uncertain activities

Identify risky activities

These are often the activities whose times are hard to estimate

Choose a single WBS Approach

- Develop the WBS with different approaches. This is good, because it allows you to identify activities that you may overlook otherwise

- Choose a *single* WBS approach to be used in the SPMP and for your project:
  - Nothing confuses people fast than trying to use two different work breakdown structures to describe the same project.

How Detailed should the WBS be?

- Sometimes the activities are not clear at all, especially in software projects, because of:
  - Unclear requirements and/or changing requirements
  - Dependency on technology enablers that are promised to appear after project kickoff
  - Simultaneous development of hardware and software ("concurrent engineering")
- Heuristic: A project plan, especially for an innovative software project, should not address details beyond 3 months.
  - Even for the first 3 months project activities might not all be detailable, for example when the requirements are unclear or change or introduction of technology enablers is expected.
- How should we describe a WBS for a longer project?

Doing a WBS for Long-Term Projects

- When developing a work breakdown structure for a long-term project (longer than 3 months), introduce at least two phases
- *Phase 1* (3 months): Plan your WBS in detail
  - List all activities that take two weeks or less to complete
- ***Phase 2, Phase 3, …*** *(n-months)* Plan the WBS for these phases in less and less detail
  - List activities that will take between one and two months
- At the end of phase 1, revise the phase 2 activities and plan them on the two week level for the next 3 months.
  - Modify any future activities as necessary based on the results of your first three months work.
- Continue to revise the SPMP this way throughout the project. (The SPMP is an “evolving” document)

Phases and large Projects

- Project-Initiation Phase
- Steady State Phase
  - Initial Planning phase
- Project-Termination Phase

Project-Initiation Phase: To-Do List

- Activities
  - Meet with client, develop visionary scenario for problem statement
  - Develop initial top level design: System as a set of subsystems
  - Establish staffing plan (flat staffing, ramping up)
  - Identify human resources: existing employees, new employees
  - Hire team members
  - Assign a subsystem to each team. Establish additional cross-functional teams (e.g. architecture, documentation, demo)
  - Write problem statement (with client and other stake holders; if possible, involve project participants early)
  - Write initial SPMP with WBS, without schedule, without budget

Get project plan approved
Kick project off with 2 documents: Problem statement and SPMP
Duration of project-initiation-phase: Between 2-4 weeks
When? Before project kickoff

Initial Planning Phase: To-Do List

- Activities
  - Do scouting on technology enablers that might influence the design or nonfunctional requirements
  - Revise requirements and initial top level design if necessary
  - Revise team structure, reassign team members if necessary
  - Revise WBS and dependencies
  - Establish cost and scheduling information
  - Agree with client on requirements, duration and cost of the project
  - Write the "project agreement" (companion document to the SPMP)
- Duration: About 2 weeks time.
- When: After project kickoff, often called "planning phase", Parallel to "requirements elicitation phase"

Project-Termination Phase

- Do a project-review: “What went right, what went wrong”
  - also often called “project post-mortem review”
- Based on input from the post-mortem session
  - Revise your software process, identify in particular any new activities that happened in the project
  - Revise your project kickoff activities
  - Revise the SPMP template (to be reused for your next project)

Summary

- Different approaches to develop a WBS
  - Product Approach
  - Functional Approach
  - Geographical Approach
  - Organizational Approach
- Top down and bottom up WBS development
- Heuristics for developing good WBS
- WBS for Large Projects

Heuristic: Use Templates

- Try to derive the SPMP from a template
  - A template reflects the cumulative experience gained from doing numerous projects of a particular type.
  - Using templates can save you time and improve your accuracy
- When developing templates, develop them for frequently performed tasks (reviews, meetings, …).
- Develop "Checklists":
  - Develop and modify your WBS templates from previous projects that worked, not from plans that looked good.
  - Use templates as starting points, not as ending points
  - Continually update your templates to reflect the experience gained from performing different projects.

Heuristic: Develop always more than one WBS

- Consider to create more several different hierarchies with different categories for your work breakdown structure.
  - Having two or more different perspectivies helps you identify activities you may overlook.
- Good starting point are the following hierarchies:
  - Entity-oriented decomposition
  - Activity-oriented decomposition
- Example: You are running your first object-oriented project.
  - Develop a WBS based on the project documents
  - Develop a WBS based on the software process activities

Heuristic: Identifying Risky activities

- When you identify activities for a work breakdown structure, you can also identify the risks in your project.
- Risks are usually associated with "unknown information".
- Unknown information comes in two flavors
  - A "known unknown": **Information that you don't have but someone else does.**
    - **Find out who has the information and determine what the information is. (Interviews, Phone calls, tasks analysis)**
  - An "unknown unknown": **Information that you don't have because it does not yet exist.**
    - **Develop** contingency plans **for each of these risks.**
    - **These contingency plans need be followed when you find out the information does not exist.**
- Describe these risks in SPMP 5.4 Risk Management

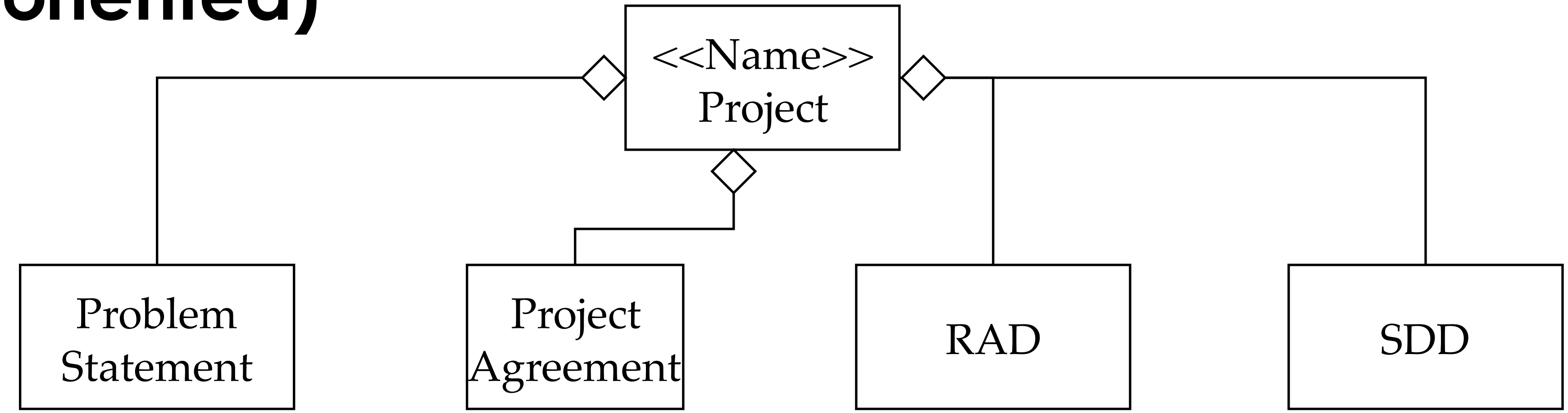
Risk Management Examples

- Risk: Members in key roles leave the project.
  - *Contingency Plan?*
  - Roles are assigned to somebody else. Functionality of the system is renegotiated with the client.
- Risk: The project is falling behind schedule.
  - *Contingency Plan?*
  - Extra project meetings are scheduled.
- Risk: Team 1 cannot provide functions needed by team 2.
  - *Contingency Plan?*
  - A: We drop the functionality.
  - B: The liaisons of both teams get together to solve this problem
- Risk: The planned PDA will not be available.
  - *Contingency Plan?*
  - We will use an IPAQ instead.

Risk Management Examples ctd

- Risk: The selection of the database system takes too much time
  - *Contingency Plan?*
  - The Database team uses a bridge pattern and provides a test stub to be used by the other teams for data access while the selection process goes on.
- Risk: The customer is not available for discussing and reviewing the user interface during development.
  - *Contingency Plan*?
  - Make the design decisions that we feel are appropriate
- Risk: No suitable wireless library can be found.
  - *Contingency Plan?*
  - The wireless team develops its own library

WBS Based on Project Documents (Entity-oriented)



- Write Introduction
- Write Requirements
- Write Constraints
- ...

- Write Requirements
- Write Constraints
- Write Acceptance Criteria
- Promise delivery date

- Write Introduction
- Describe Functional Model
- Describe Object Model
- Describe Dynamic Model

...

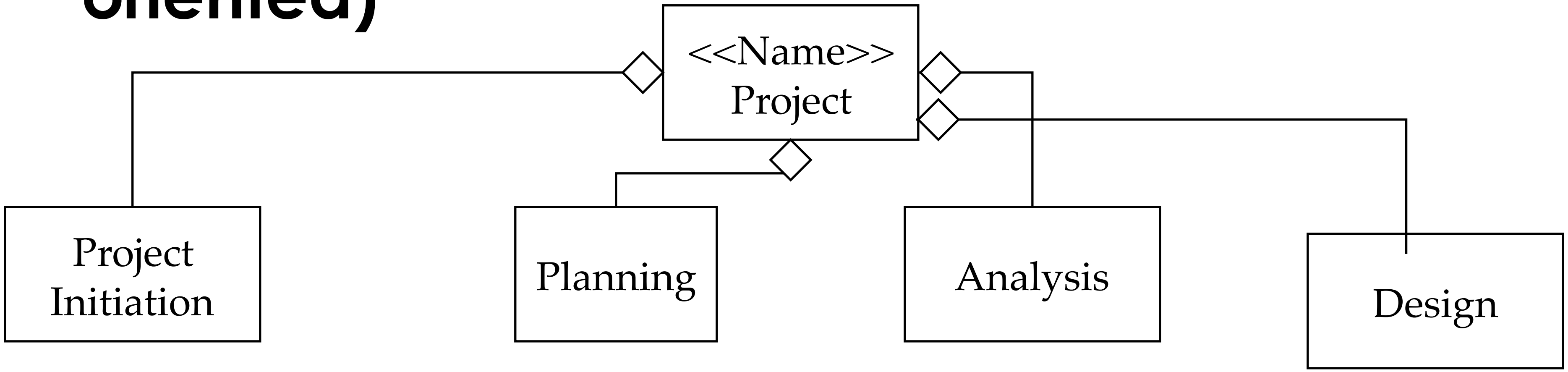
- Write Design Goals
- Write Hardware Software mapping

-Write boundary conditions

- Write Data Management
- Write Open Issues

...

WBS Based on Software Process (Activity-oriented)



- Establish guidelines
- Formulate requirements with client
- Establish scenarios
- Write project agreement

- Determine WBS
- Determine dependencies between tasks
- Write SPMP
- Assign teams to subsystems
- Establish project calendar

- Brainstorm on application domain objects
- Develop class diagram
- Partition objects into boundary, entity and control objects
- Develop use cases

- Develop Models
- Write code
- Present problems to coach
- Giove status reports
- Write RAD
- Write SDD
- Write ODD

Question: Which activities mentioned in the WBS based on Project documents is left out in the WBS based on Software Process?

Estimates for establishing WBS

- Establishing an WBS in terms of percentage of total effort:
  - Small project (7 person-month): **at least 7% or 0.5 Person Months (PM)**
  - Medium project (300 person-month): **at least 1% or 3 PMs**
  - Large project (7000 person-month): **at least 0.2 % or 15 PMs**

Source: Barry Boehm, Software Economics (rather dated now)