Software Engineering
Effort Estimation

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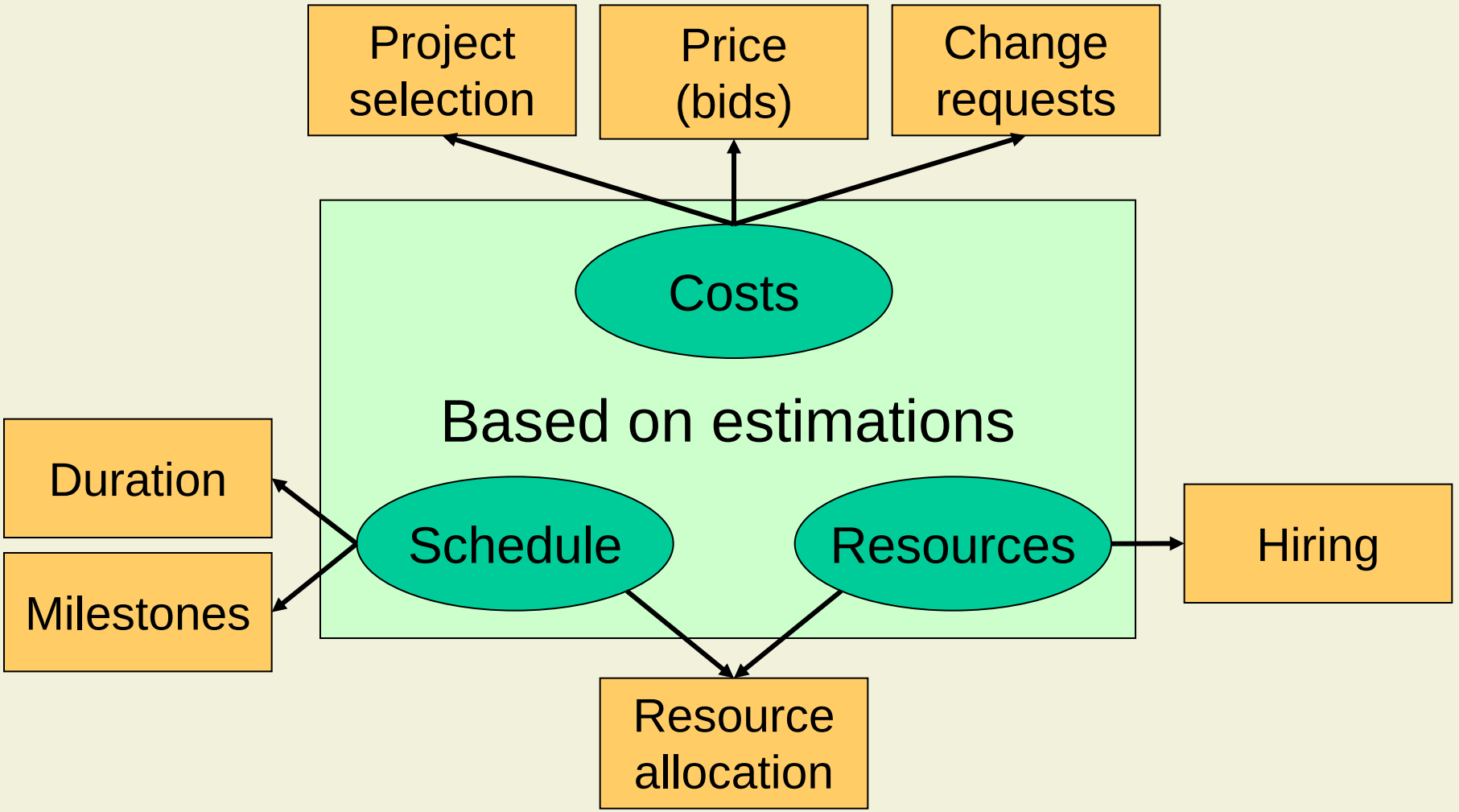
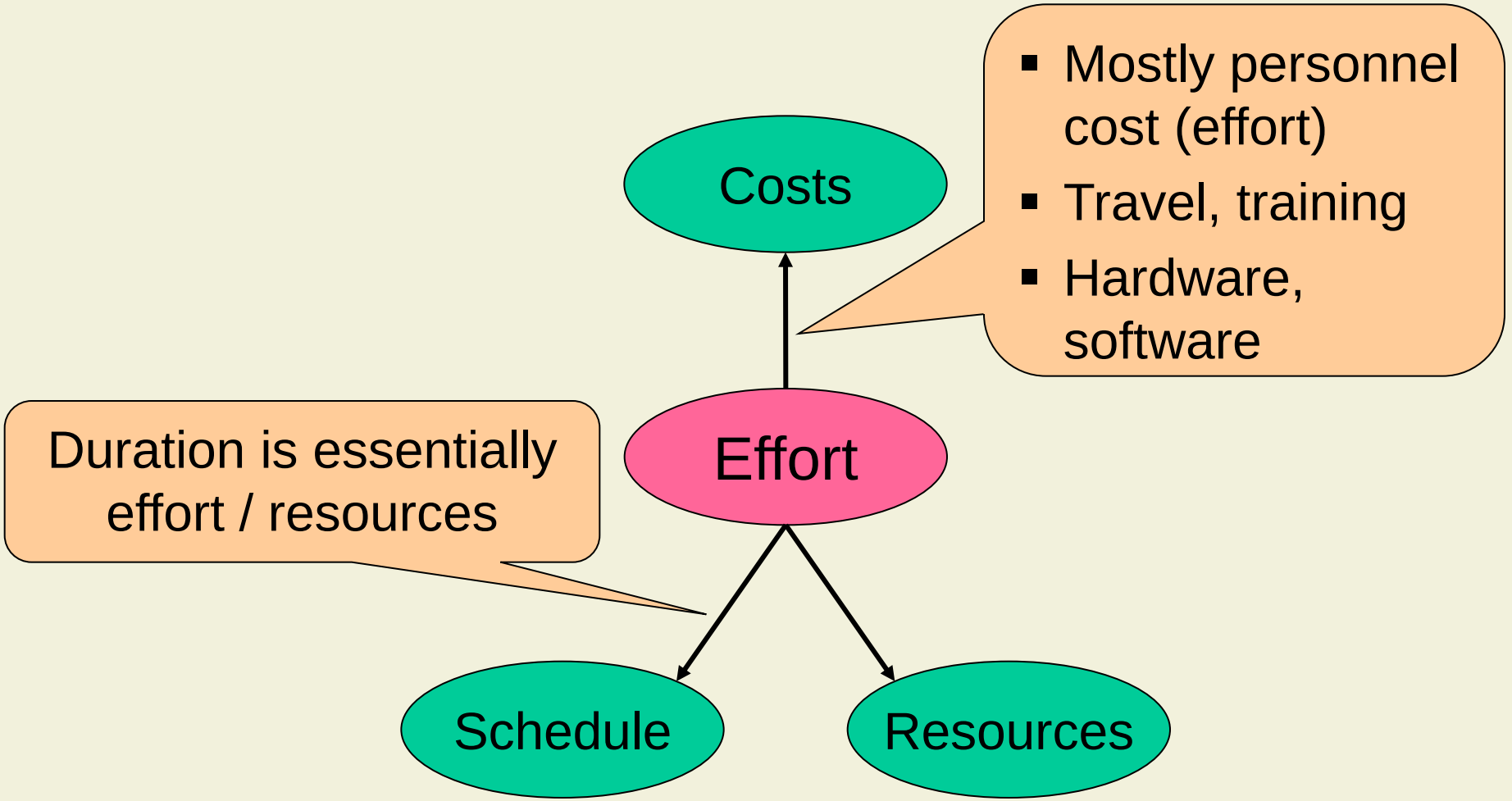
Why Estimations?



Estimations in Software Projects



9. Effort Estimation

Estimation Exercise

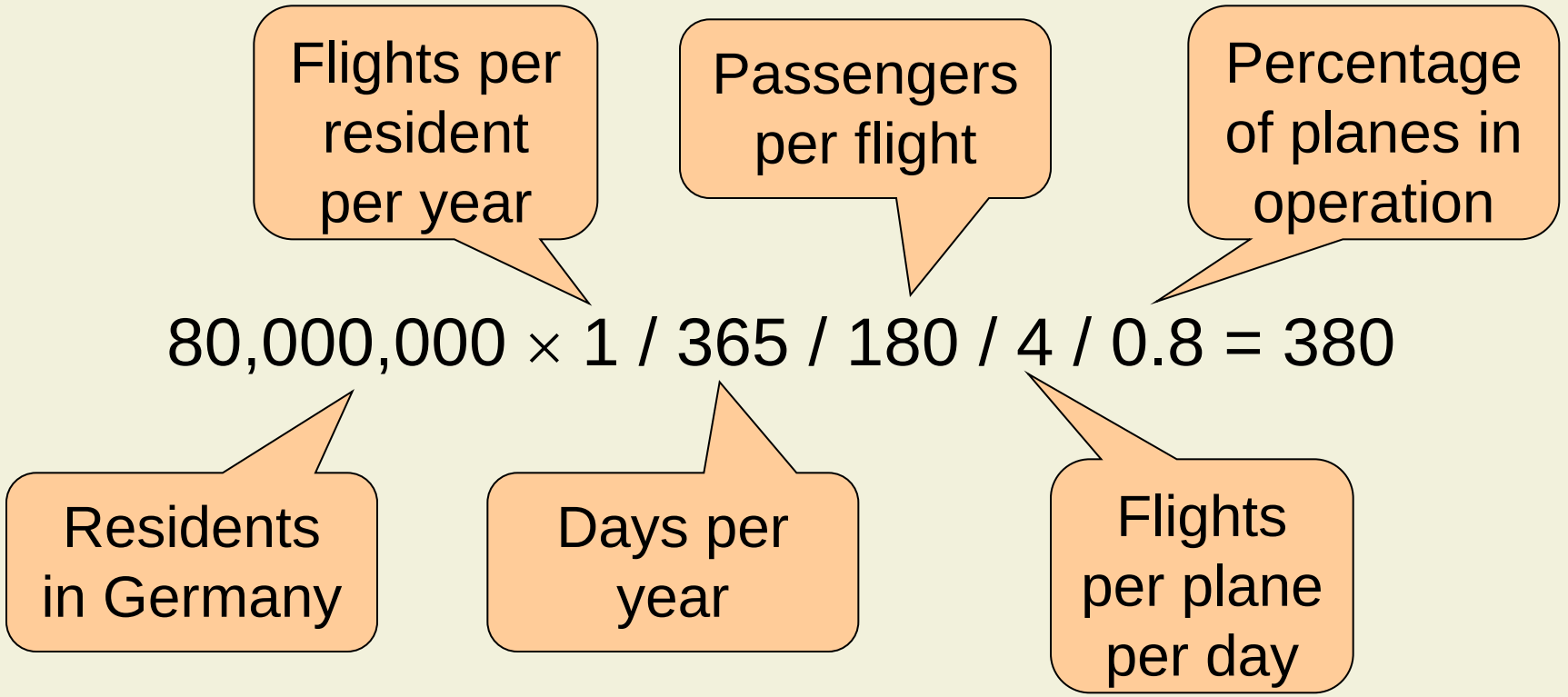
- How many passenger planes does Lufthansa have?
  - Not counting regional subsidiaries

- How can we approach this problem systematically?

Algorithmic Estimate 1

Exclude from pdf

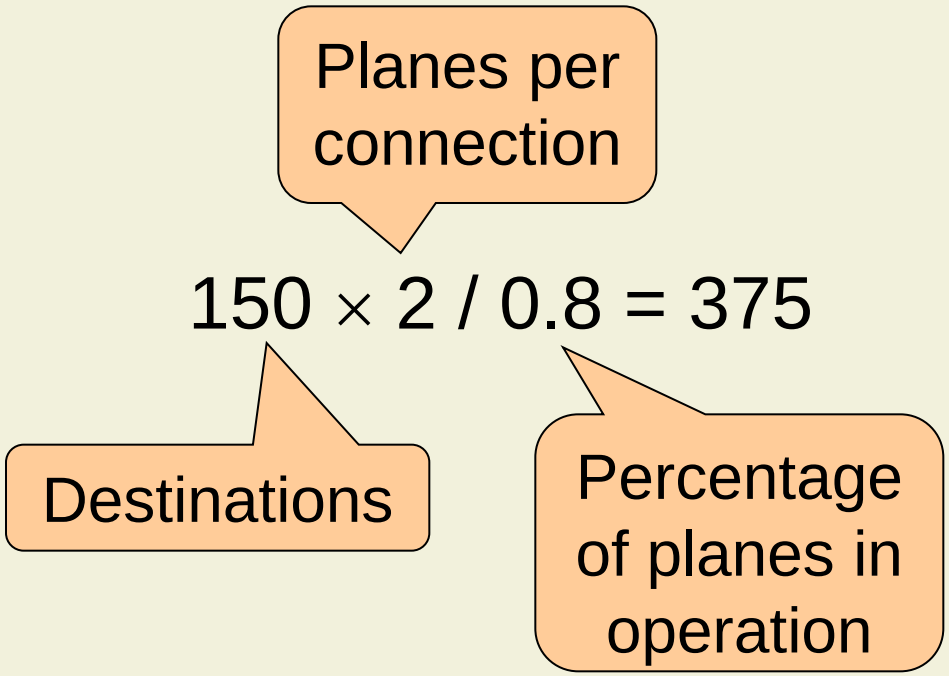
- Idea: Number of passengers corresponds to number of residents in the home country



Algorithmic Estimate 2

Exclude from pdf

- Idea: Number of planes corresponds to destinations
  - We assume a star topology



Estimation by Analogy

Exclude from pdf

- Idea: We know that Air France has 240 planes
  - We assume correlation with number of residents

Planes of Air France

$$240 / 60{,}000{,}000 \times 80{,}000{,}000 = 320$$

Residents in France

Residents in Germany

9. Effort Estimation

Empirical Estimation: Expert Judgment

- Estimate is based on **experience and historical data**
- Involve experts in
  - Development techniques
  - Application domain
- Most **common technique** in practice

Top-Down Estimation

- Estimation by **analogy**
  - Comparison with **similar projects**
  - Analysis of differences
  - Typical example: SAP introduction

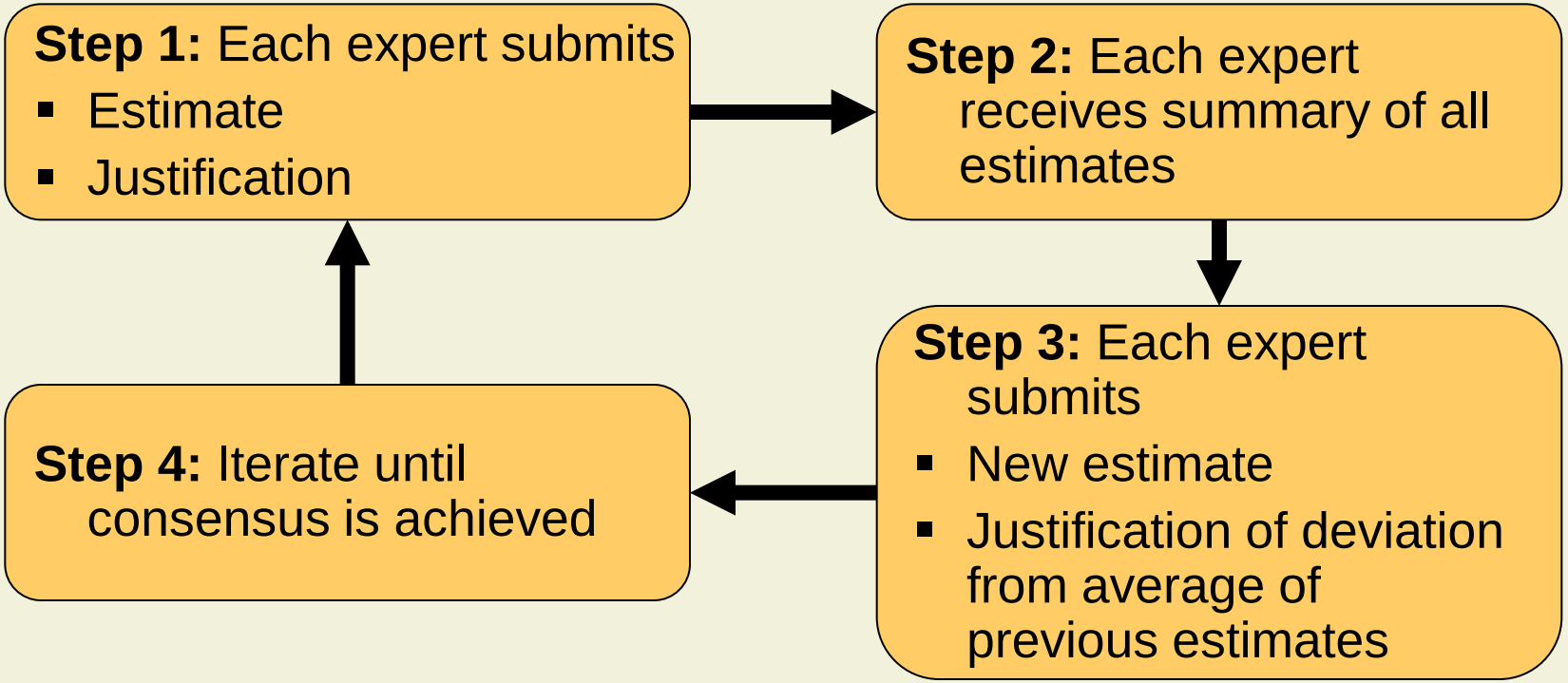
Pros

- Quicker and less expensive than other methods
- Can be done early in the project

Cons

- Underestimation of difficult technical problems likely
- No detailed justification of estimate
- Be aware of scalability problems!

Top-Down Estimation: Delphi Method

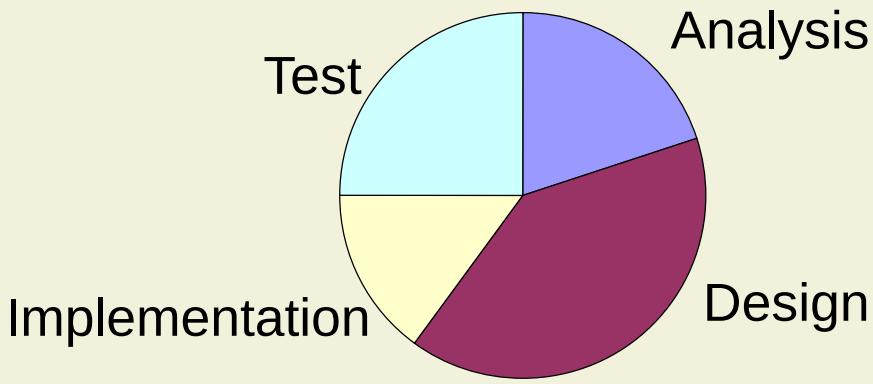


- **More accurate** than ordinary expert judgment
  - Eliminates outliers
- **More expensive** to produce

Top-Down Estimation: Typical Figures

- Typical figures for software development

- Analysis	20%
- Design	40%
- Implementation	15%
- Test	25%



- Very **helpful to validate** estimations

Bottom-Up Estimation

- Estimation by **decomposition**
  - Estimating the effort for **individual work packages**
  - Cost and accuracy depend on size of the work packages

Pros

- See “cons” of top-down estimation

Cons

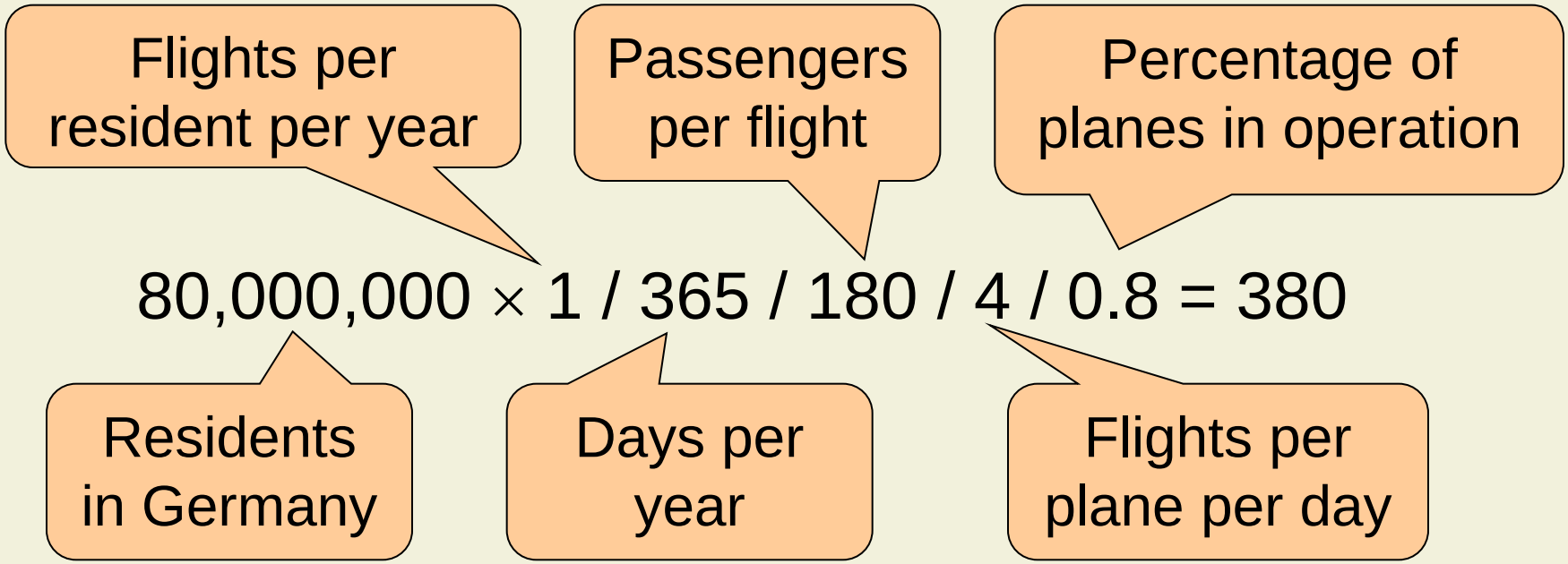
- Underestimation because effort does not grow linearly (due to complexity, etc.)
- Underestimation of integration effort
- Requires initial system design

Program Evaluation and Review Technique

- Goal: Manage probabilities with simple statistics
- Approach: Ask several experts for three estimates
  - **Optimistic, Likely (mode), and Pessimistic**
- Important formulas
  - Mean $M = (O + 4 \times L + P) / 6$
  - Deviation $V = (P - O) / 6$
- Assumptions
  - Project effort is normally distributed (more than 20 work packages)
  - Work package efforts are statistically independent (ignores single underlying cause of delay)

9. Effort Estimation

Algorithmic Estimation



- Algorithmic estimation is based on
  - **Cost model**, represented by formula
  - **Measurement of size** (passengers, destinations, etc.)
  - **Parameters** (size of planes, planes in operation, etc.)

Algorithmic Estimation of Software

- Basic cost model

$$\text{Effort} = A \times \text{Size}^B \times m(X)$$

- Size: Some measurement of the software size
- A: Constant factor that depends on
  - Organizational practices
  - Type of software
- B: Usually lies between 1 and 1.5
- X: Vector of cost factors
- m: Adjustment multiplier

Cost Models

$$\text{Effort} = A \times \text{Size}^B \times m(X)$$

- Cost models
  - Define a way to determine the size
  - Define cost factors X
  - Provide defaults for parameters A, B, m (based on hundreds of projects)

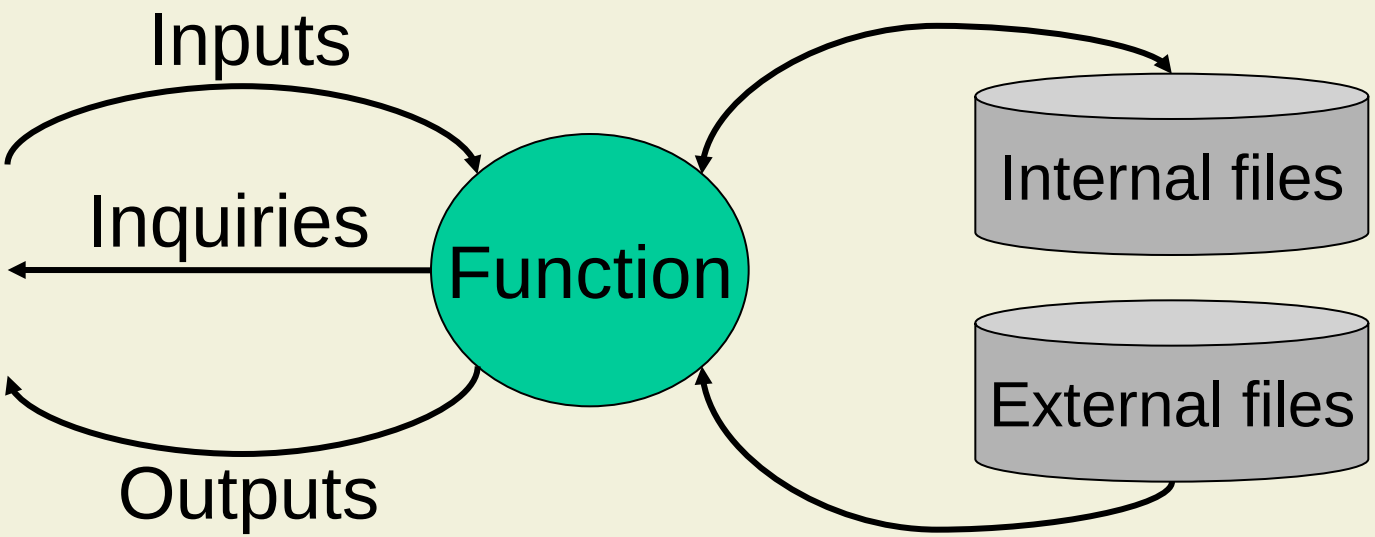
- Important examples
  - Function point analysis
  - Constructive cost model (COCOMO)

Measuring Size: Lines of Code

- Software size can be measured in lines of source code
  - Most commonly used metric
- **Difficult in early phases** of the project (before design is known)
  - Reuse, make-or-buy decisions
- **Influenced** heavily by choice of **programming language**
- Should only be **used indirectly**

Function Point Analysis

- Size is estimated based on **requirements**



Functions

- **Inputs**
  - Forms, dialogs, messages, XML documents
- **Outputs**
  - Web pages, reports, graphs, messages, XML documents
- **Inquiries** (input/output combinations)
  - Simple web inputs, generally producing a single output
- **Logical internal files** (controlled by the program)
  - Tables, views or files in database
- **External files** (controlled by other programs)
  - Tables or files used from other systems or databases

Complexity of Functions

- Determine **complexity** of each function

Input	Simple	Average	Complex
Data elements	1-5	6-10	>10
Checking	Formal	Formal, logical	Formal, logical, requires DB access

- **Weight** each function according to complexity

Factor	Simple	Average	Complex
Inputs	3	4	6
Outputs	4	5	7
Inquiries	3	4	6
Ext. files	7	10	15
Int. files	5	7	10

Cost Factors

- Data communications
- Distributed processing
- Performance
- Heavy use
- Transaction rate
- Online data entry
- Complex interface
- Online data update
- Complex processing
- Reusability
- Installation ease
- Operational ease
- Multiple sites
- Facilitate change

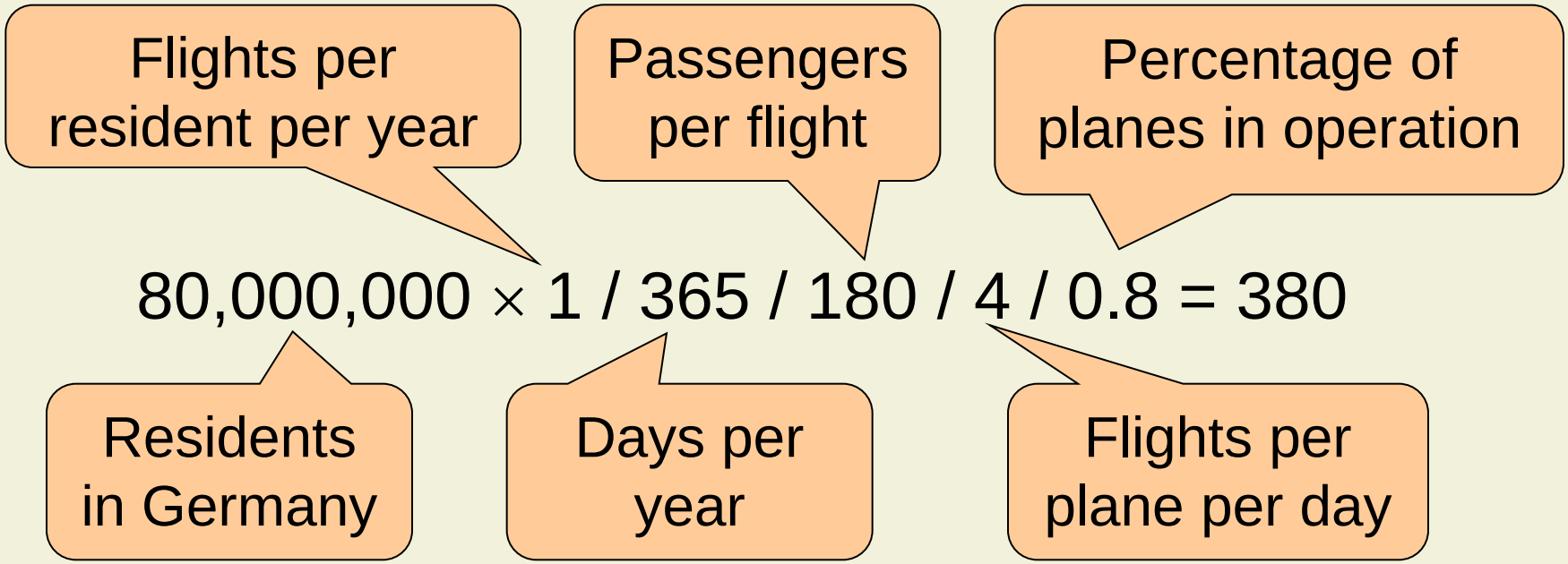
- Rate each element from 0 – 5
  - 0: no influence
  - 1: insignificant influence
  - 2: moderate influence
  - 3: average influence
  - 4: significant influence
  - 5: strong influence
- **Technical complexity factor**
  - TCF = 0.65 + 0.01 × sum
  - Varies between 0.65 and 1.35

Function Point Computation

	Simple	Average	Complex
Inputs	6 x 3 = 18	2 x 4 = 8	3 x 6 = 18
Outputs	7 x 4 = 28	7 x 5 = 35	0 x 7 = 0
Inquiries	0 x 3 = 0	2 x 4 = 8	4 x 6 = 24
Ext. files	9 x 5 = 45	0 x 7 = 0	2 x 10 = 20
Int. files	5 x 7 = 35	2 x 10 = 20	3 x 15 = 45
Unadjusted function points (UFP)			304
Technical complexity factor (TCF)			1.15
Adjusted function points			**350**

- **Adjusted function points**: FP = UFP × TCF

Calibration



- Assume that model (formula) is correct
- **Calibrate** model based on **comparable** airlines
- Estimate number of residents in the country

Determining Effort and Size

- Empirical value for effort
  - Or use a table

$$\text{Effort} = FP^{1.4} / 150$$

- Empirical value for size
- Huge differences in productivity
  - Factor 10-20 between individual programmers
  - Factor 4 between companies

Language	Level	Statements per UFP
Assembler	1	320
C	2.5	125
C++	6.5	50
Perl	15	25
Pascal	3.5	90
Visual Basic 3	10	30
Excel	50	6

Observation about Software Size

- Consider a project that requires 10 Web pages, 15 reports, and 20 database tables
  - 315 function points, if each item is medium complexity
- How many lines of C code would it have?
  - About 32,000 lines
- What if you used Excel?
  - About 2,000 lines

- Why do you think there are so many spreadsheets out there?

Function Point Analysis: Discussion

Pros

- Based on requirements (instead of code size)
- Can be applied in early project phases
- Can be calibrated (for company, project type)
- Counting standards by "International Function Points User Group"
- Technology-independent

Cons

- Estimation of overall effort (not per phase)
- Tailored towards functional decomposition (rather than OO)
- Tailored towards information systems
- Needs calibration to produce reliable results

Adaptation for OO: Use Case Points

1. Rank **actors**
   - Simple (1 point): a machine with a programmable API
   - Average (2 points): a human with a command line interface or a machine via some protocol (no API written)
   - Complex (3 points): a human with a GUI
2. Rank **use cases**
   - Simple (5 points): 3 or fewer transactions
   - Average (10 points): 4 to 7 transactions
   - Complex (15 points): 8 or more transactions
3. Calculate unadjusted use-case point count, TCF, and **adjusted use-case point** (AUCP) count
4. Compute effort: 20-30 person hours / AUCP

Constructive Cost Model (COCOMO II)

- **Three models** for three major project stages
  - Different size metrics and cost factors

Application Composition

- Used for prototypes
- Size: application points

Early Design

- Used for initial estimates based on requirements and design options
- Size: function points and language

Postarchitecture

- Used for development effort based on design specification
- Size: source LOC

Example: Early Design Model

$$\text{Effort} = 2.94 \times \text{Size}^{B} \times m(X)$$

- $B = 0.91 + 0.01 \times SF$
- SF: sum of five scale factors
  - Determined by tables
- B lies between 1.1 and 1.24

Scale factors

- Precedentedness
- Development flexibility
- Architecture / risk resolution
- Team Cohesion
- Process maturity

Example: Early Design Model (cont'd)

$$\text{Effort} = 2.94 \times \text{Size}^{B} \times m(X)$$

- m(X): product of seven cost factors
  - Determined by tables
- m(X) lies between 0.08 and 60.68

Cost factors

- Product reliability and complexity
- Development for reusability
- Platform difficulty
- Personnel capability
- Personnel experience
- Facilities
- Required development schedule

Estimation Techniques: Discussion

Empirical Estimation

- Accurate if experts are experienced
- Experts can be strongly biased (over-optimism)

Algorithmic Estimation

- Very accurate if model is calibrated
- Calibration is very difficult and expensive
- Estimation is expensive

- Empirical studies
  - Do not show that uncalibrated algorithmic estimation is, in general, more accurate
  - Show that algorithmic estimation is more accurate than experts who do not have important domain knowledge

Other Estimation Strategies

Parkinson's Law

- Work expands to fill the time available
  - Gold plating
- Effort is determined by available resources
- Important for team management

Pricing to win

- Cost is estimated to whatever the customer is willing to spend
- Common strategy to win projects
- Features are negotiated later, constrained by agreed costs
- Costs are fixed, not requirements

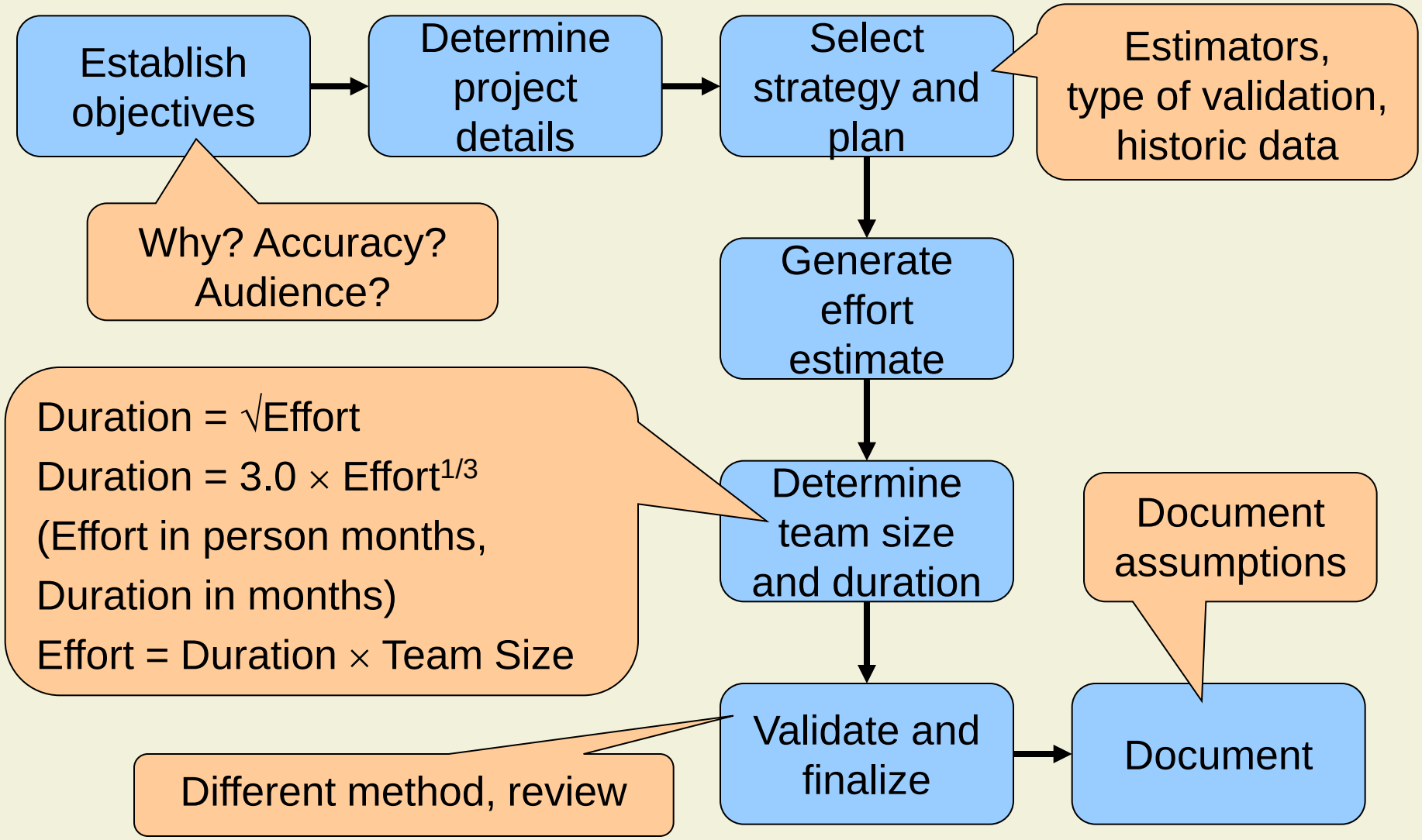
9. Effort Estimation

Estimate Types

Rough order of magnitude	Budgetary	Definitive
-25 / +75%	-10 / +25%	-5 / +10%
Initial estimates	Decision making, response to proposals	Project plan, proposals

- **Refine** your estimates at each project stage
  - Requirements document, system design, detailed design, working code

Estimating Process



Estimation Tips

- Avoid off-the-cuff estimates
- Allow time for the estimate, and plan it
- Use historic data
- Use **developer-based estimates**
- Estimate by walkthrough
- Estimate by categories
  - e.g. easy, medium, hard
- Estimate at a low level of detail
- Don’t omit common tasks (management; use **checklists**)
- Use **different techniques** and compare the results
- Change estimation practices as the project progresses

From Effort to Costs

- **Direct costs**: Costs incurred for the benefit of a specific project
  - Salaries of project staff
  - Equipment bought specifically for the project
  - Travel expenses
- **Indirect costs**: Costs incurred for the joint benefit over multiple projects (“overhead”)
  - Accounting, quality assurance department
  - Line management
  - Rooms, electricity, heating

Unit Costs

- Projects have to budget for
  - Direct costs
  - A certain share of indirect costs
- Budgets are usually determined by using unit costs
  - Unit cost: Price per unit of a resource
  - **Loaded rate**: Including indirect costs
  - **Unloaded rate**: Without indirect costs
- Examples
  - Loaded day rate for senior IT consultant: CHF 3.500
  - Loaded day rate for internal developer: CHF 1.200

From Costs to Prices

- The price is often based on the costs and a margin
- Price = Costs / (1 - Margin)
- Example
  - Costs = CHF 1.000.000
  - Margin = 5%
  - Price = CHF 1.052.632
- Price is influenced by
  - Market situation
  - Business strategy