Engineering & Economics Concepts for Understanding Software Process Performance
(Chapter 2 – Software Project Estimation)

Alain Abran

(Tutorial Contribution: Dr. Monica Villavicencio)

Topics covered

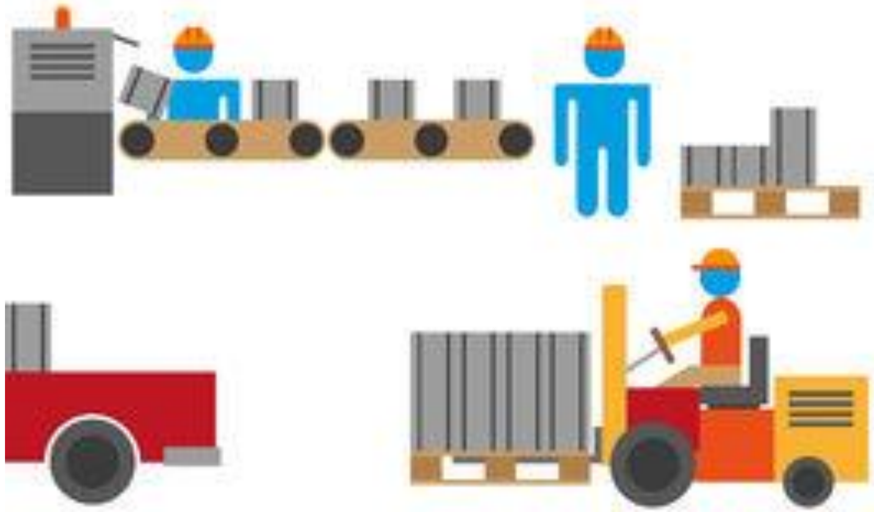
1. The production process
2. Engineering & Management perspective
3. Simple quantitative process models
4. Quantitative models & Economics concepts
5. Datasets and distributions
6. Explicit & implicit variables
7. Multi-dimensional vs multiple simpler models

2.1 The production (development) process

Concerns about the development process

- How can we figure out the performance of a software development process?
- How can we build quantitative models of development processes?

The development process can be modeled as a production process.



http://www.dreamstime.com/stock-photography-teamwork-construction-workers-vector-image1238322

The production process

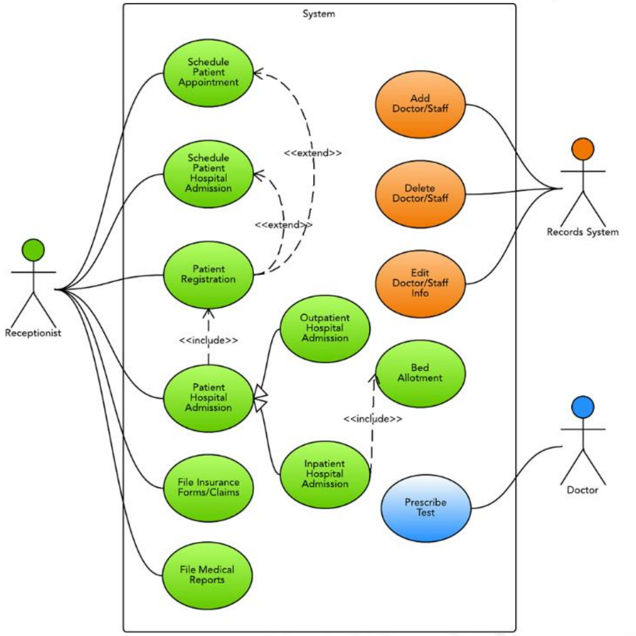
- Process order
- Inputs
- Process activities
- Outputs

A process order

Engineering plans

http://homearchitecturedesign.com/architecture-house-plans/luxury-architecture-house-plans-on-architecture-with-modern-houses-architectural-plans-home-design-ideas-dokity/

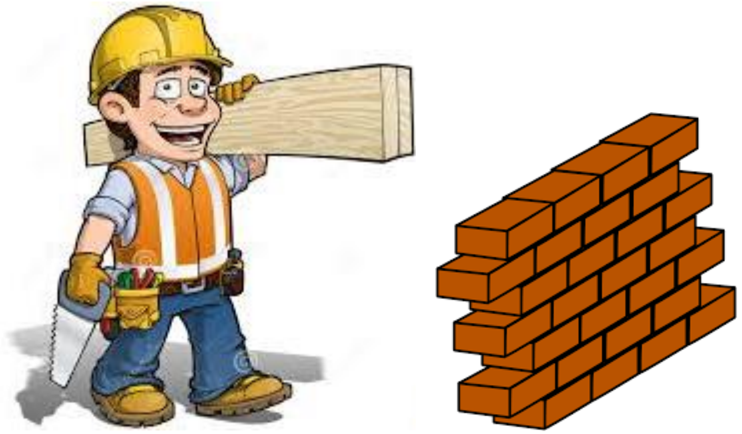
Requirements (Ex. UML Diagrams)



http://vustudents.ning.com/group/cs619finalproject/forum/topics/complete-information-about-srs-document-and-other-project

Inputs

Resources for construction



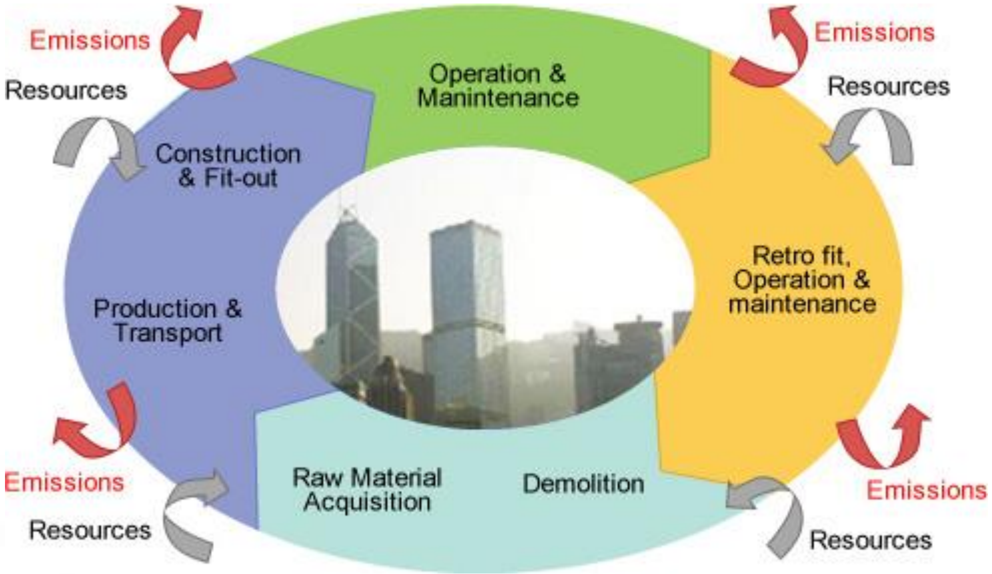
http://imgkid.com/construction-worker-tools-clip-art.shtml
http://imgkid.com/laying-bricks-clipart.shtml

Human Resources

http://openexhibits.org/downloads/

Activities

Construction activities



http://www.energyland.emsd.gov.hk/en/building/assessment/

Software development activities

http://www.atksolutions.com/articles/software_development_life_cycle.html

Outputs

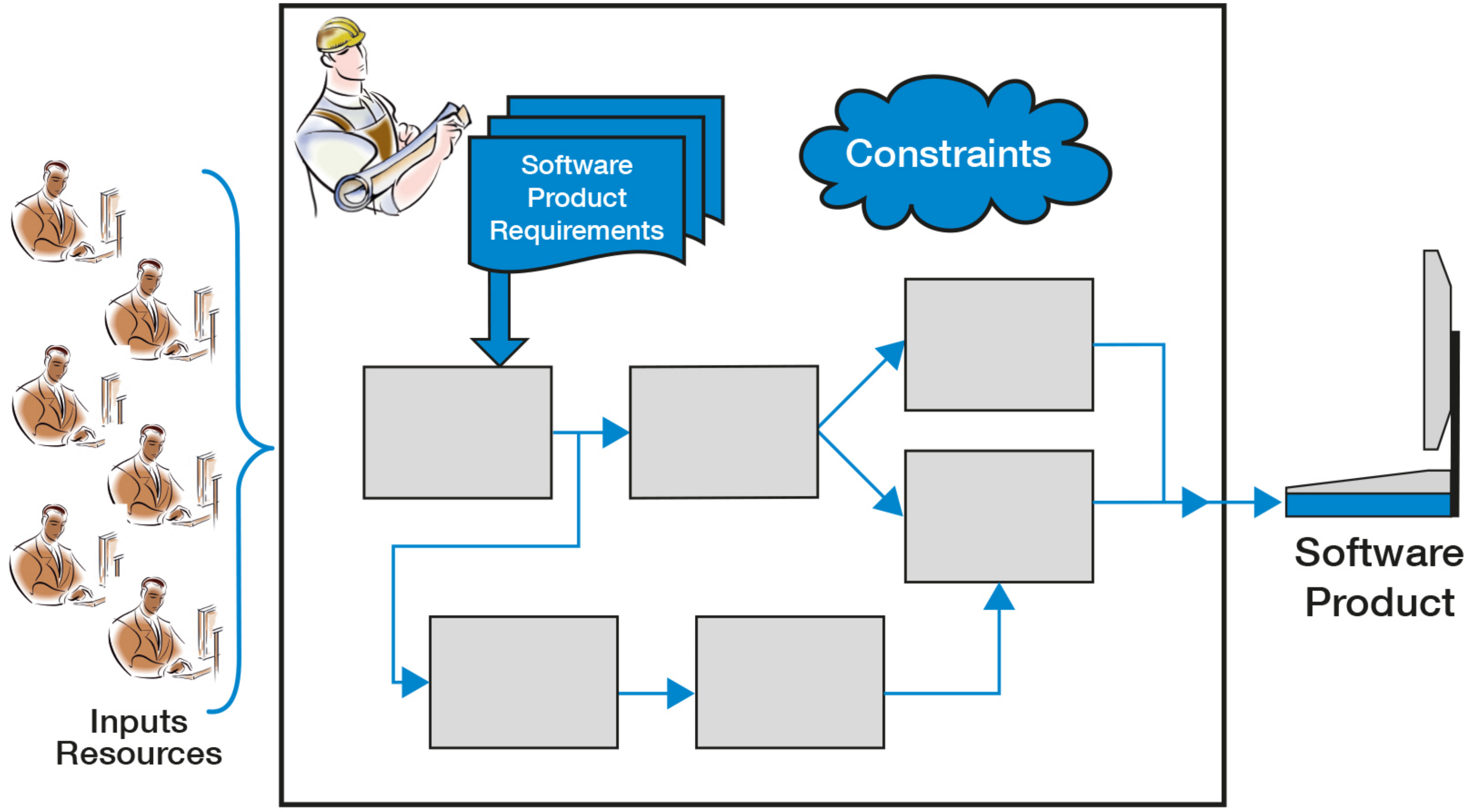
A house

http://osc-vector.com/tag/colonial-house-clip-art

The software

http://www.clker.com/clipart-software.html

A production process of software



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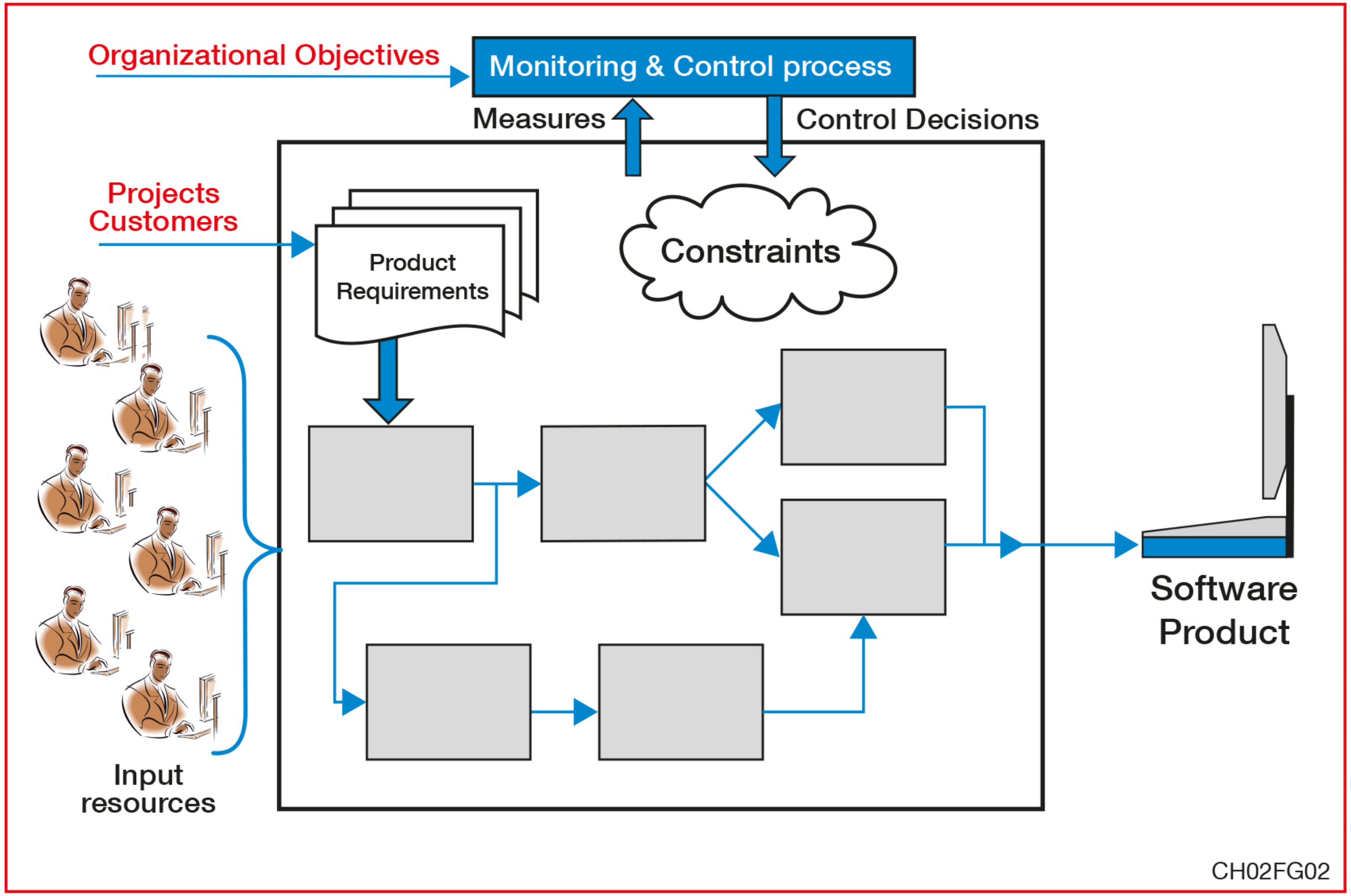
2.2 Engineering & Management perspective on a production process

Engineering & Management perspective



Monitoring & Control Process

- This process includes:
    - A collection of measurement results about the current and past performance of the process.
    - An analysis of the process performance against the project objectives and the goals of the organization.
    - Decisions to make adjustments (through evaluation and decision models)

Project objectives

- Specific to a project
- Generally multiple and concurrent:
  - Deliver a number of software functions,
  - within a specified time frame,
  - within a specified (limited) budget, and
  - with a level of quality (not always precisely specified)

http://projectplanonline.com/risk-management/motherhood-statements-project-management-objectives/

In the Agile methodology, these correspond to Sprint objectives.

Organizational objectives

https://www.managingamericans.com/business-templates.htm

- Broader scope, not limited by the project objectives.
- Longer term view.
- Concerned with issues that extend beyond the life of the project.
    - Impact of the quality delivered by a development project over the many years of maintenance of the software being developed.
    - Usage of standards

2.3 Simple Quantitative Process Models

Productivity

Productivity = Outputs / Inputs

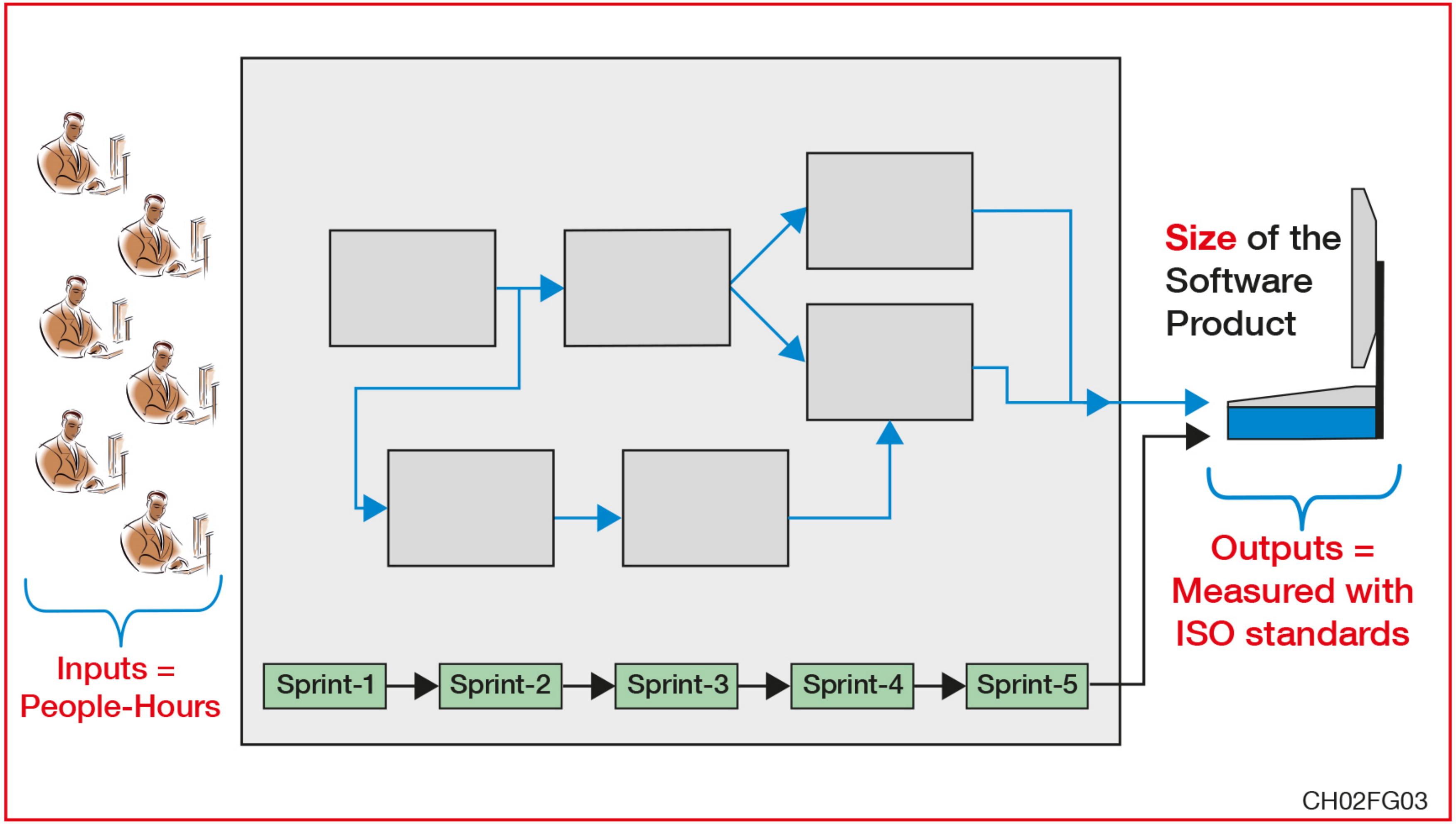
Outputs: Number of functions delivered

Inputs: Number of worked hours

Examples of productivity

- Web-based catalog application:
  - Average productivity of organization A = 30 Function Points per person-month
  - Average productivity of organization B = 33 Function Points per person-month.

The productivity ratio



Unit effort (unit cost)

Unit effort = Inputs / Outputs

Examples of unit effort

- Web-based catalog application:
  - Organization A:
    - 210 work-hours in a person-month
    - 30 Function Points per month
    - unit effort = 210 hours/30 Function Points = 7 hours/Function Point
  - Organization B:
    - 210 work-hours
    - 10 Function Points per month
    - Unit effort = 210 hours/10 Function Points = 21 hours/Function Point

Average

- The average productivity is built by:
  - calculating the productivity ratios of each individual project in a sample
  - adding them up, and
  - dividing the total by the number of projects in the sample

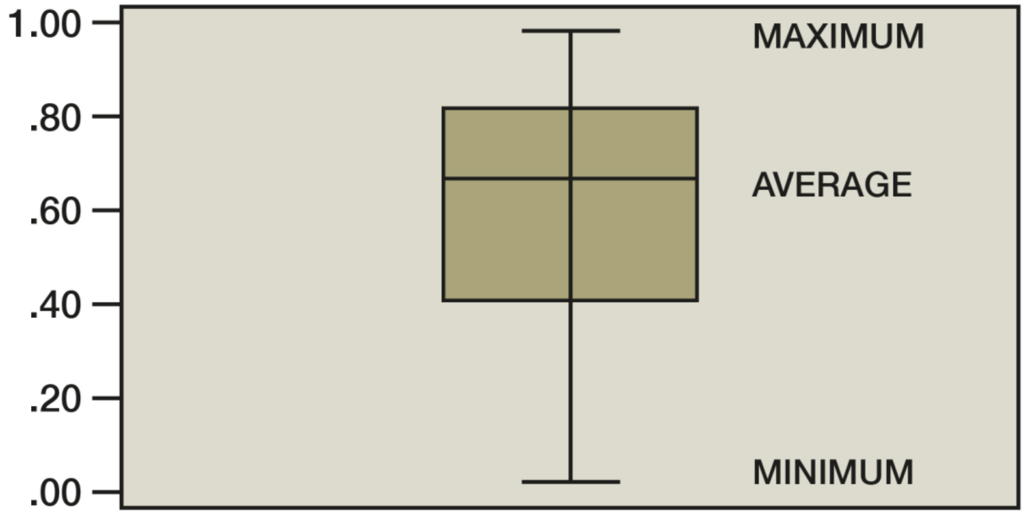
Characteristics related to the Average

- Minimum
- Maximum
- First quartile
- Last quartile
- 1 standard deviation
- 2 standard deviations
- Skewness
- Kurtosis

Standard deviation

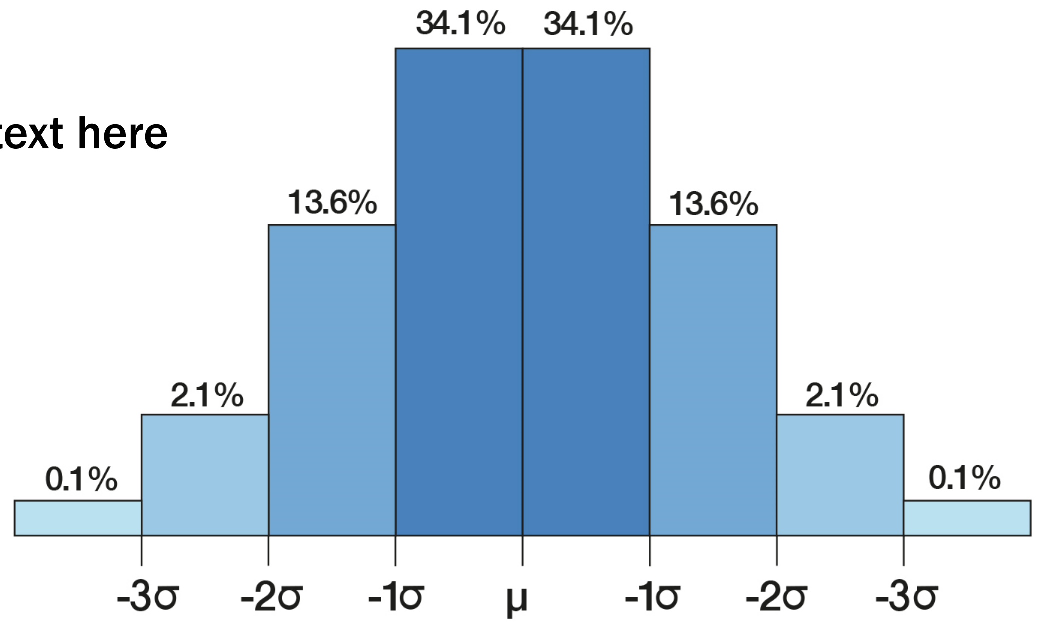
- Shows how much variation (or dispersion) there is from the average.
  - Low standard deviation: the data points tend to be very close to the average.
  - High standard deviation: the data points are spread out over a large range of values.

Average



Box-plot: Average and Quartiles

Your text here

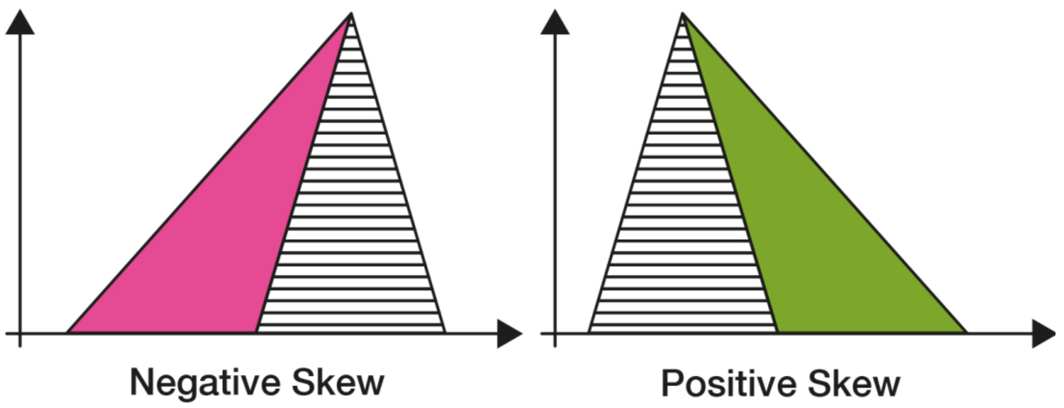


A normal distribution and standards deviations

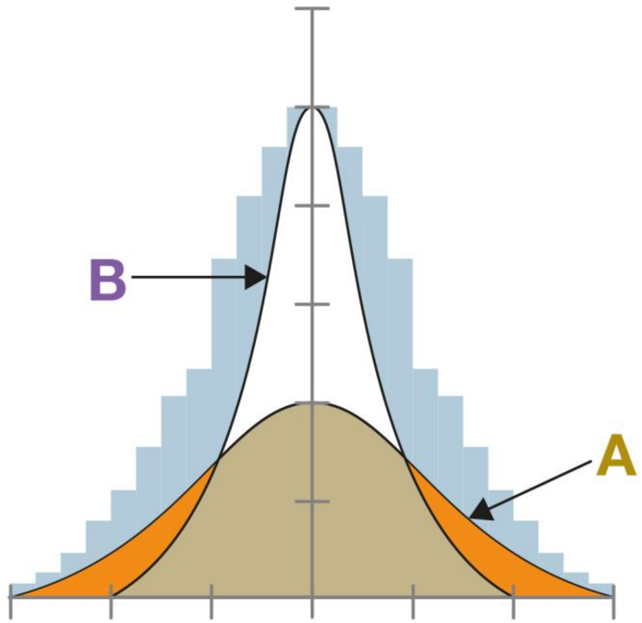
Skewness and Kurtosis

- Skewness is a measure of the asymmetry of the probability distribution of a random variable with a real value.
  - It can be positive or negative
- Kurtosis is a description of the ‘peakedness’ of a distribution.

Average



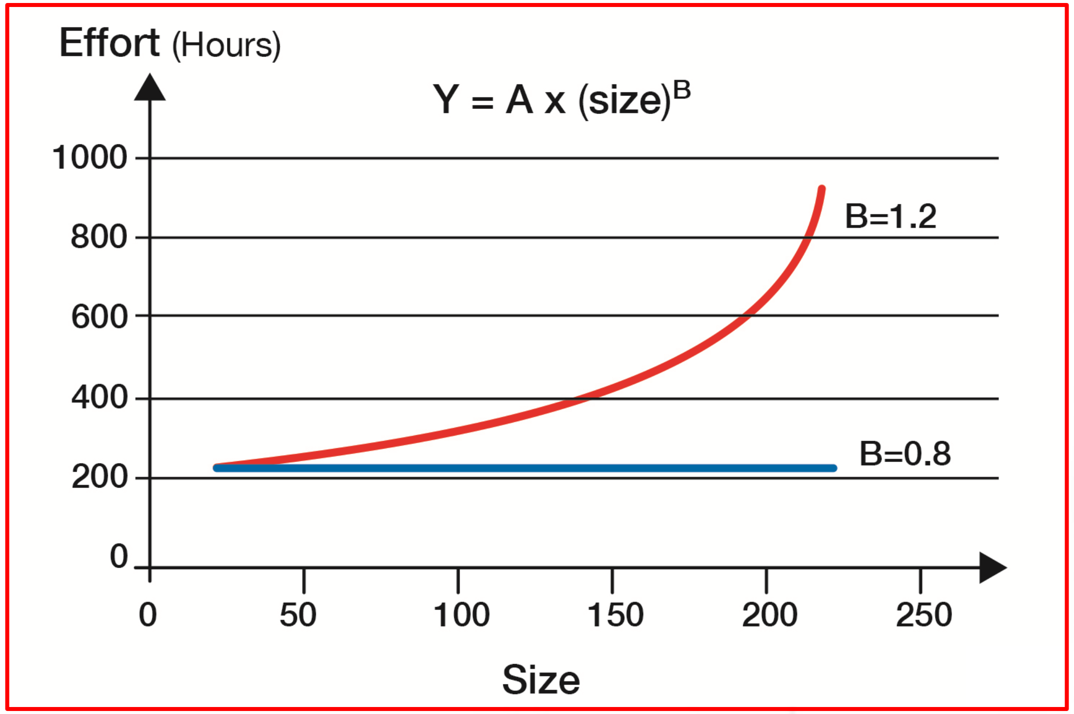
Skewness



Kurtosis

Linear & non-linear models

- Technique: statistical regression
- The Least-Squares Regression method is typically used to derive the regression equations.



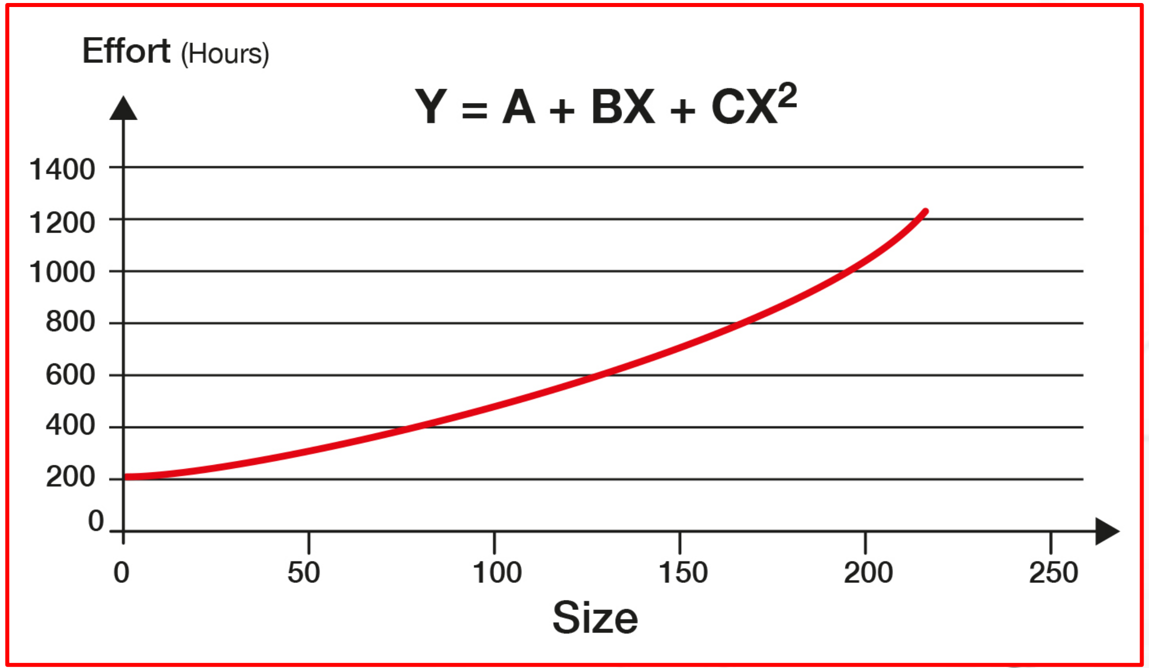
Power models with exponents larger (blue line) or smaller than-1 (red line)

Nonlinear production models

- A model of a production process could be represented by any shape.
- Statistical techniques are available to model any shape.
- Example

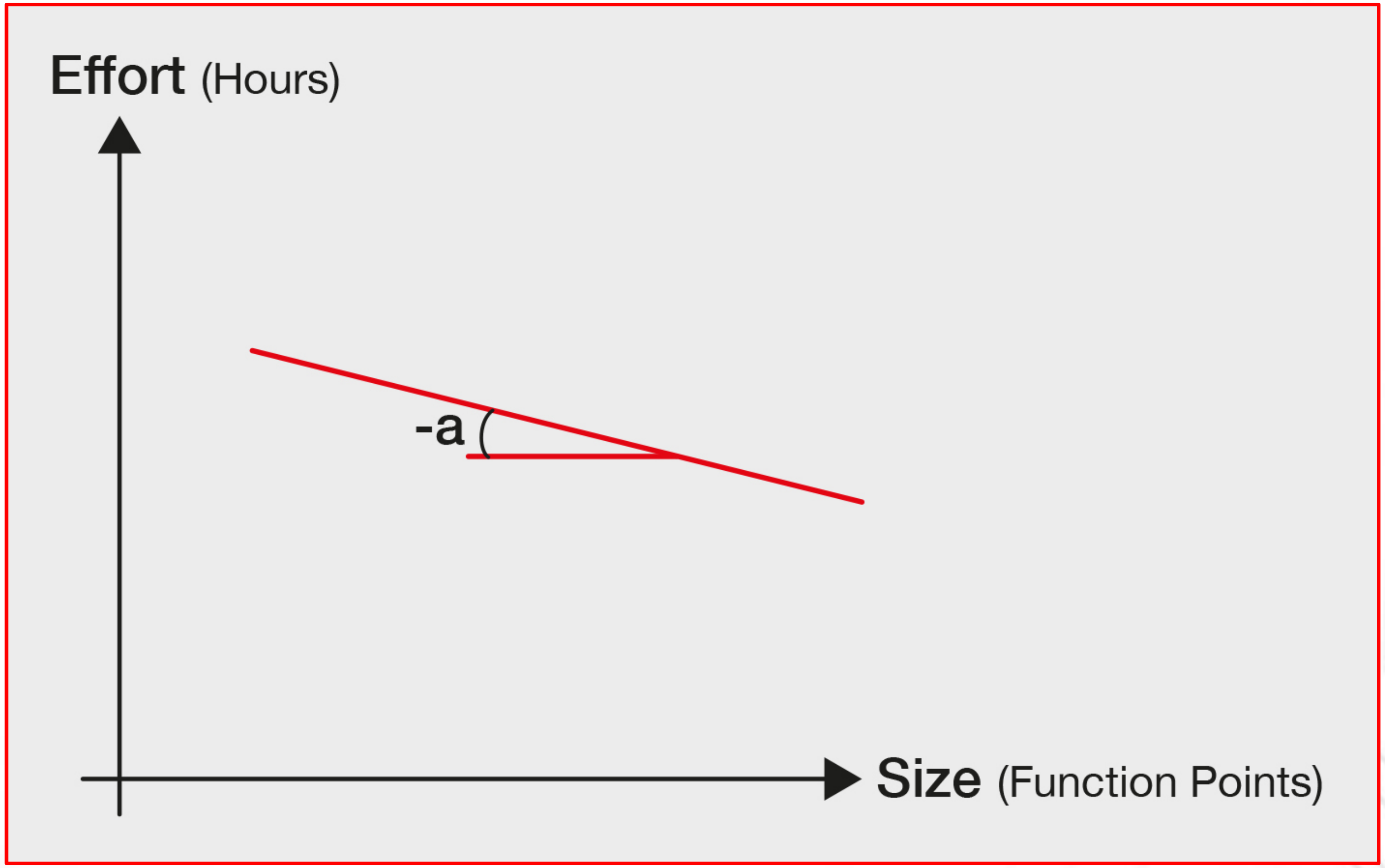
  Y (effort) = A * (Size)B

  $Y = A + BX + CX^2$



Quadratic model

Production model with negative slope

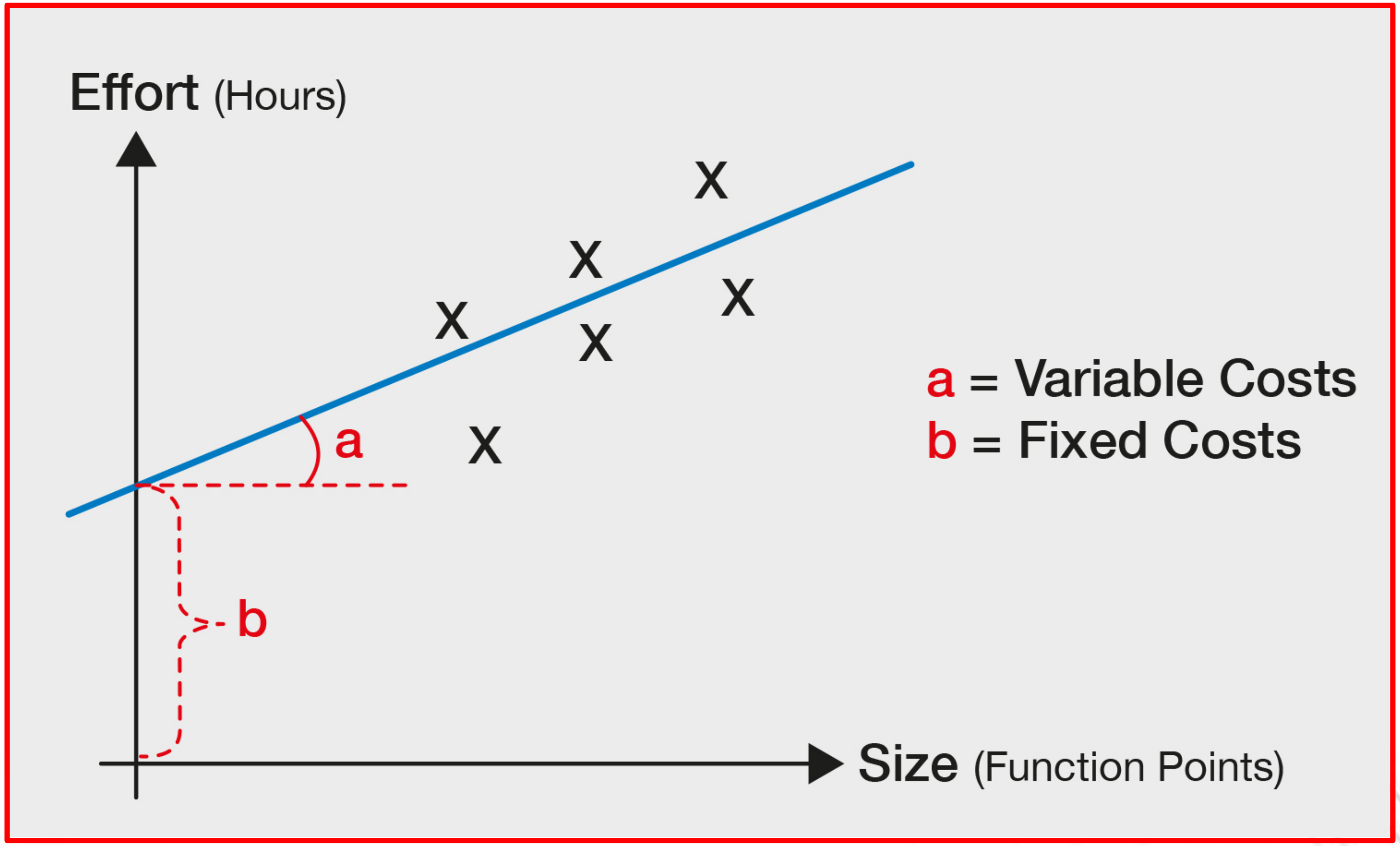


2.4
Quantitative Models & Economics Concepts

Variable and Fixed costs

- Variable:
  - Expenses that depend directly on the number of outputs produced.
  - Ej: Number of work hours
- Fixed:
  - Expenses that not depend on the number of outputs.
  - Ej: Project management plans, change control procedures, quality controls, audits, etc.

Variable and fixed costs



A linear model

$$Y \text{ (effort in hours)} = f(x) = a * \text{Size} + b$$

Size = number of Function Points (FP)

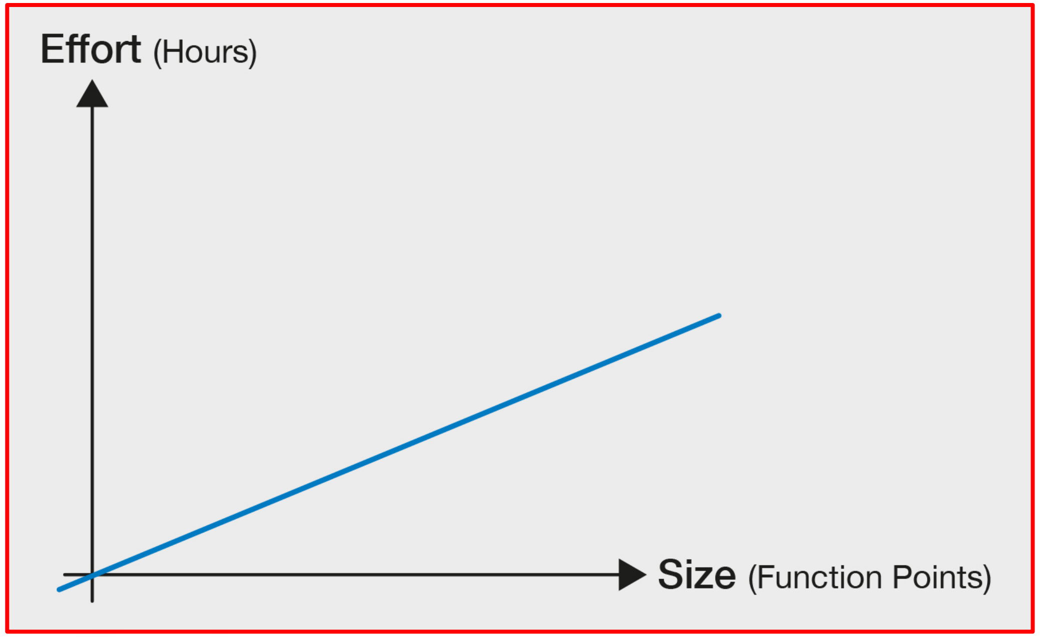
a = variable cost = number of hours per Function Point (hours/FP)

b = fixed cost in hours

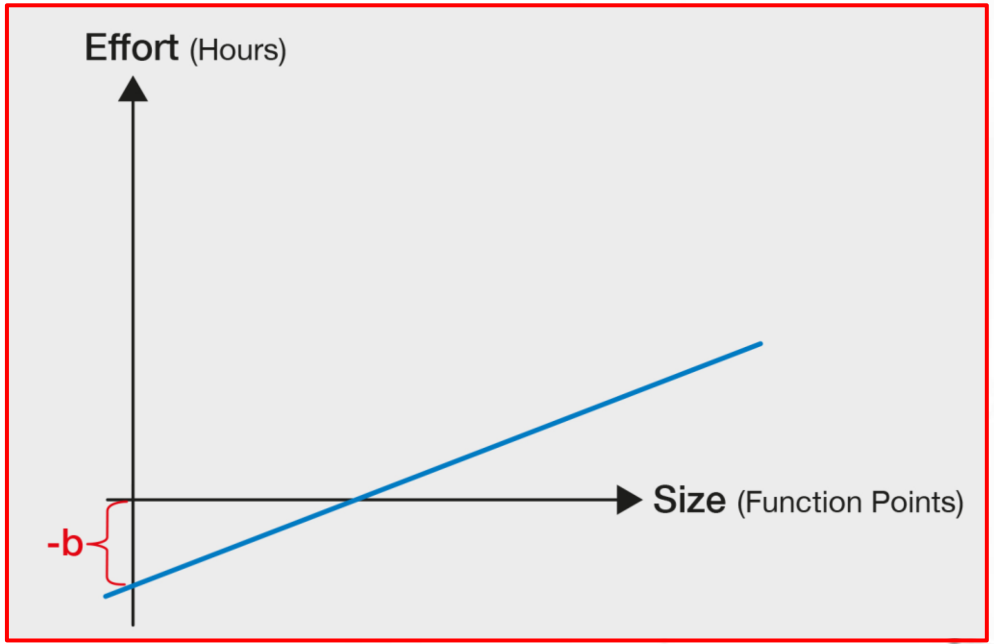
Units:

Y (hours) = (hours/FP) x FP + hours = hours

Production models and fixed costs



No fixed costs

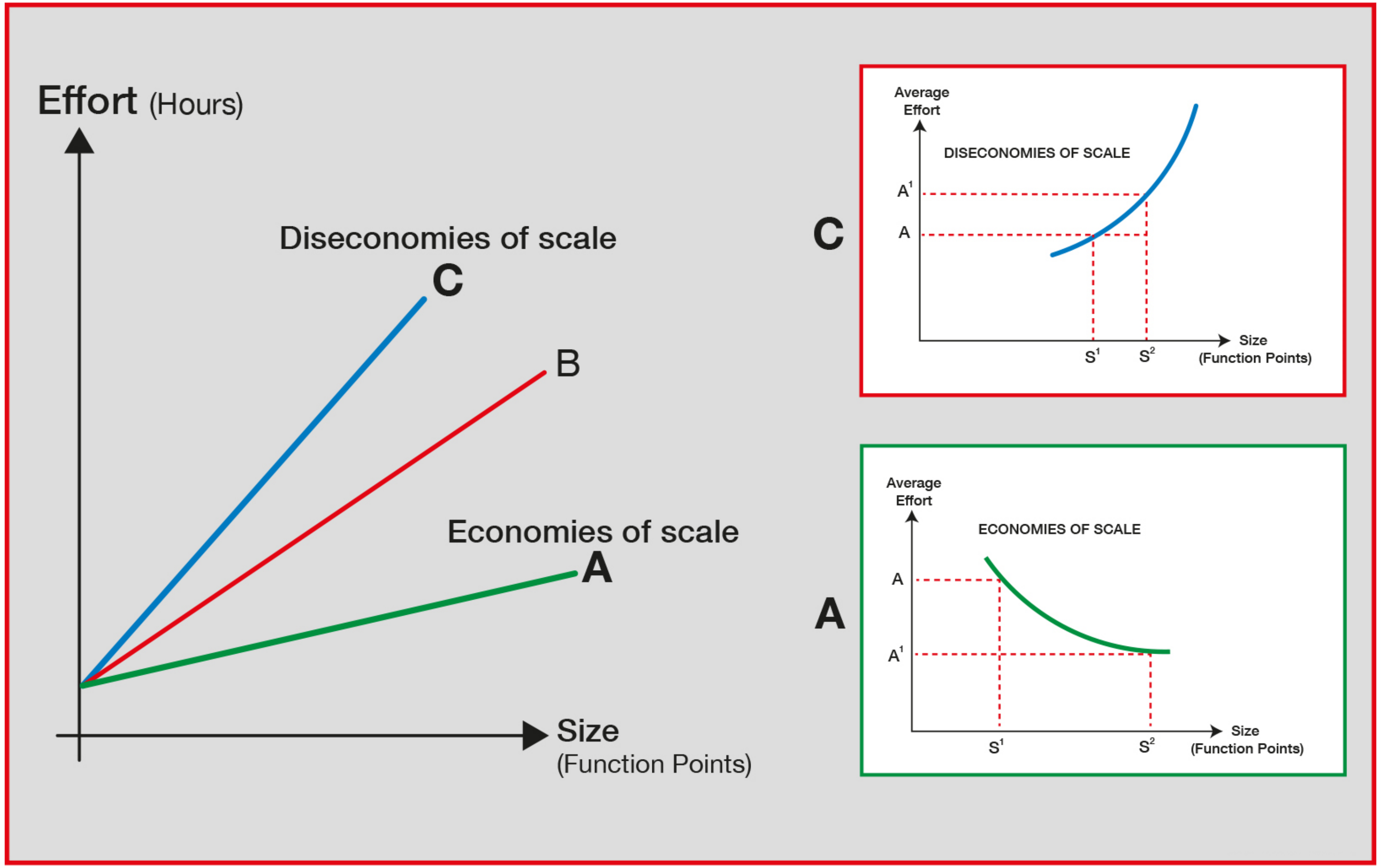


Negative fixed costs (theoretical)

Economies and diseconomies of scale

- Economies of scales
  - The increase in output units requires a smaller increase in input units.
- Diseconomies of scales
  - The increase in output units requires a larger increase in input units.

Economies and diseconomies of scale

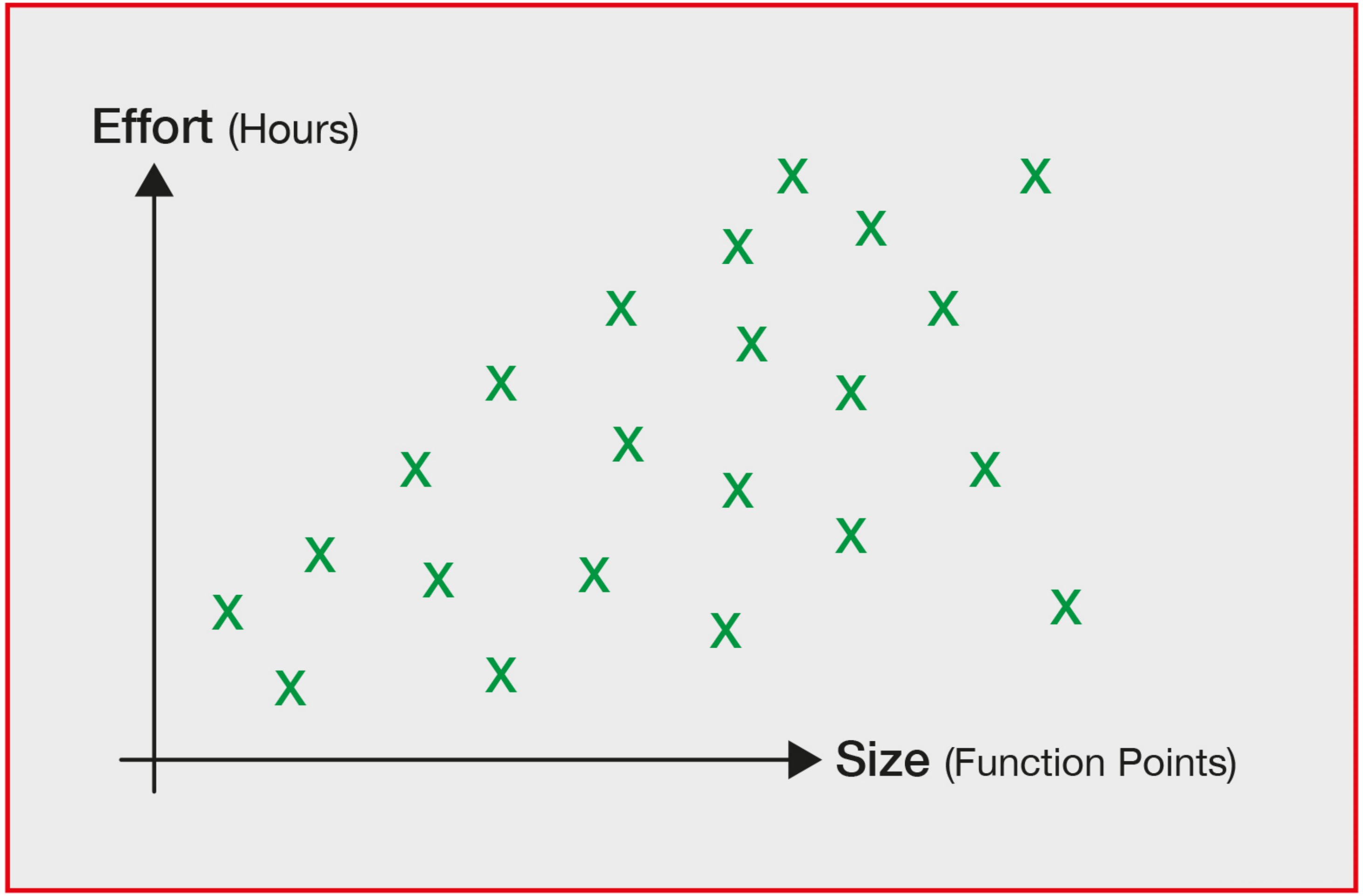


2.5
Software Engineering Datasets & their Distribution

Wedge-shaped data sets

- Behaviour: Increasing dispersion of effort as size increases.
- Consequence (when all the projects are combined into a single set)
  - Size alone does not adequately describe the relationship with effort.
  - Additional independent variables are necessary.

Wedge-shaped data sets



Wedge-shaped data sets

- Behaviour: Increasing dispersion of effort as size increases.
- Consequence (when all the projects are combined into a single set)
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  - Additional independent variables are necessary.

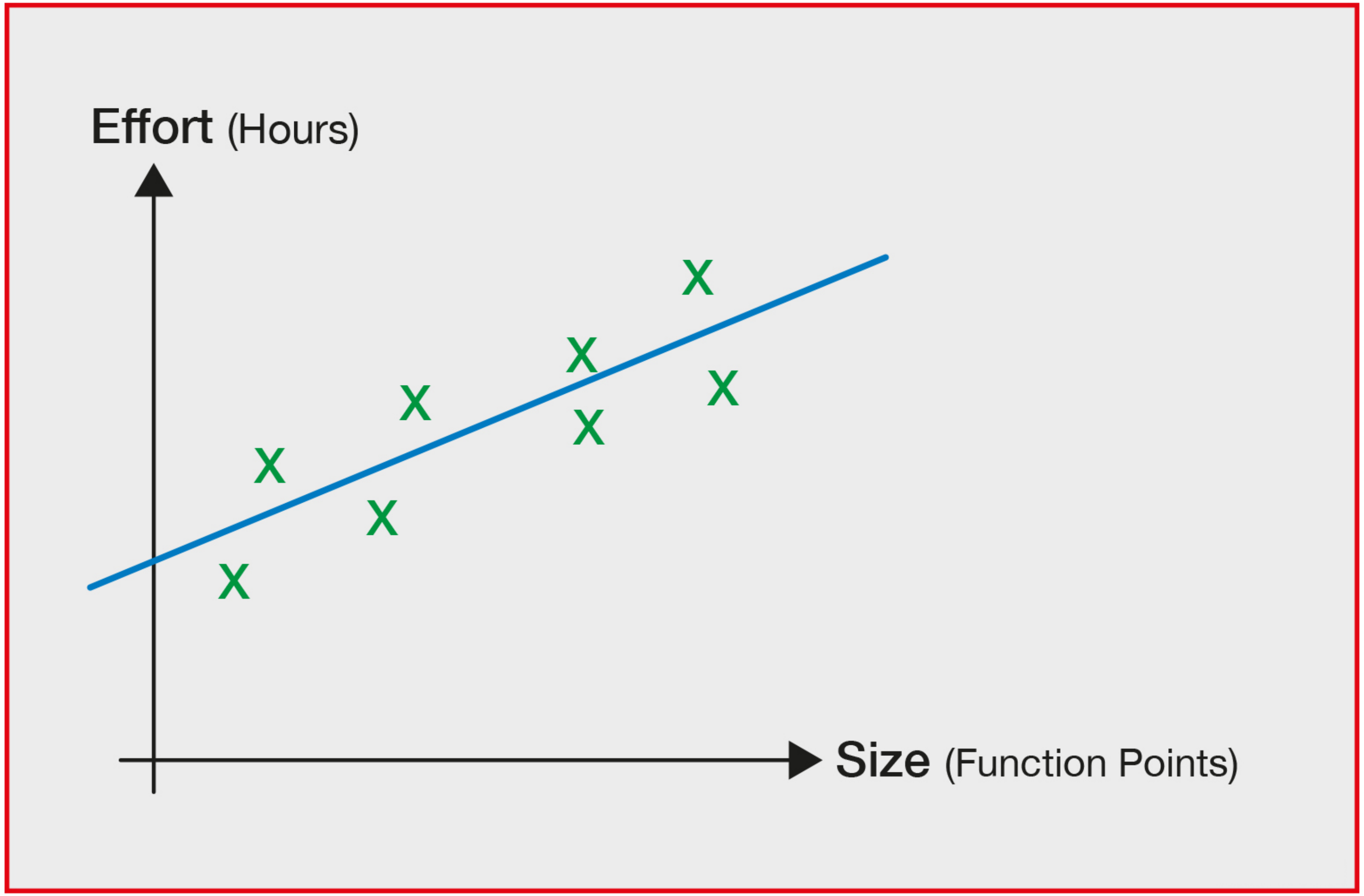
Wedge-shaped data sets: Causes of high dispersion in productivity

- The project data come from organizations with distinct production processes (distinct productivity behavior).
- The project data represent the development of software products with major differences (software domains, non functional requirements, etc.).
- The development process is out of control (unpredictable productivity performance from projects developed in an ad hoc manner).
- Data collected is based on post-event opinions, outside a sound measurement program.

Homogeneous data sets

- The dispersion of the effort as size increases is highly consistent.
- The increases in functional size explain 80% to 90% of the increases in effort.
  - All the other factors together explain only 10% to 20% of those increases.

Homogeneous data sets



Homogeneous data sets: Causes of low dispersion in productivity

- The project data come from a single organization with well implemented development standards.
- The project data represent the development of software products with very similar characteristics.
- The development process is under control, with predictable productivity performance (levels 4 or 5 of the CMMi model).
- The data were collected in an organization based on a sound in-process measurement program.

2.6
Productivity Models: Explicit & Implicit variables

Explicit variables

- The output (size) → independent variable
- The input (effort) → dependent variable

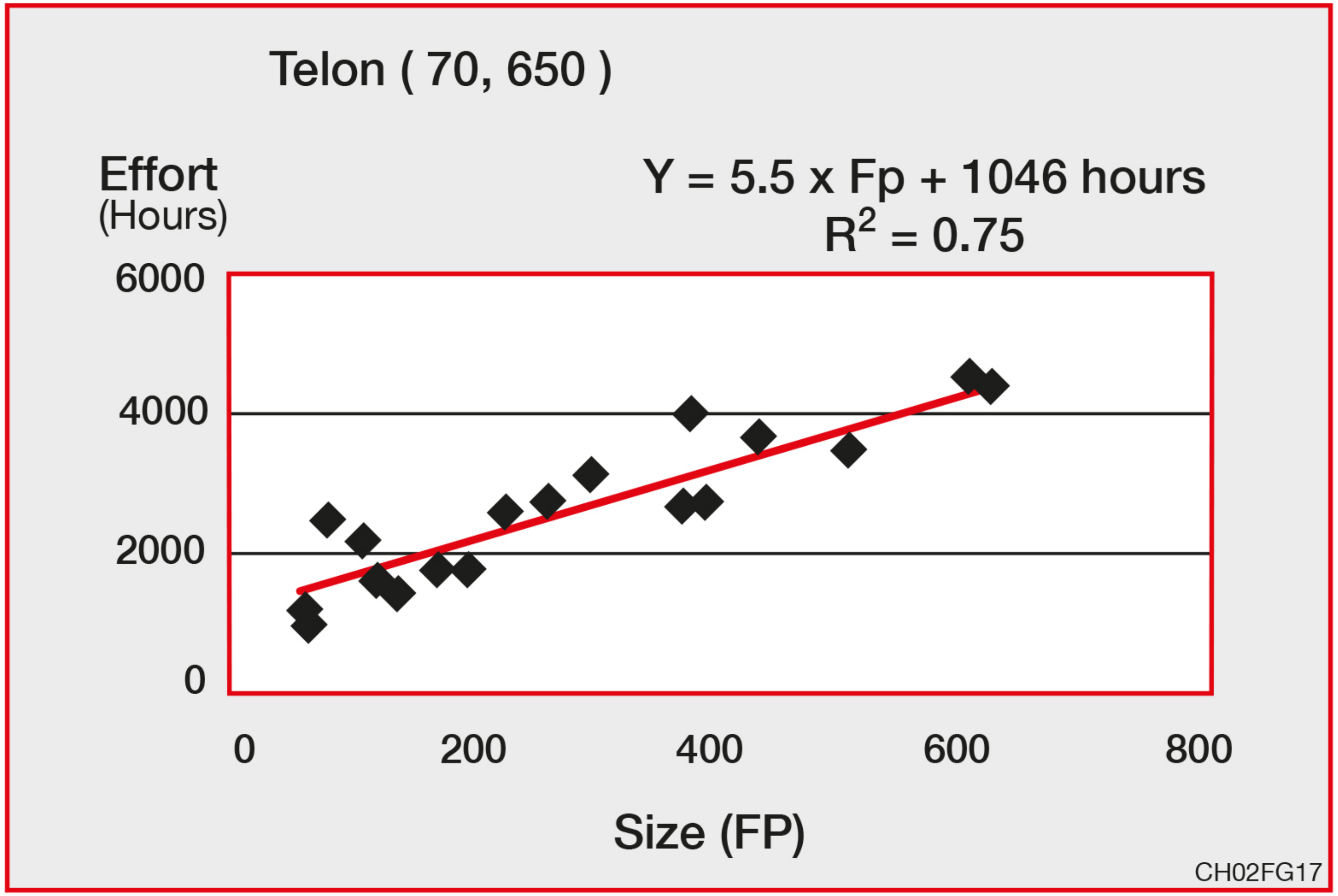
Implicit variables

- Team experience
- Project manager experience
- Software engineering environment platform
- Design methodology
- Quality controls

Size: Dominant variable in datasets

- Size is dominant if:
  - Most of the implicit variables in a set of projects are similar for all the projects in the sample.
    - These variables should have minimal impact on the unit cost.
    - The functional size will be the dominant independent variable impacting size.

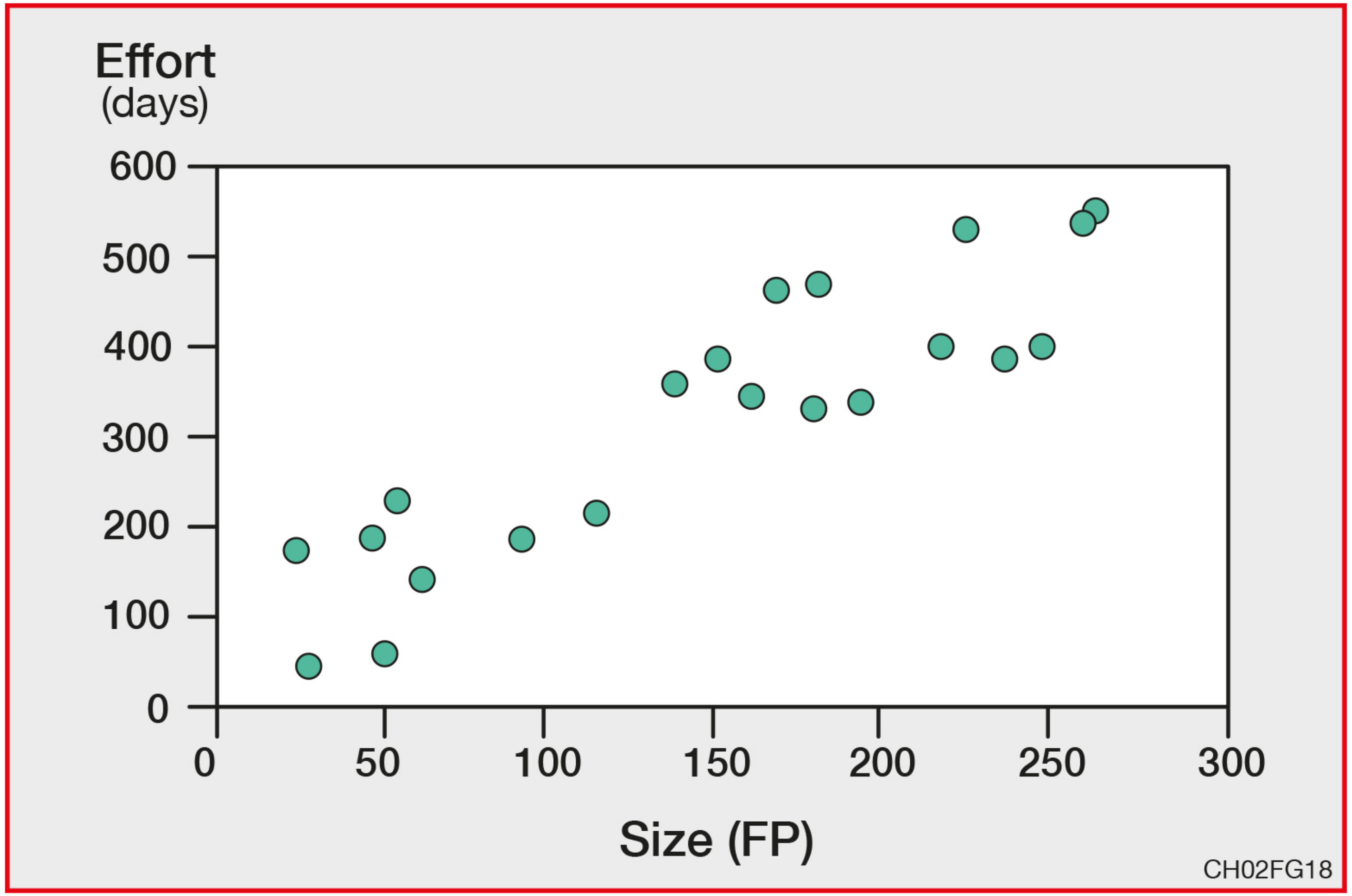
Example 1: Size as a dominant variable in a dataset



The TELON dataset in the ISBSG 1999 Release

(Abran, Ndiaye, Bourque, 2007)

Example 2: Size as a dominant variable in a dataset



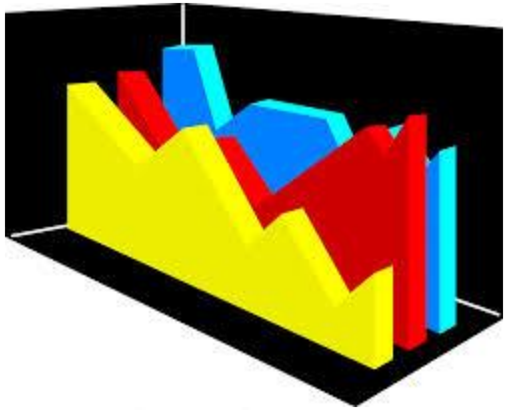
Homogeneous dataset of 21 projects (Abran 1994)

2.7
Multi-Dimensional vs Simpler Models

A classical approach

To build a single multi-variable estimation model and include in it as many cost drivers (i.e. independent variables) as possible (a ‘catch-all’ model).

Building models ....



- From available data.
- On opinions on cost-drivers.
- Multiple models with coexisting economies and diseconomies of scale.

Models from available data

- The builders have access to a reasonable set of data points on completed projects.
  - The largest possible number of variables included in the available dataset
  - Cost drivers (the authors' own definition)
  - Measurement rules for these costs drivers (authors' own definition)
  - Impact factors (authors' own assignment).
- Complex models with a large number of variables 'n'

Models built on opinions on cost-drivers

http://blog.capterra.com/much-membership-management-software-cost/

- Feel good estimation models
- Based on practitioners' opinions
  - about various variables and the corresponding estimated impact.
- This 'expert judgment approach'
  - It is used when an organization does not collect data.

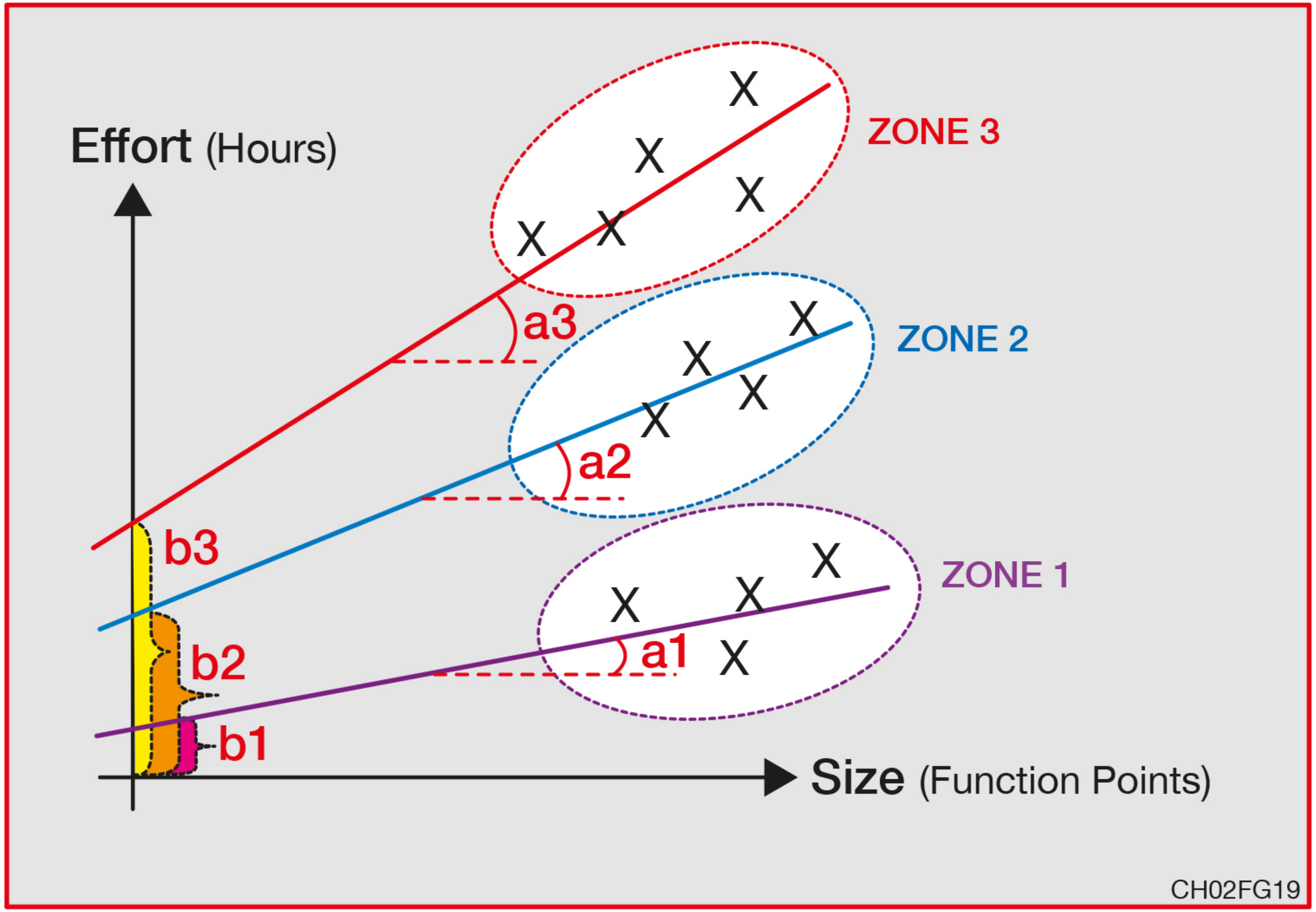
A more realistic approach

A single model cannot be the best in all circumstances.

There is a very large diversity of development processes, different mixes of costs drivers, and most probably different impacts of these cost drivers, depending on the contexts.

A more realistic approach

The classical concepts of economies and diseconomies of scale are applicable to software development processes.



Wedge shape with 3 data subsets with economies/diseconomies of scale.

Economies and diseconomies of scale

- Zone 1: The lower part of the wedge-shaped dataset represents the set of projects demonstrating large economies of scale.

- Zone 2: Middle of the wedge-shaped dataset.

- Zone 3: The upper part of the wedge-shaped dataset represents the set of projects demonstrating diseconomies of scale.

Economies and diseconomies of scale

- Three distinct productivity models within this single dataset:

$f1(x) = a1*x + b1$	zone 1
$f2(x) = a2*x + b2$	zone 2
$f3(x) = a3*x + b3$	zone 3

Discussion

Group discussion on Figure 2.19 with multiple candidate models from a wedge-shape dataset.

Exercises 1 to 5

Term Assignments 1 to 3