Management IS
Organizational level

- STRATEGIC LEVEL
- MANAGEMENT LEVEL
- KNOWLEDGE LEVEL
- OPERATIONAL LEVEL

Group served by IS

- SENIOR MANAGERS
- MIDDLE MANAGERS
- KNOWLEDGE & DATA WORKERS
- OPERATIONAL MANAGERS
Management Control

Goal definition (Planning)

Outcome control (Delta analysis)

Identification of corrective actions

Information about outcomes

EXECUTION / MONITORING
Guiding principle

What gets measured gets done

- Attributed to P. Drucker
Indicators

- What gets measured, gets done
- Indicators are measures
- Management and Strategic level IS should support managers in
  - Monitoring and controlling
  - Using few, reliable indicators
- How to define the indicators?
Approaches

- Management accounting
- CSF
- KPI
- Balanced scorecards
- (Customer and market profiling)
- (Strategic analysis methods)
# Approaches

<table>
<thead>
<tr>
<th>Financial performance monitoring</th>
<th>Process performance monitoring</th>
<th>Customers and market monitoring</th>
<th>Innovation and critical resources monitoring</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CSF (Critical Success Factors)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Management Accounting</td>
<td>KPI &amp; SCOR</td>
<td>Customer profiling &amp; Market analysis</td>
<td>Strategy Management Matrix</td>
</tr>
<tr>
<td>BSC (Balanced Score Cards)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Warning

The more any quantitative social indicator is used for social decision-making, the more subject it will be to corruption pressures and the more apt it will be to distort and corrupt the social processes it is intended to monitor.

• Campbell’s law
MEASUREMENT
Measurement

I often say that when you can measure what you are speaking about, and express it in numbers, you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meager and unsatisfactory kind. If you can not measure it, you can not improve it.

William Thomson, 1st Baron Kelvin
Measurement

the process of empirical objective assignment of numbers to entities, in order to characterize a specific attribute thereof
Measurement

- **Entity:**
  - an object or event

- **Attribute:**
  - a feature or property of an entity

- **Objective:**
  - the measurement process must be based on well-defined rules whose results are repeatable
Measurement Conceptual Model

Adapted from ISO/IEC 15939:2007
Terms

Measure (noun): variable to which a value is assigned as the result of measurement.

Measure (verb): Make a measurement.

Measurement: The process of assigning a number or category to an entity to describe an attribute of that entity.

Metric: A measurement scale and the method used for measurement

Indicator: Measure that provides an estimate or evaluation derived from a model with respect to defined information needs
## Examples of measures

<table>
<thead>
<tr>
<th>Entity</th>
<th>Attribute</th>
<th>Measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Person</td>
<td>Age</td>
<td>Year of birthday</td>
</tr>
<tr>
<td>Person</td>
<td>Age</td>
<td>Months since birth</td>
</tr>
<tr>
<td>Source code</td>
<td>Length</td>
<td># Lines of Code (LOC)</td>
</tr>
<tr>
<td>Source code</td>
<td>Length</td>
<td># Executable statements</td>
</tr>
<tr>
<td>Testing process</td>
<td>Duration</td>
<td>Time in hours from start to finish</td>
</tr>
<tr>
<td>Tester</td>
<td>Efficiency</td>
<td>Number of faults found per KLOC</td>
</tr>
<tr>
<td>Testing process</td>
<td>Fault frequency</td>
<td>Number of faults found per KLOC</td>
</tr>
<tr>
<td>Source code</td>
<td>Quality</td>
<td>Number of faults found per KLOC</td>
</tr>
<tr>
<td>Operating system</td>
<td>Reliability</td>
<td>Mean Time to Failure</td>
</tr>
</tbody>
</table>
Measurement Process

Establish & sustain commitment

Requirements

Info needs

Tech/Mgmt Process

Plan

Perform

Evaluate

Experience base

Improvement actions

Adapted from IEC/ISO 15939:2007
Rules

- Specify both entity and attribute
  - The entity must be defined precisely
- You must have a reasonable, even intuitive understanding of the attribute before you propose a measure.
- You must not re-define an attribute to fit in with an existing measure.
Direct measures

- **Length** of source code
  - E.g. measured by LOC
- **Duration** of testing process
  - E.g. measured by elapsed time in hours
- **Number of defects discovered** during the testing process
  - E.g. measured by counting defects
- **Effort** of a programmer on a project
  - E.g. measured by person months worked
Indirect measures

Programmer productivity = \frac{\text{LOC produced person}}{\text{months of effort}}

Module defect density = \frac{\text{number of defects module}}{\text{size}}

Defect detection efficiency = \frac{\text{number of defects detected}}{\text{total number of defects}}

Requirements stability = \frac{\text{# of initial requirements}}{\text{total #of requirements}}

Test effectiveness ratio = \frac{\text{number of items covered}}{\text{total number of items}}

System spoilage = \frac{\text{effort spent fixing faults}}{\text{total project effort}}
Entity classes

- **Resource**
  - an item which is input to a process

- **Process**
  - a software related activity or event

- **Product**
  - an object which results from a process
Internal vs. External

Given an entity:

- **Internal** (intrinsic) measures can be collected in terms of the entity itself
  - e.g. length or structuredness of source code
- **External** measures can only be collected observing the entity in its environment
  - e.g. reliability or maintainability of source code (product)
- **In–Use** measure depends on the use of the entity by different user classes
  - e.g. user satisfaction or usability
## Metrics

<table>
<thead>
<tr>
<th>Entities</th>
<th>Attributes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PRODUCTS</strong></td>
<td><strong>Internal</strong></td>
</tr>
<tr>
<td>Specification</td>
<td>Length, functionality</td>
</tr>
<tr>
<td>Source Code</td>
<td>modularity, structuredness, reuse</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>PROCESSES</strong></td>
<td><strong>time, effort, #spec</strong></td>
</tr>
<tr>
<td>Design</td>
<td>faults found time, effort, #failures</td>
</tr>
<tr>
<td>Test</td>
<td>observed</td>
</tr>
<tr>
<td><strong>RESOURCES</strong></td>
<td><strong>age, price, CMM level</strong></td>
</tr>
<tr>
<td>People Tools</td>
<td>price, size</td>
</tr>
</tbody>
</table>
MEASUREMENT THEORY
Evolution of measures

- More sophisticated measures can be defined as understanding of an attribute grows
- E.g. temperature of liquids:
  - 200BC: rankings, “hotter than”
  - 1600: first thermometer still “hotter than”
  - 1720: Fahrenheit scale
  - 1742: Centigrade scale
  - 1854: Absolute zero, Kelvin scale
Measurement theory

- Scientific basis to determine formally:
  - When we have defined an actual measure
  - Which statements involving measurement are meaningful
  - What the appropriate scale type is
  - What types of statistical operations can be applied to measurement data

- Based on foundation laid down by S.S. Stevens (1946)
Empirical relation system

- A set of **entities**
- The **relations** which are observed on entities in the real world which characterize our understanding of the attribute in question
  - e.g. ‘Fred taller than Joe’ (for **height** of **people**)
- The closed **operations** that can be performed on the objects
Measurement mapping

- Mapping from the empirical relation system onto a **formal relation system**
- Consists of
  - Metric
  - Relation mapping
- A.ka. representation, homomorphism
- Measure: the value (formal element) assigned to an entity in order to characterize an attribute
Measurement mapping

Joe IS TALLER THAN Fred

Height

M(Joe) = 180

M(Fred) = 172

M(Joe) > M(Fred)
Representation condition

- Measurement mapping implies that all empirical relations are preserved in formal (numerical) relations and no new relation is introduced
  - e.g. $M(Fred) > M(Joe)$ precisely when Fred is taller than Joe

- **Admissible metric** if the representation condition holds
  - Measurement scale
Formally

- We can define a homomorphism $m$

  scale: $(E, \mathcal{F}, m)$

  empirical system: $\mathcal{E} = (E, \text{taller})$

  formal system: $\mathcal{F} = (\mathbb{R}, >)$

  mapping function: $m : E \rightarrow \mathbb{R} |$

  $\forall a, b \in E, a \text{ taller } b \implies m(a) > m(b)$
Additive metric

- A possible additional requirement is to have and additive measure

\begin{align*}
 \text{scale:} & \quad (\mathcal{E}, \mathcal{F}, m) \\
 \text{empirical system:} & \quad \mathcal{E} = (E, \text{taller, added}) \\
 \text{formal system:} & \quad \mathcal{F} = (\mathbb{R}, >, +) \\
 \text{mapping function:} & \quad m : E \to \mathbb{R} | \\
 & \quad \forall a, b \in E : \\
 & \quad a \text{ taller } b \implies m(a) > m(b) \\
 & \quad m(a \text{ added } b) = m(a) + m(b)
\end{align*}
Admissible transformation

- Metrics are not unique, in general there are several homomorphisms

- Admissible transformation $\Phi$
  - $\Phi \circ m$ is an homomorphism
  - Mapping between two measures, e.g. length
    - Admissible transformation: $M' = a \cdot M$
    - Inadmissible transformation: $M' = a \cdot M + b$
Issues

- **Representation problem**
  - How do we know if a particular empirical relation system has a representation in a given numerical relation system?

- **Uniqueness problem**
  - How do we deal with several possible alternative representations (scales) in the same numerical relation system?

- **Pragmatic problem**
  - Which is the preferred numerical relation system for a given empirical relation system?
Relation System richness

- $RS_A$ is richer than $RS_B$ if all relations in $RS_B$ are contained in $RS_A$
- The richer the empirical system the more sophisticated the scale
- Complex and well understood phenomena require more sophisticated measurement scales
MEASUREMENT SCALES
Scale classification

- Measurement scales can be classified according to the class of admissible transformations
  - The larger the set of admissible transformations, the looser, less accurate, and less rich the scale
  - The smaller the set of admissible transformations the more accurate and richer the scale
Scale types

- Nominal
- Ordinal
- Interval
- Ratio
- Absolute

Richness

Simplicity
Nominal scale

- Places elements in classification scheme
- Empirical relation: different classes
  - No ordering relation
- Any distinct numbering or symbolic representation is acceptable
  - No notion of magnitude
Nominal scale example

- **Empirical system**
  - Entity: person
  - Attribute: origin
    - Italy, EU, Extra-EU

- **Admissible mapping**
  - \( M(p) = \)
    - \( 1 \) if \( p \) is from Italy
    - \( E \) if \( p \) is from any EU country
    - \( X \) if \( p \) is from a non EU country
Nominal Statistics

- Only a base operation: count
- Available statistics
  - Frequency (per category)
  - Mode
Ordinal scale

- Empirical system: classes of entities ordered w.r.t. attribute
- Empirical relation: total order
- Acceptable mapping: any mapping preserving the order
  - Measure represent ranking only
  - Acceptable transformations are the set of all monotonic mappings
  - \(<C_1, C_2, \ldots, C_n> \rightarrow <a_1, a_2, \ldots, a_n>\)
  - Where \(\forall i>j, \ a_i > a_j\)
Ordinal scale example

- **Empirical system**
  - **Entity:** statement
  - **Attribute:** agreement
    - Completely disagree, Mostly disagree, Mostly agree, Completely agree

- **Admissible mapping**
  - \[ M(x) = \begin{cases} 
  -2 & \text{if } x \text{ is Completely disagree} \\
  -1 & \text{if } x \text{ is Mostly disagree} \\
  1 & \text{if } x \text{ is Mostly agree} \\
  10 & \text{if } x \text{ is Completely agree} 
  \end{cases} \]
Ordinal Statistics

- Operations:
  - Counting
  - Sorting

- Available statistics
  - Frequency (per category)
  - Mode
  - Rank
  - Quantiles (Median)
Interval scale

- Empirical system: order and differences between classes
- Empirical relation: distance from a reference point
- Acceptable mappings: preserve order and difference
  - Addition and subtraction make sense
  - The ratio makes no sense
- Acceptable transformations are affine transformations
  - $M' = a \times M + b$
Interval scale example

- **Empirical system**
  - Entity: activity
  - Attribute: calendar start time
    - Gregorian calendar
    - Months since project begin

- **Admissible transformation**
  - PM counts month since project start
    - Jan 1, 2010
  - CEO uses calendar year

  \[ M_{PM} = 12 \times (M_{CEO} - 2010) \]
Interval Statistics

- Operations:
  - Counting, sorting
  - Sum, Difference, Scalar division

- Available statistics
  - Frequency, Mode, Rank, Quantiles
  - Mean (Arithmetic Average)
  - Variance (and derivatives)
Ratio scale

- Empirical system: there is a **zero element**
  - Represents total lack of attribute
  - Measurement starts at zero and increases at equal intervals (or part of): called **units**
  - All arithmetic can be applied meaningfully to classes in the range of the mapping
- Empirical relation: ratio between entities
- Admissible transformation
  - Ratio transformation
  - \( M' = a*M \)
Ratio scale example

- **Empirical system**
  - Entity: person
  - Attribute: age
    - Years, Months

- **Admissible transformation**
  - \( M_{\text{Months}} = a \times M_{\text{Year}} \)
    - Where \( a = 12 \)
Ratio Statistics

- **Operations:**
  - Counting, sorting
  - Sum, Difference, Scalar division
  - Division, (Multiplication)

- **Available statistics**
  - Frequency, Mode, Rank, Quantiles, Mean (Arithmetic Average), Variance (and derivatives)
  - Standardized mean difference, etc.
  - Geometric mean, etc.
Absolute scale

- Measurement made simply counting items in the entity set
  - Number of occurrences
  - Only one possible mapping
  - All arithmetic analysis is meaningful
Absolute scale (counter)examples

- Empirical system
  - Entity: project
  - Attribute: full time staff
    - Number of full time developers

- The attribute definition implies the items to be counted!
  - Length is not measurable on an absolute scale, # of lines it is
  - Age is not measurable on absolute scale
# Scales

<table>
<thead>
<tr>
<th>Scale</th>
<th>Admissible Transformations</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal</td>
<td>1–to–1 mapping</td>
<td>Labeling, classifying entities</td>
</tr>
<tr>
<td>Ordinal</td>
<td>Monotonic increasing function</td>
<td>Preference, hardness</td>
</tr>
<tr>
<td>Interval</td>
<td>$M' = a \cdot M + b$&lt;br&gt;With: $a &gt; 0$</td>
<td>Relative time, temperature</td>
</tr>
<tr>
<td>Ratio</td>
<td>$M' = a \cdot M$&lt;br&gt;With: $a &gt; 0$</td>
<td>Time interval, length</td>
</tr>
<tr>
<td>Absolute</td>
<td>$M' = M$</td>
<td>Counting entities</td>
</tr>
</tbody>
</table>
Meaningful statements

- A statement involving measurement is meaningful if its truth is invariant of transformation of allowable scales
  - i.e. the conclusion is the same after an admissible transformation is applied
Meaningful statements

- Statements
  - ✓ The number of errors discovered during the integration testing was at least 100
  - ✓ The cost of fixing each error is at least 100
  - ✓ A semantic error takes twice as long to fix as a syntactic error
  - ✓ A semantic error is twice as complex as a syntactic error
Meaningful statements?

- Fred is twice as tall as Jane

- The temperature in Tokyo today is twice that in London

- The difference in temperature between Tokyo and London today is twice what it was yesterday
### Statistical operations

#### Central tendency

<table>
<thead>
<tr>
<th>Type</th>
<th>Mean</th>
<th>Median</th>
<th>Mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal</td>
<td>✓</td>
<td>✗</td>
<td>✓</td>
</tr>
<tr>
<td>Ordinal</td>
<td>✓</td>
<td>✗</td>
<td>✓</td>
</tr>
<tr>
<td>Interval</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Ratio</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Absolute</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>
Objective vs. Subjective

- Objective measures do not depend on the environment or the person collecting the measure
  - A small portion of subjectivity cannot be avoided
- Subjective measures depend on the context where they are collected
  - Can change according to the person
  - They reflect the perception and judgment of the person performing the measurement
Interpretation

- If only measure values are available you know nothing
- Interpretation requires a reference to
  - Target
  - Benchmark
  - Time series
  - Population norm
Interpretation

- **Conformance**: compare to a specific business or usage requirement
- **Benchmark**: compare with a benchmark for similar product or system
- **Time series**: observe trend in time
- **Population norms**: compute quantile
  - Require a db of previous values
Interpretation: rating

Measurement scale

Rating level

Opportunity

Acceptable

Unacceptable

Minimum level of measure for providing opportunity

Minimum level of measure to avoid risk
MANAGEMENT ACCOUNTING
Accounting

- Accounting
  - Focuses on cost, revenues, cash flow, investment, capital
  - Financial accounting
    - Public data, accounting standards and laws
    - Historical perspective
  - Management accounting
    - Private, sensible data
    - Fit for use of company/managers (no standards)
Management accounting

- **Cost accounting**
  - Budget and actual cost of operations, processes, departments, products
  - Analysis of variances and profitability

- **Direct and indirect costs**
  - Direct: directly traceable to a product/service sold to customer
  - Indirect: all others

- **Fixed and variable costs**
  - Fixed: do not depend on number of units produced
  - Variable: depend on the number of units
Activity based costing

- Management accounting technique
- Developed to overcome problems in direct/indirect costs
  - Traditionally, indirect costs were attributed proportionally to all products
    - Ex, direct cost 100, indirect cost 40%
  - Since indirect costs grow, proportional allocation hides costs of some products
    - Ex. Product1 consumes much more design or manufacturing than product2, true cost of product1 is higher
Activity based costing

- Activity based costing
  - From indirect (taxes, administration, security) to direct costs (traceable to product or service)
  - Allocates cost of each activity/resource to product and services in function of actual consumption
  - Aims at knowing true cost of product/service, identify profitable ones, define selling costs
Critical Success Factors

CSF
CSF

- Critical Success Factors
- Concept
  - Few areas (4–5) in a company are responsible for business success (failure)
  - They should be monitored constantly
- CSF refer to internal areas, not objectives or targets
  - Ex. objective: be market leader
  - Ex. target: acquire 25% of market share

[Rockart 79]
CSF – levels

- CSF exist at different levels
- Following organizational structure
  - Corporate
  - Function
    - Production, product design, etc.
  - Role
    - Manager
CSF – examples

- Corporate
  - Brand recognition, image
  - Dealers network
  - Equipment of cars
  - Reliability of cars
  - After sales service

- Function (manufacturing)
  - Production costs
  - Quality of product
  - Environment issues
  - Relationship with trade unions

- Manager (quality manager)
  - Reputation w.r.t. other functions/roles
  - Skills of technicians
  - Process certification
  - Technology for monitoring quality
CSF – Types

- **Industry / Domain**
  - the structure of the particular industry

- **Strategy**
  - competitive strategy, industry position, and geographical location

- **Environment**
  - the macro environment

- **Temporal / Contingency**
  - problems or challenges to the organization

- **Management**
  - management perspective
CSF objective

- To identify in top down mode essential information for managers
  - Cfr. bottom up: starting from currently available information
  - Cfr. Information vs. data
- To define / modify a reporting system within IS
CSF method

1. Identify candidate CSFs
2. Interview managers and identify indicators
3. Indicator robustness analysis
4. Refinement, presentation, implementation
1) Identify candidates

- For each candidate CSF
  - Level (corporate, function, role)
  - Name
  - Type
  - Description
CSF Examples

- Business domain
  - Key areas for all companies in same business domain
  - Ex: cost for PC manufacturers, skill of personnel for consulting companies
- Competitive factors within business domain
  - Factors that differentiate company from others
  - Ex: for airlines, low cost vs. quality of service
CSF Examples

- **Environmental factors**
  - Constraints from outside such as norms, rules, standards
  - Ex.: for car manufacturers, euroX pollution norms

- **Contingency factors**
  - Temporary constraint
  - Ex.: merge IS of two companies after financial merge/acquisition
  - Ex.: recover brand reputation after failures (see Benz Class A, BP oil spill)
## Example: Restaurant CSF

<table>
<thead>
<tr>
<th>CRITICAL SUCCESS FACTOR</th>
<th>TARGET</th>
</tr>
</thead>
<tbody>
<tr>
<td>Customer Satisfaction</td>
<td>83% extremely satisfied</td>
</tr>
<tr>
<td>Market Share</td>
<td>20% of 10 mile radius</td>
</tr>
<tr>
<td>Employee Turnover</td>
<td>25% per year</td>
</tr>
<tr>
<td>Food Quality</td>
<td>5% returned meals</td>
</tr>
</tbody>
</table>
Example: Non-profit Org. CSF

<table>
<thead>
<tr>
<th>CRITICAL SUCCESS FACTOR</th>
<th>TARGET</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Donors</td>
<td>15,000 monthly donors</td>
</tr>
<tr>
<td>People Served</td>
<td>2000 per month</td>
</tr>
<tr>
<td>Volunteers</td>
<td>350 active volunteers</td>
</tr>
<tr>
<td>Customer Satisfaction</td>
<td>92% extremely satisfied</td>
</tr>
</tbody>
</table>
2) Interview managers

- Interview managers on candidate CSFs
  - CSF for function and role (max 5) and measures (1 or more) for each CSF
- Output, for each CSF
  - Measures,
  - Source of (raw) data,
  - Rationale
  - Reference
## 2) Output

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Unit</th>
<th>Source</th>
<th>Motivation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cost</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unit product cost</td>
<td>EUR</td>
<td>ERP</td>
<td>Key factor for production process competitiveness</td>
</tr>
<tr>
<td>Unit overhead</td>
<td>EUR</td>
<td>ERP</td>
<td></td>
</tr>
<tr>
<td><strong>Quality</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Production defect</td>
<td>Ratio</td>
<td>ERP</td>
<td>Measure of objective quality</td>
</tr>
<tr>
<td>Support defect</td>
<td>Ratio</td>
<td>Post–sale IS</td>
<td></td>
</tr>
</tbody>
</table>
## 2) Output

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Unit</th>
<th>Source</th>
<th>Motivation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Quality</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Customer judgment</td>
<td>Score</td>
<td>Sample interviews</td>
<td>Perceived quality</td>
</tr>
<tr>
<td>Comparison to competitors</td>
<td>Score</td>
<td>Test and sample interviews</td>
<td>Actual gaps</td>
</tr>
<tr>
<td>Comparison with historical data</td>
<td>Score</td>
<td>Test</td>
<td>Achieved improvements</td>
</tr>
<tr>
<td>Produced waste</td>
<td>Tons</td>
<td>Ad-hoc measure</td>
<td>Key for green image of organization</td>
</tr>
<tr>
<td>Recyclable materials</td>
<td>Tons</td>
<td>Ad-hoc measure</td>
<td></td>
</tr>
<tr>
<td>Energy consumption</td>
<td>Kw</td>
<td>Ad-hoc measure</td>
<td>Energy efficiency</td>
</tr>
</tbody>
</table>

**Environ**
3) Indicator Robustness

- Understandability
- Processing cost
- Significance
- Frequency
- Structuredness
3) Indicator Robustness

- Comprehensibility / Understandability
  - How simple

- Processing Cost
  - Cost and delay to process
  - Cost and delay to collect raw data
  - Initial and incremental

- Significance / Meaningfulness
  - How much the indicator covers the CSF

- Frequency
  - How often indicator varies

- Structuredness
  - How much the indicator is objective/not ambiguous
## Robustness

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Understand</th>
<th>Cost</th>
<th>Relevance</th>
<th>Frequency</th>
<th>Structure</th>
<th>Robustness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit direct cost</td>
<td>5</td>
<td>4</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>4.8</td>
</tr>
<tr>
<td>Unit overhead</td>
<td>4</td>
<td>5</td>
<td>4</td>
<td>2</td>
<td>4</td>
<td>3.8</td>
</tr>
<tr>
<td>Production defects</td>
<td>4</td>
<td>5</td>
<td>4</td>
<td>5</td>
<td>5</td>
<td>4.6</td>
</tr>
<tr>
<td>Support defects</td>
<td>5</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>5</td>
<td>4.4</td>
</tr>
<tr>
<td>Customer rating</td>
<td>5</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>3.0</td>
</tr>
<tr>
<td>Competitor comparison</td>
<td>2</td>
<td>3</td>
<td>5</td>
<td>3</td>
<td>3</td>
<td>3.2</td>
</tr>
<tr>
<td>Past comparison</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>3.0</td>
</tr>
<tr>
<td>Waste processing</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>5</td>
<td>4</td>
<td>3.8</td>
</tr>
<tr>
<td>Recyclable materials</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>3.4</td>
</tr>
<tr>
<td>Energy consumption</td>
<td>2</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>5</td>
<td>3.8</td>
</tr>
</tbody>
</table>
4) Refinement, presentation

- **Refinement**
  - Aggregate, simplify CSFs
- **Presentation**
  - And acceptance from managers
- **Implementation**
  - Define requirements and design for IS
  - Implement
CSF – Case study

- Company: Politecnico di Torino
- Missions
  - Education
  - Research
  - Technology transfer
KPI – KEY PROCESS INDICATOR
KPI

- Process perspective
  - Cfr CSF, focuses on areas
    - May correspond to process but in general wider and cross processes
  - Cfr financial indicators (traditional management accounting), focus on finance only
  - Cfr. SLA (service level agreement), ITIL, focuses on process
KPI

- **Process view**
  - Involves one or more hierarchical nodes
  - Financial and non financial indicators
  - Process as a chain of services
SMART KPI

- **S**pecific purpose for the business,
- **M**easurable
- **A**chievable
- **R**elevant
- **T**imely
KPI

- Ex. Average delay to satisfy order
- Ex. Average productivity of resource
KPI General framework

Input volume
Output volume
Human resources
Material resources
Inventory
Other resources

General

KPI

Efficiency
- Cost per unit
- Productivity of unit
- Utilization of resources

Quality
- Conformity
- Reliability
- Customer satisfaction

Service
- Response time
- Lead time
- On time ratio
- Perfect orders ratio
- Flexibility towards customers
### General KPIs – examples

<table>
<thead>
<tr>
<th>General KPIs</th>
<th>Hotel reservation</th>
<th>Lift maintenance</th>
<th>Product sale supermarket</th>
<th>Book sale on web</th>
<th>Building license (e.gov)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Input volumes</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td># reservation requests, modify, delete</td>
<td>#urgent requests, normal requests</td>
<td>#sales (person passing at register)</td>
<td># orders</td>
<td>#licences requested</td>
<td></td>
</tr>
<tr>
<td><strong>Output volumes</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>#reserved rooms</td>
<td>#services completed</td>
<td>#invoices</td>
<td># shippings</td>
<td>#books sold</td>
<td>#licences issued</td>
</tr>
<tr>
<td><strong>Human resources</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>#full time, part time employees</td>
<td>#personnel for maintenance (technical)</td>
<td>#personnel (at cash register, security)</td>
<td>#personnel for sales and distribution</td>
<td>#employees</td>
<td></td>
</tr>
<tr>
<td><strong>Material resources</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Supporting IS</td>
</tr>
<tr>
<td>Call center, reservation system, workstations, supplies</td>
<td>Reservation and dispatch system, tools</td>
<td>Sales building, storage building, products</td>
<td>CRM, call center, website, storage building</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Inventory</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>#rooms</td>
<td>--</td>
<td>#products on shelves</td>
<td>#books</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td><strong>Other resources</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>Laws</td>
<td></td>
</tr>
</tbody>
</table>
Efficiency KPIs

- Cost per unit
  - Total cost / I/O volume

- Productivity
  - Volume/resource

- Utilization
  - Used resource / available resource

Volumes and Resources refer to any general → indirect measures
## Efficiency KPI

<table>
<thead>
<tr>
<th></th>
<th>Unit cost</th>
<th>Productivity</th>
<th>Utilization</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Input</strong></td>
<td>Cost per unit of input</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td><strong>Output</strong></td>
<td>Cost per unit of output</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Human resources</strong></td>
<td>--</td>
<td>Output/ # employees</td>
<td>Used / Available</td>
</tr>
<tr>
<td></td>
<td>--</td>
<td>Output/ resource (ex # machines)</td>
<td>Used capacity / available capacity</td>
</tr>
<tr>
<td><strong>Non human resources</strong></td>
<td>--</td>
<td>Sales/ stock</td>
<td>Load factor</td>
</tr>
<tr>
<td><strong>Inventory</strong></td>
<td>--</td>
<td>Time to produce/output</td>
<td>Time to service/ total time</td>
</tr>
<tr>
<td><strong>Time</strong></td>
<td>--</td>
<td>Amount information/output</td>
<td>Amount info / total amount information</td>
</tr>
<tr>
<td><strong>Information</strong></td>
<td>Amount information/output</td>
<td>--</td>
<td></td>
</tr>
</tbody>
</table>
# Efficiency KPI

<table>
<thead>
<tr>
<th>Input</th>
<th>Unit cost</th>
<th>Productivity</th>
<th>Utilization</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost per unit of input</td>
<td>--</td>
<td>Design and Sw Industries</td>
<td></td>
</tr>
<tr>
<td>Cost per unit of output</td>
<td>--</td>
<td>Output/ # employees</td>
<td>Used/ Available</td>
</tr>
<tr>
<td>Human resources</td>
<td>Depends on industry</td>
<td>Output/ resource (ex # machines)</td>
<td>Immaterial sales e.g. plane seats</td>
</tr>
<tr>
<td>Non human resources</td>
<td>--</td>
<td>Sales/ stock</td>
<td>Load factor</td>
</tr>
<tr>
<td>Inventory</td>
<td>Inventory turnover</td>
<td>Time to produce/output</td>
<td>Time to service/ total time</td>
</tr>
<tr>
<td>Time</td>
<td>--</td>
<td>Time to produce/output</td>
<td>--</td>
</tr>
<tr>
<td>Information</td>
<td>Amount information/output</td>
<td>--</td>
<td>Amount info / total amount information</td>
</tr>
</tbody>
</table>
Exercise

- List efficiency KPIs for the following processes
  - Hotel reservation
  - Product sale supermarket
<table>
<thead>
<tr>
<th>Hotel Reservation</th>
<th>Unit cost</th>
<th>Productivity</th>
<th>Utilization</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input/output</td>
<td></td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Human resources</td>
<td></td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>Non human resources</td>
<td></td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>Inventory</td>
<td></td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>Time</td>
<td></td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>Information</td>
<td></td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Hotel Reservation</td>
<td>Unit cost</td>
<td>Productivity</td>
<td>Utilization</td>
</tr>
<tr>
<td>-------------------</td>
<td>-----------</td>
<td>--------------</td>
<td>-------------</td>
</tr>
<tr>
<td><strong>Input/output</strong></td>
<td>Total cost / # reservation reqs</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td>Total cost / # reserved rooms</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td><strong>Human resources</strong></td>
<td>#reservation reqs / #employees</td>
<td>#reserved rooms / #employees</td>
<td>Time servicing/shift duration</td>
</tr>
<tr>
<td><strong>Non human resources</strong></td>
<td>--</td>
<td>--</td>
<td>#hours worked(call center)/24hrs</td>
</tr>
<tr>
<td><strong>Inventory</strong></td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td><strong>Time</strong></td>
<td>--</td>
<td>--</td>
<td>Distribution of requests per hours</td>
</tr>
<tr>
<td><strong>Information</strong></td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
</tbody>
</table>
Quality KPIs

- **Conformity**
  - With defined service/product description
  - Non conform items/total # items
  - Items
    - Input requests (from customer)
    - Intermediate output
    - Final output (defects, complaints from customer)

- **Reliability**
  - Probability that product/system satisfies its function after time $T$
  - MTTF – mean time to failure
  - MTTR – mean time to repair
  - MTBF – mean time between failures ($= MTTF + MTTR$)

- **Customer satisfaction**
  - Satisfaction through interviews/questionnaires
    - Qualitative scales (very high, high ..)
# Quality KPIs

<table>
<thead>
<tr>
<th>Conformity</th>
<th>Input</th>
<th>Internal</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non conforming requests</td>
<td>Number discarded</td>
<td>Reject ratio</td>
<td>Complaints</td>
</tr>
<tr>
<td></td>
<td>Rework cost/total</td>
<td></td>
<td>Non conformity to requests, contract, or expectations</td>
</tr>
<tr>
<td>Reliability</td>
<td>--</td>
<td>MTTF</td>
<td>MTTF</td>
</tr>
<tr>
<td></td>
<td>MTBF</td>
<td></td>
<td>MTBF</td>
</tr>
<tr>
<td></td>
<td>MTTR</td>
<td></td>
<td>MTTR</td>
</tr>
<tr>
<td>Satisfaction</td>
<td>--</td>
<td>--</td>
<td>Satisfied customers ratio</td>
</tr>
<tr>
<td></td>
<td>--</td>
<td></td>
<td>Evaluation of product/service</td>
</tr>
</tbody>
</table>
# Quality KPIs

## Conformity

<table>
<thead>
<tr>
<th>Input</th>
<th>Internal</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non conforming requests</td>
<td>Number</td>
<td>Non-conformity to requests, contract, or expectations</td>
</tr>
<tr>
<td></td>
<td>Reject ratio</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Rework cost/total costs</td>
<td></td>
</tr>
</tbody>
</table>

## Reliability

<table>
<thead>
<tr>
<th></th>
<th>MTTF</th>
<th>MTBF</th>
<th>MTTR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input</td>
<td>--</td>
<td>MTTF</td>
<td>MTBF</td>
</tr>
<tr>
<td>Internal</td>
<td>MTBF</td>
<td>--</td>
<td>MTTR</td>
</tr>
</tbody>
</table>

## Satisfaction

<table>
<thead>
<tr>
<th></th>
<th>Satisfied customers ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input</td>
<td>--</td>
</tr>
<tr>
<td>Internal</td>
<td>Judgment collected through polls</td>
</tr>
<tr>
<td></td>
<td>Evaluation of product/service</td>
</tr>
</tbody>
</table>
Exercise

- Define quality KPI for
  - Hotel reservation process
<table>
<thead>
<tr>
<th>Hotel Reservation</th>
<th>Input</th>
<th>Internal</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conformity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reliability</td>
<td>--</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Satisfaction</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
</tbody>
</table>
# Quality KPIs

<table>
<thead>
<tr>
<th>Hotel Reservation</th>
<th>Input</th>
<th>Internal</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Conformity</strong></td>
<td>#reservations with problem/#reserved rooms</td>
<td>#cancelled reservations/#reserved rooms</td>
<td>Complaints from customers</td>
</tr>
<tr>
<td><strong>Reliability</strong></td>
<td>--</td>
<td>#lost reservations/#reserved rooms</td>
<td></td>
</tr>
<tr>
<td><strong>Satisfaction</strong></td>
<td>--</td>
<td>--</td>
<td>Customers’ opinion</td>
</tr>
</tbody>
</table>
Service KPIs

- **Response time (supplier pov), Lead time (customer pov)**
  - Time to satisfy order, from reception to delivery of good/service
    - To be checked in peak periods
- **Timeliness**
  - delay = actual lead time – nominal lead time
  - Average delay
  - # delayed orders
- **Perfect orders**
  - On time and within specifications
- **Flexibility towards customer**
  - # modified orders/ total # orders
  - value modified orders/ total value of orders
    - It is NOT internal flexibility = how internal resources can respond to changes in mix/number of orders
Processes and stakeholders

- Process has several stakeholders
  - Operator
  - Manager
  - Customer

- Process (and consequently KPIs) should be designed by considering all stakeholders
  - Ex cost
    - Cost for operator: work fatigue
    - Cost for manager: financial cost
    - Cost for customer: price tag + cost for finding ordering and obtaining the product
## KPIs and stakeholders

<table>
<thead>
<tr>
<th>Cost</th>
<th>Quality</th>
<th>Service</th>
</tr>
</thead>
<tbody>
<tr>
<td>• T non value activity / T total</td>
<td>• Conformance and internal reliability (System error rate)</td>
<td>• System response time by Operator process</td>
</tr>
<tr>
<td>• T occupied / T total</td>
<td>• Operator satisfaction</td>
<td></td>
</tr>
<tr>
<td>• T info access</td>
<td>• Conformance (input &amp; output quality)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Internal reliability (MTBF, MTTR)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Customer satisfaction</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operator</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manager</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Unit cost</td>
<td>• Conformance to request</td>
<td>• Response time, lead time</td>
</tr>
<tr>
<td>• Resource Productivity</td>
<td>• Product/service reliability</td>
<td>• Timeliness</td>
</tr>
<tr>
<td>• Resource saturation</td>
<td>• Satisfaction</td>
<td>• Perfect orders</td>
</tr>
<tr>
<td>• Time saturation</td>
<td></td>
<td>• Flexibility</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Customer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Price / Supplier cost</td>
<td>• Conformance to request</td>
<td></td>
</tr>
<tr>
<td>• Time and cost to get product or service</td>
<td>• Product/service reliability</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Satisfaction</td>
<td></td>
</tr>
</tbody>
</table>
Interpretation

- If you only have absolute values and no reference you know nothing

- Reference to
  - Target
  - Benchmark
  - Time series
  - Population norm
KPI – steps

1. Select processes to monitor
2. For each process, select KPIs
3. Profile KPI
4. Robustness and CSF
5. Dimensions
6. Requirements and design
1. Select processes

- Starting from models
  - SCOR
  - AP
  - Measurement standards (e.g. SQUARE)
  - Business domain specific
2. Select KPIs

- Using KPI templates
  - General
  - Efficiency
  - Quality
  - Service
3. Profile KPI

- Name
- Category
- Goal
- Metric definition
  - Measurement procedure
  - Formula
  - Unit of Measure
  - Scale
  - Interpretation
- Source (where the data comes from)
4. Robustness

- Are KPIs covering strategic areas?
  - Cross check with CSF

- Are KPIs robust?
  - Comprehension
  - Cost
  - Meaningfulness
  - Frequency
  - Structure
4. Indicator Robustness

- Comprehensibility / Understandability
  - How simple

- Processing Cost
  - Cost and delay to process
  - Cost and delay to collect raw data
  - Initial and incremental

- Significance / Meaningfulness
  - How much the indicator covers the CSF

- Frequency
  - How often indicator varies

- Structuredness
  - How much the indicator is objective/not ambiguous
5. Dimensions

- Or segmentation:
  - Entities to which indicator is associated and therefore
  - Data the indicator can be aggregated on
  - Dimensions are typically nominal or ordinal metrics
Common dimensions

- **Time window**
  - Sales per hours/per day/per month ..
- **Hierarchical node in organizational – geographical structure**
  - Sales per country/per region/per shop
  - Expenses per company/per division/per group/per person
- **Product / product category**
  - Sales per phone xy / per business phones
- **Customer / customer category**
- **Activity in process**
  - Cost per design / production
  - Defects from design/ from production
- **Project**
  - Cost per project
  - Defects per project
6. Requirements and design

For supporting IS

- Define requirements
- Design
  - Presentation (visual literacy)
  - Interaction (exploration)
  - Dashboard
KPI vs CSF

- **CSF**
  - vital for a strategy to be successful.
  - drives the strategy forward, it makes or breaks the success of the strategy
  - “Why would customers choose us?”

- **KPI**
  - quantify management objectives
    - along with a target or threshold
  - enable the measurement of strategic performance.
BALANCED SCORECARDS
Balanced scorecards

- Financial perspective on company performance is limited
- Managers can only partially act on financial outcome of a company
- Better to focus on more perspectives

[Kaplan and Norton1992]
Perspectives

- **Financial**
  - To succeed financially, how should we appear to our shareholders?

- **Customer**
  - To achieve our vision, how should we appear to our customers?

- **Internal process**
  - To satisfy our shareholders and customers, what business processes must we excel at?

- **Innovation and learning**
  - To achieve our vision, how will we sustain our ability to change and improve?
Balanced Scorecard for Performance Measurement

Figure 1 shows the original structure for the Balanced Scorecard approach. It consists of four perspectives:

1. **Financial Perspective**
   - Objectives: “To succeed financially, how should we appear to our shareholders?”
   - Measures
   - Targets
   - Initiatives

2. **Customer Perspective**
   - Objectives: “To achieve our vision, how should we appear to our customers?”
   - Measures
   - Targets
   - Initiatives

3. **Internal Business Process Perspective**
   - Objectives: “To satisfy our shareholders and customers, what business processes must we excel at?”
   - Measures
   - Targets
   - Initiatives

4. **Learning and Growth Perspective**
   - Objectives: “To achieve our vision, how will we sustain our ability to change and improve?”
   - Measures
   - Targets
   - Initiatives

These perspectives are interconnected, forming a comprehensive view of organization performance.
Indicators

- Objectives
- Measure
- Target
- Initiative
Perspectives and indicators

- Financial
  - Cash flow
  - Return on investment
  - Financial result
  - Return on capital invested
  - Return on equity

- Customer (the value proposition)
  - Customer satisfaction
  - Market share
  - Quality
  - Service
Perspectives and indicators

- **Internal process (that deliver the customer value proposition)**
  - Number of activities
  - Opportunities success rate
  - Accident ratios
  - Manufacturing indicators (loading, availability, performance quality)

- **Innovation and learning**
  - Investment rate
  - Illness rate
  - Internal promotions %
  - Employee turnover
  - Gender ratios
## Dashboard BSC

<table>
<thead>
<tr>
<th>Financial perspective</th>
<th>Customer perspective</th>
</tr>
</thead>
<tbody>
<tr>
<td>- turnover</td>
<td></td>
</tr>
<tr>
<td>- ROI</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Internal processes</th>
<th>Innovation and learning</th>
</tr>
</thead>
</table>
How to implement

- Define vision, translate into operational goals
- Communicate vision, link to individual performance
- Business planning
- Feedback
DATA QUALITY
## ISO – SQuaRE

### Family of standards

<table>
<thead>
<tr>
<th>2503x</th>
<th>2501x</th>
<th>2504x</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quality Requirements</td>
<td>Quality Model</td>
<td>Quality Evaluation</td>
</tr>
<tr>
<td>2500x</td>
<td>Quality Management</td>
<td></td>
</tr>
<tr>
<td>2502x</td>
<td>Quality Measurement</td>
<td></td>
</tr>
</tbody>
</table>
Data Quality Standard

- ISO 25012–Data Quality Model
  - Quality characteristics

- ISO 25024–Data Quality Measurement
  - Measures
### ACCURACY (Acc-I-1)

<table>
<thead>
<tr>
<th>ID</th>
<th>Name</th>
<th>Description</th>
<th>Measurement function</th>
<th>DLC</th>
</tr>
</thead>
</table>
| Acc-I-1| **Syntactic data accuracy** | Ratio of closeness of the data values to a set of values defined in a domain | $X = A/B$  
$A =$ **number of data items** which have related values syntactically accurate  
$B =$ **number of data items** for which syntactic accuracy is required | All DLC except Data design  
Data file  
Data item, data value |

**NOTE 1**  
A single value is considered “syntactically accurate” when it is the same as one from an identified source of validated information: the result is “yes” or “no”.

**NOTE 2**  
An example of a low degree of syntactic accuracy is when the word Mary is stored as Marj.

**NOTE 3**  
See ISO/IEC 25012, 5.3.1.1.
References