University of Pisa

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Efficiency and benchmarking analysis in the water industry

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TÉCNICO LISBOA

Agenda

1 Introduction

2 Performance Evaluation

3 Performance Indicators

4 Other related tools

5 Performance Indices

6 Performance Level

7 Key-ideas

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INTRODUCTION

Importance of Benchmarking

Performance assessment of the water sector related activities generally reveals very high potential efficiency and productivity earnings;

... these activities are generally out of the market and there are several failures in the way they work (e. g. natural monopoly, scale, density and scope economies, sunk costs and assets, services of general economic interest obligations, ...);

... application of benchmarking can turn out to be a very relevant tool to save resources and improve the quality of service delivered.

Importance of Benchmarking

- ✓ *Benchmarking application in the water sector has been characterized by two groups of participants:*
  - ✓ *Operators and their associations (e. g. Holland, Germany, Northern countries, …);*
  - ✓ *Regulatory commissions (e. g. England, Brazil, …), either in tariff setting (such as public utilities) or in performance publicizing;*
- ✓ *A new regulatory paradigm, in the water sector based on competition by comparison (CC) is being mentioned.*

Definitions

Robert Camp (1989):

> *"Benchmarking is the search for industry best practices that lead to superior performance."*

Marques (2005):

> *"Benchmarking can be defined, straightforwardly, as the process of seeking the excellence, by systematic comparison of performance measures with reference standards".*

Definitions

Benchmarking application objective:

↳ *Efficiency (productivity) and effectiveness earnings;*

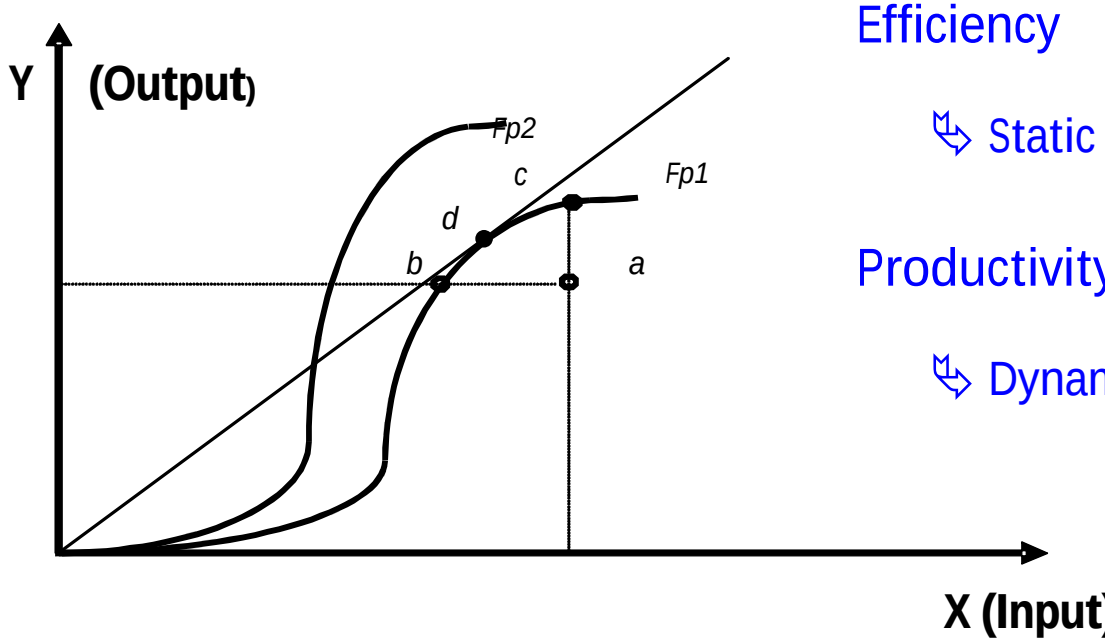
Efficiency *of a given organization or activity/process refers to the comparison between the values of the production factors (inputs) and the products/results (outputs) and their optimal values;*

Effectiveness *measures the level of accomplishment of a given activity (a level of outputs or results) rather than the way it is developed, which is the object of efficiency.*

Definitions

The concept of *efficiency* is different from that of *productivity*;

Productivity is the ratio between the products (outputs) and the resources (inputs) used. The productivity of an organization (activity) only coincides with its efficiency in particular situations. For example, the operation at different scales or distinct operational environments leads to different productivities.



Efficiency

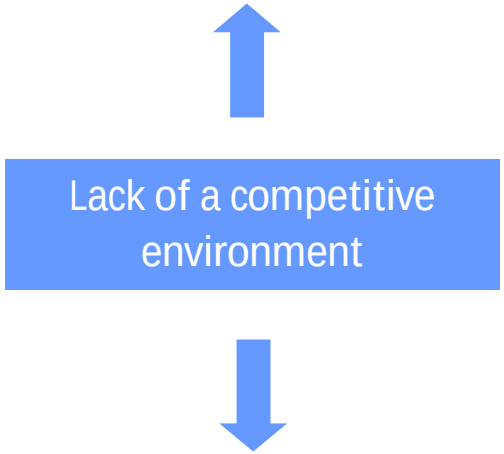
↳ Static nature

Productivity

↳ Dynamic nature

Critical factors

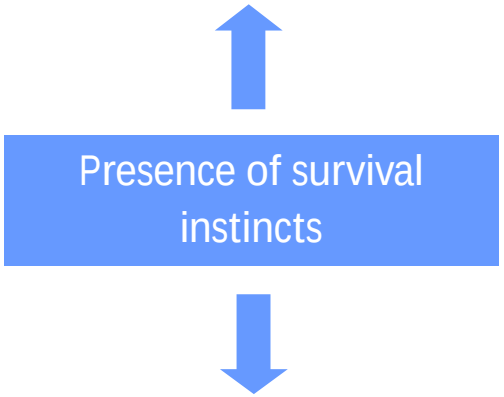
- It may lead *benchmarking* to be seen not as a powerful management tool, but rather as a burden and a threat, which will ultimately lead to the organizations' lack of initiative to implement such tools;



The stimulus to evaluation and comparison may be introduced by regulation or legislation.

Critical factors

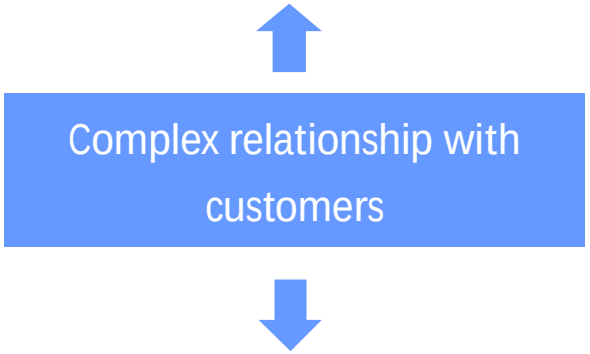
- When applied to the public (water) sector in a voluntary or in a compulsory way,) may lead to an inaccurate assessment, due to attempts to cover for service inefficiencies;



- Validation and monitoring by an independent external entity;
- Adoption of methods of use, interpretation and an objective investigation, based mostly on quantifiable indicators;
- Special care in the use of self-assessment.

Critical factors

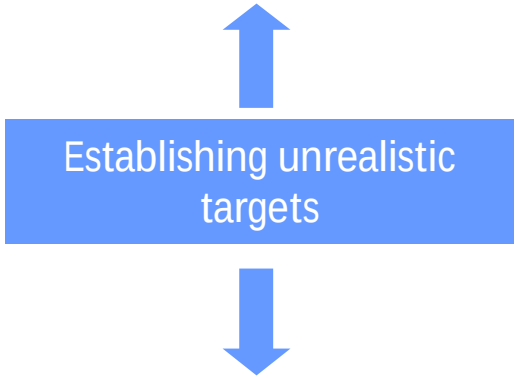
- It is clearly distinct from what is observed in the private sector, since it takes many forms, depending on the agencies or departments, and the customers do not have, in most cases, any alternative options. The perception of service can, therefore, be biased;



- There should be caution when applying *benchmarking* to the private sector performance, especially due to the weight given to this issue;
- Particular attention should be given to the definition and use of consulting instruments.

Critical factors

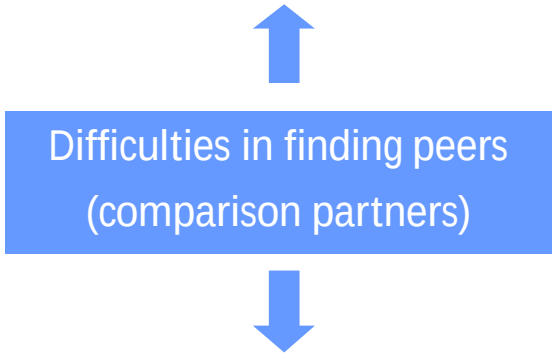
- Since the primal goal of *benchmarking* is the demand and adoption of best practices, the consequences may be the frustration and discouragement of its agents, and it may even lead to their demobilization;



- There is a need to recognize the long road that separates 'us' from the best practices and that the choice of peers is guided by reasonable criteria;
- The definition of actions that can lead to short-term results, even if in a developing stage, may also play an important role.

Critical factors

- The water utilities are mostly unique. It is believed that this characteristic does not assume the relevance that it is sometimes given, recognizing, however, that it is worthy of attention;



- In addition to the obvious internal comparisons between decentralized services, when the performance evaluation detail is extended, there are numerous examples of similar processes across organizations in different sectors;
- On a global level, the creation of a common platform to the water sector, allows to avoid these difficulties by increasing the comparable universe (see ib-net).

Classification

Benchmarking methods are classified into:

- ✓ *Metric: the comparative and quantitative process that enables the operators to keep track of their performance through time and compare it with other (similar) operators;*

- ✓ *Process: identifies in a first phase, the aspects to be improved and then compares them with best practices from other operators.*

- ❖ *Metric benchmarking ⇨ answers the question about what to improve!*

- ❖ *Process benchmarking ⇨ answers the question about how to improve!*

Classification

Other classifications:

- **Macrobenchmarking (*top down*)**: consists in processes of analysis based on results modeling at a high aggregation level;

  ↳ Determines efficiency and productivity global measures. Generally, it is used by the regulators or higher levels of organizations to get information about the operators' performance and its kind and to **establish their own o**bjectives;

- **Microbenchmarking (*bottom up*)**: regards the analysis of the different practices and activities *per se*;

  ↳ Determines partial measures of productivity. It is mainly adopted by the operators with the aim of identifying areas or activities to improve.

Other classifications for Benchmarking

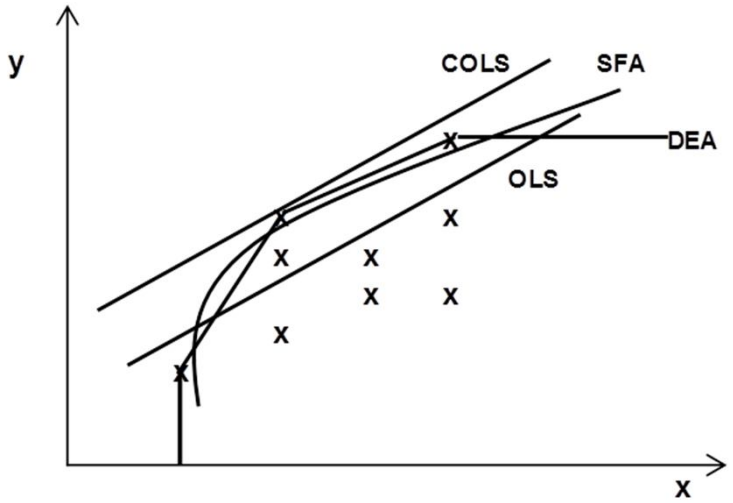
Classifications for Metric Benchmarking

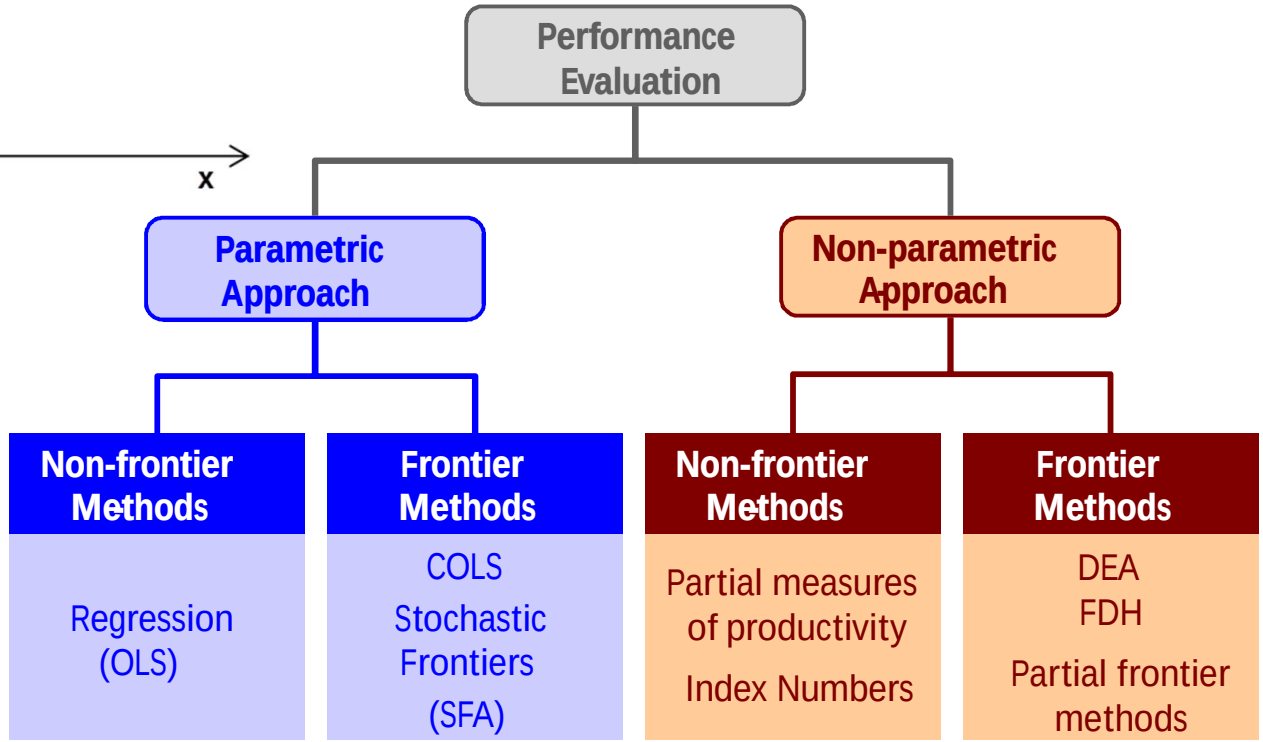
- Total methods or partial methods;
- Frontier or non-frontier;
- Parametric or non-parametric;
- Stochastic or deterministic;

Other types of Benchmarking

- Process Benchmarking
- Customer Perception Surveys
- Model Company Comparisons (engineering models)

Methods


y
COLS
SFA
DEA
OLS
x


Performance Evaluation
Parametric Approach
Non-parametric Approach
Non-frontier Methods
Frontier Methods
Non-frontier Methods
Frontier Methods
Regression (OLS)
COLS
Stochastic Frontiers
(SFA)
Partial measures of productivity
Index Numbers
DEA
FDH
Partial frontier methods

Stages of Application

- First stage: comprises, among other aspects, the definition of the object of benchmarking, the selection and training of the team responsible for its development and the programming of all tasks involved in the process;

- Second stage: includes the understanding of the context and the collection of data and relevant information with the aim of measuring the performance;

- Third stage: entails the identification of potential partners, the collection and analysis of data and the application of comparison methods;

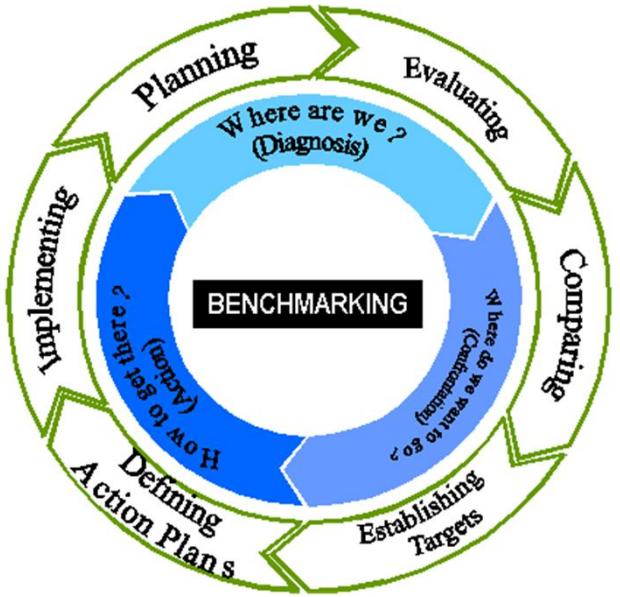
Stages of Application

- Fourth stage: tries to identify the main weaknesses and strengths and quantify the potential for improvement;

- Fifth stage: tries to assess the inefficiency causes, identify improvement and understand and adapt the reference practices observed;

- Sixth stage: consists of the implementation of change, not only with regard to the accomplishment of plans and actions previously defined but it also should include publicizing and sensitizing for the need of change;

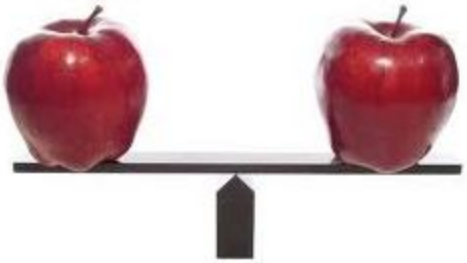
- Finally, the exercise ends with the revision of the process which merges with the beginning of a new cycle.



Success Factors

Compare apples with apples (like with like)

The organizations/activities, object of benchmarking, must be comparable. Although heterogeneity can be modeled and included in the analysis, a minimum standard is necessary (e. g. we cannot compare the water utility of Pisa with that of New York or of Lusaka).



Success Factors

Weight all factors

Avoid simplistic analyses. The adoption of a single performance indicator can, sometimes, lead to that situation!

Success Factors

Awareness that the process is not immediate and that the results are not promptly tangible

It is necessary to look for a consensus among various stakeholders, continuity through time and definition of medium and long term goals so that the system of performance measurement may have success and produce the desired results;

Benchmarking application as well as performance measurement should not be an end in itself.

Success Factors

Some results are supposed to be obtained

Performance should be objectively evaluated, by displaying the areas where it is necessary to improve, identifying other organizations with processes that show a higher performance, aiming at their adoption and testing whether the improvement programmes have had success.

PERFORMANCE EVALUATION

Performance evaluation

Performance indicators *are quantified measures that translate the way or the intensity by which a given activity is accomplished in the form of ratio;*

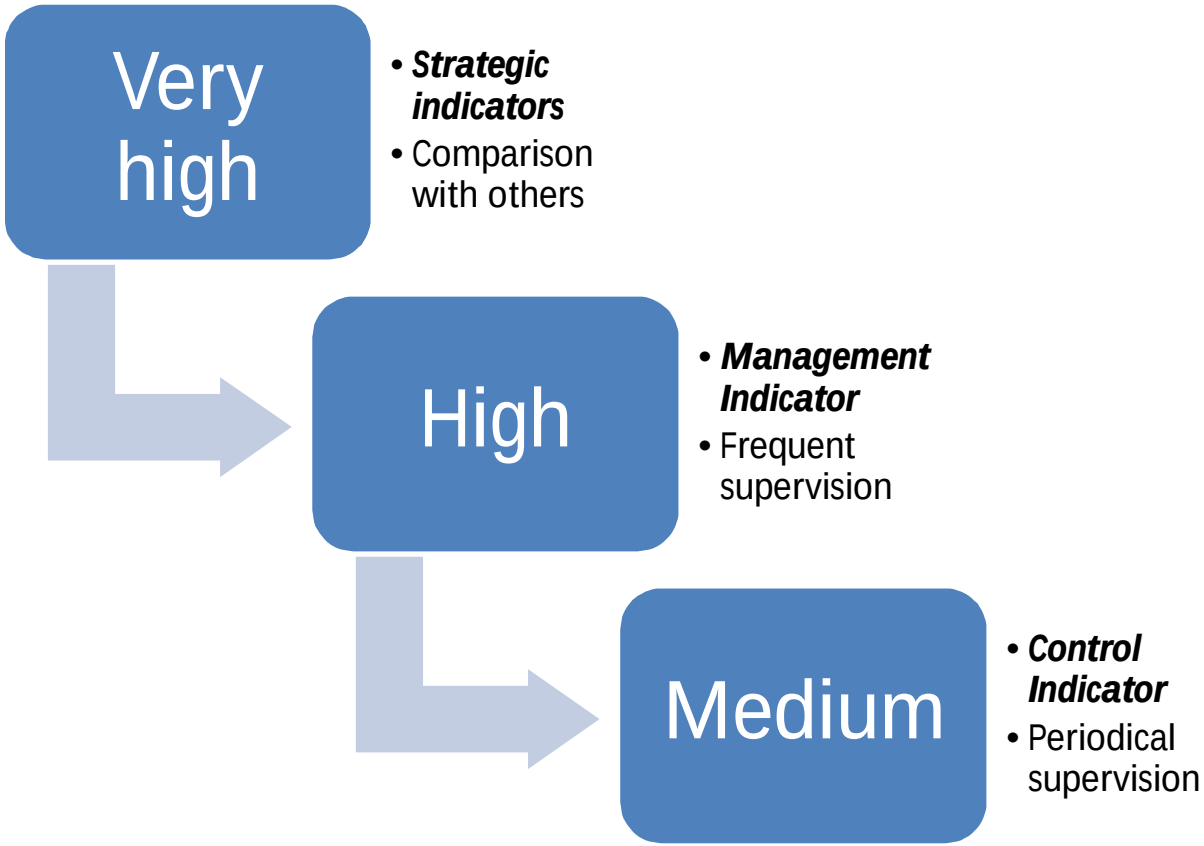
Performance indices *are aggregating measures and are often specially tailored for regulators, mainly if they adopt performance-based regulation in the tariff setting process, such as price cap and/or yardstick competition methods;*

Performance levels *are related to qualitative measures associated with the quality of service provided.*

PERFORMANCE INDICATORS

Importance

- *Performance indicators are usually sorted according to their **importance**.*



Performance Indicators (PI)

It can be adimensional (e. g. %) or intensive (e. g. €/km).

A performance indicator does not intend to be a characteristic of the organization (e. g. population density)

A performance indicator does not stop being a partial measure of productivity

A performance indicator cannot be analyzed out of context

Performance Indicators

- ✓ *A performance indicator, when analyzed individually, has a reduced interest. Therefore, it should be part of a framework or system of indicators:*

- ✓ *The selection of an indicators framework should comply with the following requests:*

  - ❖ *Clear identification of the time span considered, as well as the geographic area of the entity being evaluated;*

  - ❖ *Definition of indicators according to the different stages of development that may exist;*

  - ❖ *Establishment of a results band of the indicators proposed, corresponding to a qualitative evaluation;*

  - ❖ *Identification of the aspects to examine, both from the perspective of the operator under analysis and of the other sector stakeholders;*

Performance Indicators

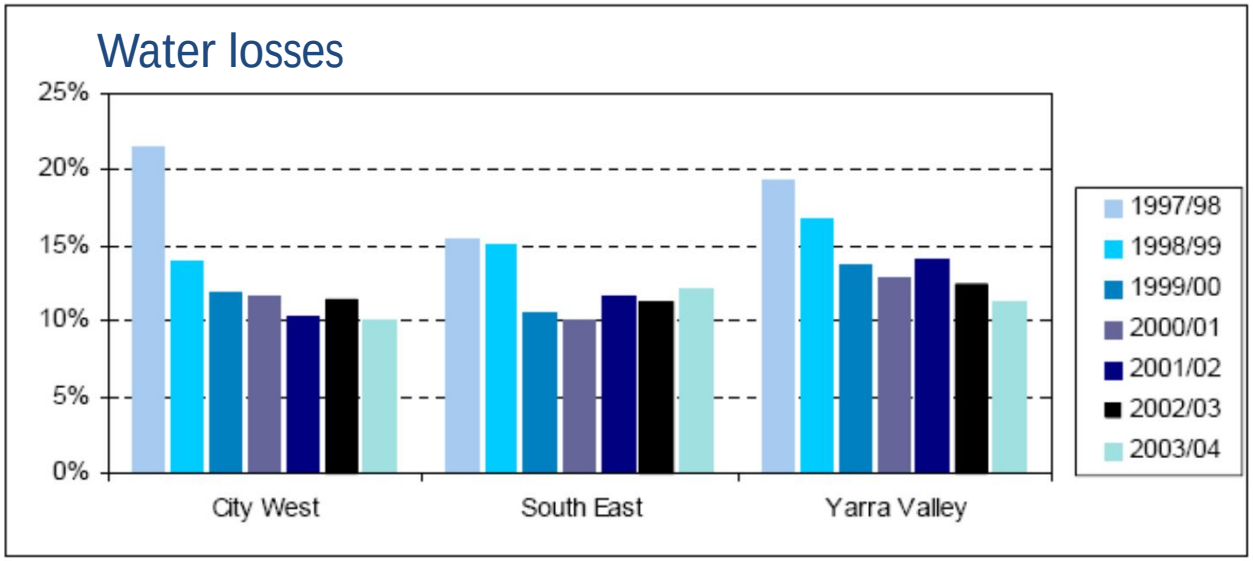
- Coherent and clear definition of the indicators, avoiding subjective evaluations and interpretations, as well as duality of criteria in their determination;
- Independence of the indicators whenever possible, preventing their overlaying;
- Definition of criteria that enable the validation and extrapolation of the results obtained as well as of the quality of the data collected;
- Use of relatively simple equipment in the definition of indicators (adequate to the level of development of the operator) and of easy implementation at short and medium term;
- Checking the results without difficulty;
- Easy understanding of the results obtained relative to the indicators by non-specialized entities such as the users, the media or politicians.

Advantages of PI application

- The use of performance indicators can have different goals, according to the entity which is applying them:
- Firms:
  - ✓ Compulsory data collection and management;
  - ✓ Faster decision-making process;
  - ✓ Gives more power to the decision makers, making the justification of the decisions taken and the establishment of priorities easier;
  - ✓ Pro-active management;
  - ✓ Identification of weaknesses and strengths of the system;
  - ✓ Implementation of an objective-oriented management as it defines targets for the PIs;
  - ✓ Finally, makes it easier to carry out external and internal auditing and the activities results become more transparent.

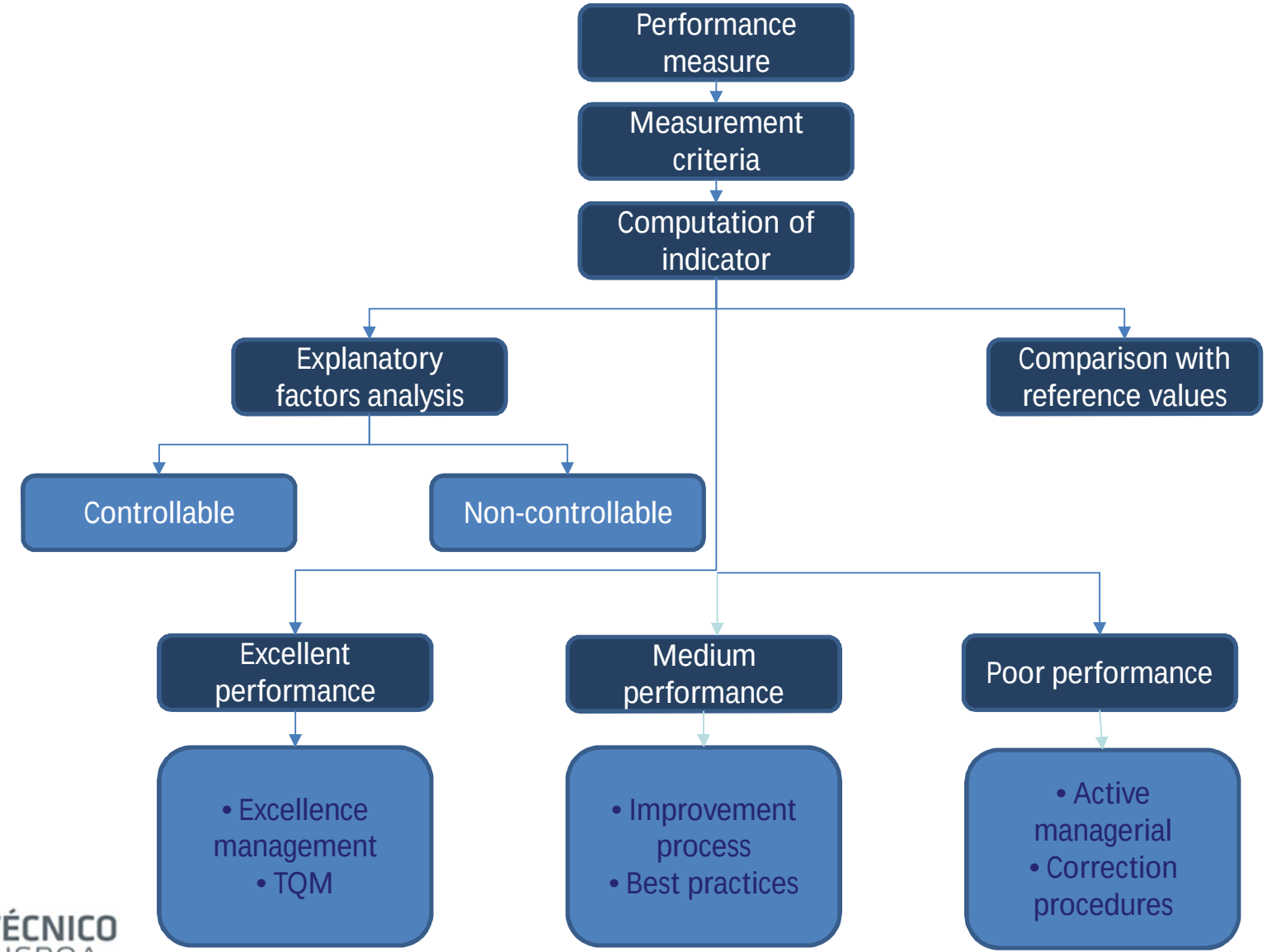
Advantages of PI application

- Regulatory commissions:
  - ✓ Key-tool for the supervision of the quality of service provided by the operator.



- PIs are also important for the entities responsible for the policies adopted in the sector at national, regional or local levels, for the users, financial entities and supranational organizations.

Methodology



Variables and data

"garbage in equals garbage out"

Which variables to use?

Are the selected variables consistent with the concept and phenomena they are supposed to capture?

What sources should be used for each variable?

What is the reliability of data that are compiled?

Are there measurement errors and outliers?

Outputs

Output measures…

… for firm-level analysis	…for service industries	… and quality differences
[redacted]	[redacted]	[redacted]

Inputs

- Quantities or monetary variables?

- CAPEX
  - Replacement value;
  - Sale price;
  - Physical measures.

  - Can it be excluded?

OPEX	CAPEX
OPEX	CAPEX

Inputs

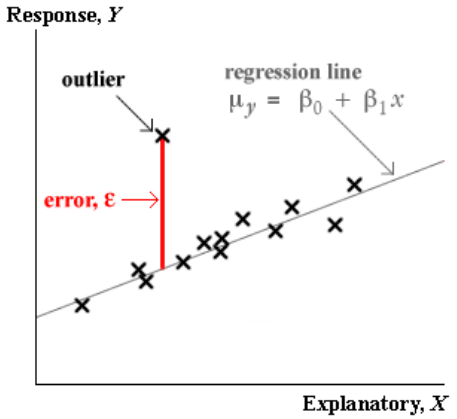
- Capital (K) – *or proxy*
- Labor (L)
- Energy (E)
- Material inputs (M)
- Purchased services (S)

KLEMS approach

Data editing and errors

- Data collection and editing is a key step in efficiency and productivity measurement;

- Main reasons for outliers presence:
  - Typographical errors;
  - Invalid observations;
  - Unusual observations that are real outliers;



Check it again...

Reliability

The provision of reliable and accurate information by companies is vital if meaningful comparative assessments are to be made. A reliable standardized parameter should be associated with each one of the indicators, where factors of reliability and accuracy should be distinguished;

Reliability is defined as the confidence degree of how the data was gathered.

A (high reliability)	Sound textual records, procedures, investigations or analysis properly documented and recognised as the best method of assessment;
B (reliability)	As A, but with minor shortcomings. Examples include previous assessment, some missing documentation, some reliance on unconfirmed reports, some use of extrapolation;
C (low reliability)	Extrapolation from limited samples for which Grade A or B data is available;
D (without reliability)	Unconfirmed verbal reports, cursory inspections or analysis.

Accuracy

Accuracy is a number indicating its likely range of error.

Accuracy bands	
1	Accuracy better or equal to 1%.
2	Accuracy better or equal to 5%.
3	Accuracy better or equal to 10%.
4	Accuracy better or equal to 25%.
5	Accuracy better or equal to 50%.
6	Accuracy better or equal to 100%.
X	For very small numbers where accuracy cannot be calculated or the error can be more than ± 100

Confidence indicator

The standardized confidence indicator is built upon the **reliability** and **accuracy** factors by joining the letter with the number. Thus, for example, to data with very feasibility and accuracy equal or higher than 10% the corresponding indicator is A3.

	A	B	C	D
1	A1	-	-	-
2	A2	B2	C2	-
3	A3	B3	C3	D3
4	A4	B4	C4	D4
5	-	-	C5	D5
6	-	-	-	D6

Several Proposed Systems

Framework of IWA (international Water Association) indicators

158 indicators associated with three levels of importance, divided into water resources indicators (4), personnel indicators (25), physical indicators (15) operational indicators (40), quality of service indicators (27), economic and financial indicators (47);

These indicators are further complemented to context factors (meaningful information on the profile of the region, the system profile and the service provider profile);

Framework of the World Bank indicators (http://www.ib-net.org/):

There are 30 indicators (with subdivisions) grouped into 12 categories (service coverage, consumption and production, non revenue water, metering principles, network performance, cost and staffing, quality of service, billing and collection, financial performance, assets, affordability of services, process indicators);

The database includes thousands of service providers from a hundred countries.

Several Proposed Systems

Multiplicity of proposals:

International STANDARDS ISO 24.500 for water production and consumption, and sewage management.

Portugal: Marques (1999), IRAR/ERSAR (2005 and 2011);

The Netherlands: VEWIN;

England and Wales: OFWAT;

France: ONDEU (internal system), ...;

Nordic Countries (Six cities), associations of Norway (NVE), Denmark (DANVA), Sweden (VAV), ...;

Germany: Operator associations ATV-DVWK and DVWG, ...;

United States: WEF, AWWA, AMSA, ...;

Australia: IPART, ...;

There is no performance indicator systems a la carte for an operator. We must define our system, according to our needs, trying to use the language and the most appropriate terminology

Physical Indicators

The physical indicators aim to address the aspects of asset performance, in terms of capacity, related to their use;

The following are examples for water supply and wastewater services:

Performance Indicator	Unit	Importance
Water		
Raw water storage capacity	days	Moderate
Treatment plant utilization	%	High
Treated water storage capacity	days	Moderate
Energy consumption	kWh/m^3/m	Moderate
Wastewater		
Treatment utilization	%	High
Energy consumption	KWh/m^3/m	Moderate

Operational Indicators

A relevant part of the efficiency of a water undertaking can be lost or improved in the operation and maintenance activities. Managers need to monitor the planned activities for inspection, preventive maintenance and rehabilitation (and unplanned activities).

Performance indicators	Unit	Importance
Pump inspection	days	High
Storage tank cleaning	year	High
Meter replacement	Year	Very high
Mains replacement	%	Very high
Sewer replacement	%	Very high
Water losses	m^3/1000 customers/year	Very high
Power failures	Hours/Pumping station/year	High
Tests carried out	%	High
Vehicle availability	Km / vehicle	Moderate
Mains failures	n.º/100km/year	High
Sewer blockages	n.º/100km/year	High

Quality of Service Indicators

Quality of service indicators recommended aims are to know the extent of the service coverage within the area of influence of the undertaker and the performance of the service in terms of quantity and quality of water provided.

Performance indicators	Unit	Importance
Water		
Population coverage	%	Very high
Population connected to water system	%	Very high
Water interruptions	%	Very high
Quality of supplied water	%	Very high
Complaints per customer	n.º/1000 customers/year	High
Wastewater		
Population coverage	%	Very high
Population connected to sewer system	%	Very high
Population served by WWTP	%	Very high
Quality of discharged effluent	%	Very high
Complaints per customer	n.º/1000 customers/year	High

Personnel indicators

Personnel indicators address the viewpoints of efficiency of human resources, qualification and training, health and safety, and overtime work.

Performance indicators	Unit	Importance
Employees per customer	n.º/1000 customer	Very high
Employees per water produced	n.º/10^6 m^3	Moderate
Employees per mains length	n.º/100 km	Moderate
Employees per department	%	Moderate
Personnel qualification (Degree)	%	High
Overtime work	%	High
Absenteeism	days/employee/year	High
Training	Hours/employee/year	Very high
Working accidents	n.º/employee/year	Very high

Economic and Financial Indicators

The economic and financial indicators deal with the economic and financial performance of a utility.

Performance indicators	Unit	Importance
Unit total costs	€/m^3	Very high
Unit current costs	€/m^3	High
Unit revenue	€/m^3	Moderate
Unit investment	€/m^3	Moderate
Average water charges	€/m^3	High
Total cost coverage ratio	-	Very high
Solvency ratio	-	High
Debt equity ratio	-	High
Current ration	-	Moderate
Return on net fixed assets	%	Moderate

Explanatory factors

Explanatory factors are factors or indicators able to justify the level of performance (better or worse) attained.

Computing a performance indicator without including the explanatory factors has little interest

The explanatory factors are classified into controllable (discretionary) or non controllable (non-discretionary), according to whether or not the managers have capability to alter their values;

e. g. average aging of pipes is a controllable factor whereas temperature or customers density are non-controllable;

Explanatory factors

There are several explanatory factors related not only to the operating environment, but also to the regulatory environment (e.g.. legislation, regulator, ...), the service provider (e.g.. idle capacity) and the scale of operation;

In the analysis of explanatory factors the importance relies, mainly, on determining extreme situations, i.e., circumstances in which the providers have out of normal values.

In most situations the effect of explanatory factors may not be relevant, and therefore, they should not justify a possible worse performance

Examples

a) Treated water storage capacity

Ratio between the total volume of (treated water) tanks and the average daily consumption.

- Explanatory factors:

  Peak factor, failures in the infrastructure and water distribution and transport capacity.

b) Power costs

Ratio between the annual cost of energy and the billed water volume (annually).

- Explanatory factors:

  Topography, water treatment plants and age of the equipment.

Reference Values

- *After the metric calculation and the definition of the explanatory factors the performance level is compared with the reference values (benchmarks);*
- *These values correspond to the best practices in the market, either referred to in the literature or related to the values determined for other operators (national or international);*
- *Ultimately, the benchmark is based on the values obtained in previous years;*
- *The reference values are not only used to measure the performance but also to set targets for the future.*

Examples

a) Mains failures

Ratio between the annual number of mains failures and the total mains length;

- Value of Reference:

  10 to 20 failures / 100km / year depending on customer density. The higher the failures, the greater the value of the indicator;

b) Training

Ratio between the number of training hours made per year and the number of employees;

- Value of Reference:

  40 hours per employee per year.

Examples

c) *Sewer replacement*

The ratio between the length of the Network and the length of rehabilitated pipelines per year;

- Value of Reference:

  1.5 to 2.5% a year;

d) *Cover the costs of wastewater service*

Ratio between the annual revenues from the sewage service, and their total costs (annual);

- Benchmark

  40% above the total cost.

PERFORMANCE INDICATORS RELATED TOOLS

Balance Scorecard

Integration with Balanced Scorecard (BSC):

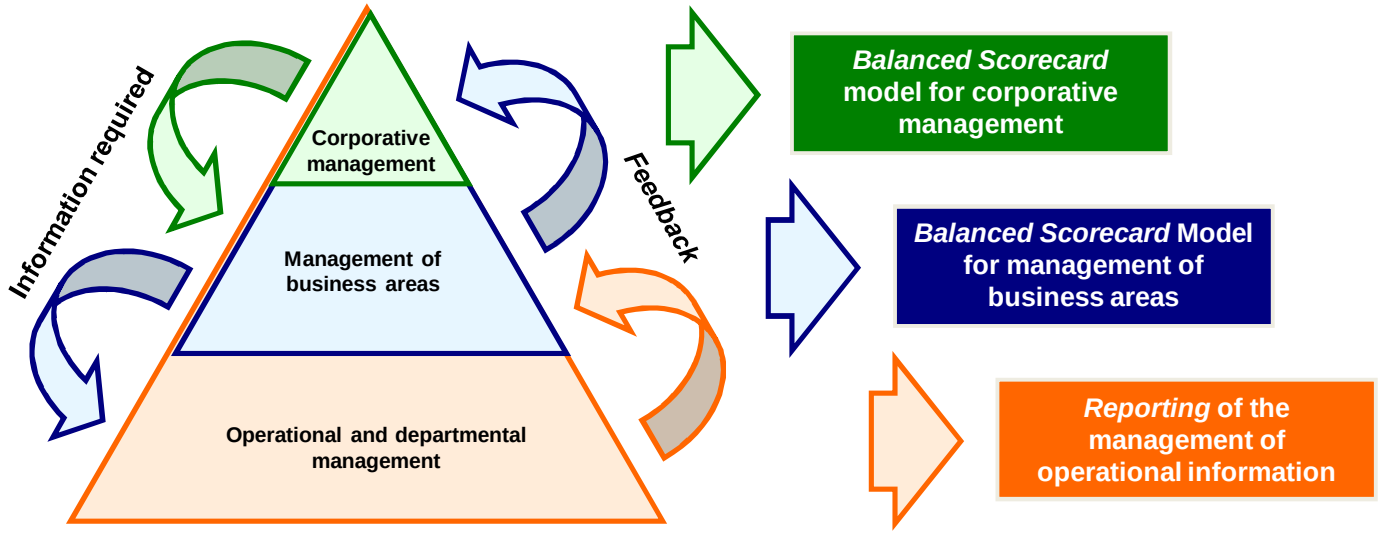
- The BSC, developed by Prof. David Norton and Robert Kaplan in the beginning of the 90's, is a methodology that intends to increase the vision of traditional control systems far beyond the financial indicators;

- Regarding the mission, vision and values of the organization, the BSC enables us to outline objectives and goals according to its four perspectives: Customer; Financial, Internal and Innovation and Learning;

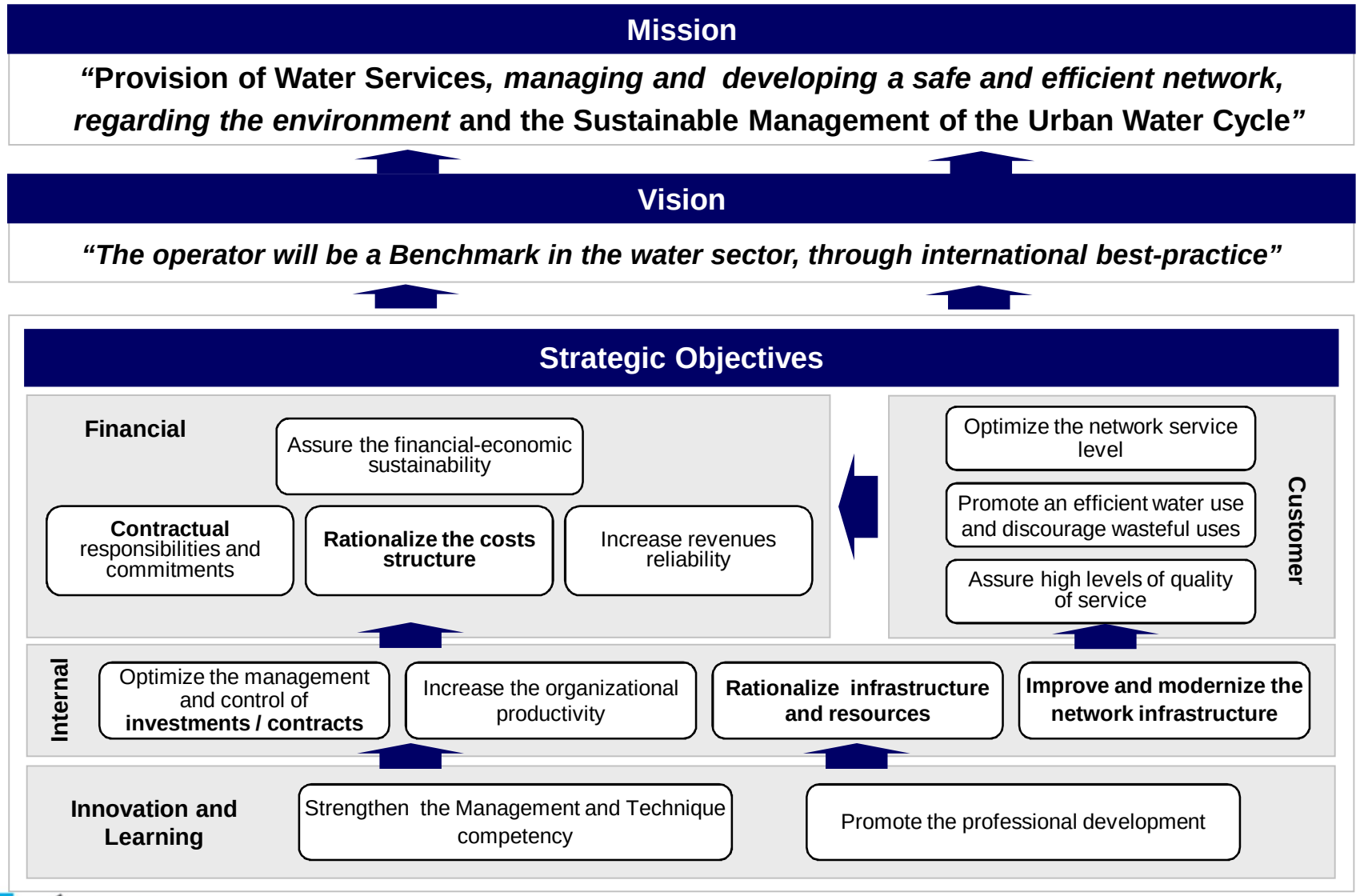
- The main goals and objectives are summarized and sorted into strategic maps adopted for the organization, while they are supervised through key performance indicators.

Balance Scorecard

Conceptual Structure:



Balance Scorecard



Balance Scorecard

Performance Indicators by perspective:

Financial perspective	• Operational result • Debt ratio • Operational Cash-Flow • Coverage level of total costs • Coverage level of operational costs • Return on regulated assets base • Importance of personnel in total operational costs • Importance of outsourcing in total operational costs • Importance of financial expenses in total costs	• Consumption limits • Quality of supplied water • Water interruptions • Complaints per customer • Population coverage • Population connected to water system • Number of failures • Supplied water pressure	**Customer perspective**
Internal / Processes perspective	• Relative financial deviation of investments • Relative deviation of execution terms of investments • Productivity index • Staff • Operational, exploration and maintenance costs by water billed • Exploration revenues by water billed • Network % with utilization under X utilizable capacity • Concentration index of maintenance cost in strategic equipment and infrastructure • Coverage of modernized network (e.g. smart metering)	• % of boards with complementary training in management • Average age of the employees • Average level of education • Employees satisfaction index • Employees turnover index • Average number of training hours per employee • Number of promotional initiatives of organizational values	**Innovation and learning perspective**

Synthesis of information - Example of Tableaux de Board

Desvio face à meta entre -10% e +10%

Desvio face à meta entre -15% e -10% e +10% e +15%

Desvio face à meta acima de 15%

Objectivo	Indicador de Objectivos	Fórmula de Cálculo	Real								Meta	Desv. / P.SIL	SINAL	Meta	Justificação / Observações
			Janeiro	Março	Abril	Maio	Junho	Julho	Agosto	Setembro	Actual			PA 07	
1. Direcção Geral de Exploração de Infraestruturas															
Celebrar contratos e acordos para a prestação de serviços extra-exploração e concessão de espaços (Dir. Gestão de Estações)	Proveitos Suplementares (Proveitos extra-exploração e concessão de espaços)	Valores contabilizados nas contas 73 e 76 (Valor acumulado) (Gestão de Estações)													
Maximizar as receitas (Dir. Gestão de Clientes)	Proveitos (Serviços essenciais, adicionais e auxiliares)	Σ Serviços essenciais + adicionais + auxiliares (valor acumulado) (Gestão de Clientes)													
Gerir a circulação com elevados níveis de pontualidade (Dir. Operações)	I. Atraso médio por causas imputáveis à REFER: A) Alta Qualidade B) Urbanos C) Restantes Passageiros D) Mercadorias	-													
	II. Número de LV's impostas pela manutenção nas Linhas do Norte(VA+VD), Sul, Beira Baixa e Beira Alta	-													
	III. Atrasos estimados devido às LV impostas pela manutenção nas Linhas do Norte(VA+VD), Sul, Beira Baixa e Beira Alta (Mês)	-													
2. Direcção Geral de Organização e Desenvolvimento															
Definir Política de serviços partilhados para o Grupo REFER (DGOD - Chefia)	Cumprimento de Prazos	Desvio meses entre a data prevista e a data efectiva													
Implementar o novo sistema de carreiras (Dir. Recursos Humanos)	Cumprimento de Prazos	Desvio meses entre a data prevista e a data efectiva													
Gerir eficazmente o stock de existências (Dir. Contratualização, Procurement e Logística)	Evolução do valor do Stock médio mensal	Valor Stock Médio REFER mês N / V.S.M.Refer ano anterior													
	Peso do valor das existências em armazéns locais	Σ valor das existências nos armazéns locais / Valor das existências REFER													
Incrementar compras por via electrónica (Dir. Contratualização, Procurement e Logística)	(%) compras Via EBP no total compras centralizadas	compras Via EBP / compras centralizadas (Valor acumulado ano à data)													
3. Direcção Geral de Planeamento e Controlo Estratégico															
Criar condições para o Estabelecimento de Contrato Programa (Dep. Estratégia e Planeamento de Negócio)	Cumprimento de Prazos	Desvio meses entre a data prevista e a data efectiva													
Apresentar ao CA o Plano Sectorial Ferroviário da Rede (Dep. Estratégia e Planeamento de Negócio)	Cumprimento de Prazos	Desvio meses entre a data prevista e a data efectiva													
Controlar garantir o cumprimento do Plano de Supressão (Dir. Gestão de Atravess. e PNs)	Densidade Média de PNS	N.de PNS / Km de via													
4. Direcções de Suporte e Apoio															

PERFORMANCE INDICES

Partial productivity measures

$$\text{Performance indicator}_m = \frac{\text{Input}_i}{\text{Output}_j}$$

Operator	OPEX / Customer (10^3 €/ 10^2)	Ranking	OPEX / mains (10^3 €/ 10^2)	Ranking	OPEX / billed water (10^3 €/ 10^3 m^3)	Ranking
Operator 1	2,57	1	3,86	3	2,75	3
Operator 2	2,69	2	3,40	1	2,70	2
Operator 3	2,95	3	3,65	2	2,04	1

- They are partial measures of productivity;
- Correlation and *trade offs* between different indicators and dependence on factors not accounted for which makes comparisons difficult;
- Ranking can change according to the indicator and weights applied;
- Aggregating the "scores" depends on weights
- Difficulty to identify best practices to adopt .

Despite being useful, easily calculated and with transparent meaning, they can provide wrong information when taken by themselves. Thus, it is justifiable that indicators and global methodologies are to be found.

Aggregation

Based on an additive indicator, whether or not weighted:

$$\text{Aggregated Indicador} = \beta_1 \cdot \text{PI}_1 + \beta_2 \cdot \text{PI}_2 + \cdots + \beta_m \cdot \text{PI}_m$$

- Distinct indicators can include similar inputs or outputs*;*
- Performance indicators are redundant and are not independent between themselves.

Methodologies based on weighted additive aggregation expressions, typical of multi-criteria methodologies, should be carefully used.

Global productivity measures

Total factor productivity (TFP):

$$TFP = \frac{\text{Weighted Sum of Outputs}}{\text{Weighted Sum of Inputs}} = \frac{\sum_{i=1}^{M} a_i \cdot y_i}{\sum_{j=1}^{N} b_j \cdot x_j}$$

- *Linear relationship between inputs and outputs;*
- *Constant weights for all the elements being compared;*
- *Different results can be reached according to the composition of weights adopted.*

Productivity change measures:

$$TFP_{t,t+1} = \frac{TFP_{t+1}}{TFP_t} = \frac{f(y_{t+1}, y_t)}{g(x_{t+1}, x_t)}$$

- *The inputs and outputs choice and the way they can be aggregated characterize the different indexes that can be built;*
- *They are non parametric and non frontier measures of performance evaluation, called Index Numbers.*

Index numbers

Laspeyres indexes:

Represents the changes in prices (price index) or in quantities (quantity index) with reference to the base year (period 1). Very popular index, being, for example, used by Statistics Portugal in the CPI computation.

$$P_{12}^{L} = \frac{\sum_{i=1}^{M} p_{i2} \cdot q_{i1}}{\sum_{i=1}^{M} p_{i1} \cdot q_{i1}} \qquad Q_{12}^{L} = \frac{\sum_{i=1}^{M} p_{i1} \cdot q_{i2}}{\sum_{i=1}^{M} p_{i1} \cdot q_{i1}}$$

Paasche indexes:

Similar to the previous one, but computed with reference to the current year (period 2).

$$P_{12}^{P} = \frac{\sum_{i=1}^{M} p_{i2} \cdot q_{i2}}{\sum_{i=1}^{M} p_{i1} \cdot q_{i2}} \qquad Q_{12}^{L} = \frac{\sum_{i=1}^{M} p_{i2} \cdot q_{i2}}{\sum_{i=1}^{M} p_{i2} \cdot q_{i1}}$$

Index numbers

Fisher indexes:

Correspond to the geometric mean between Laspeyres and Paasche indexes.
Enables us to overcome the previous limitations, with very important mathematical and economic features, as the average value and reversibility.

$$P_{12}^{F} = \sqrt{P_{12}^{L} \times P_{12}^{P}} \qquad Q_{12}^{F} = \sqrt{Q_{12}^{L} \times Q_{12}^{P}}$$

Törnqvist indexes:

Correspond to the geometric mean of the relative prices, weighted by the arithmetic mean of the values weight in the base and current dates (period 1 and 2).
Although it is not so prompt as the previous, it has very important characteristics and it is very often applied.

$$P_{12}^{T} = \prod_{i=1}^{M} \left(\frac{p_{i2}}{p_{i1}} \right)^{\frac{w_{i1}+w_{i2}}{2}} \qquad Q_{12}^{T} = \prod_{i=1}^{M} \left(\frac{q_{i2}}{q_{i1}} \right)^{\frac{w_{i1}+w_{i2}}{2}}$$

Index numbers

Characterization:

- *Establish the relationship between two states of a given dimension able to change through time or space;*
- *They are used to measure prices and quantities all over time as well as to account the differences between companies, industries, regions or countries;*

Advantages:

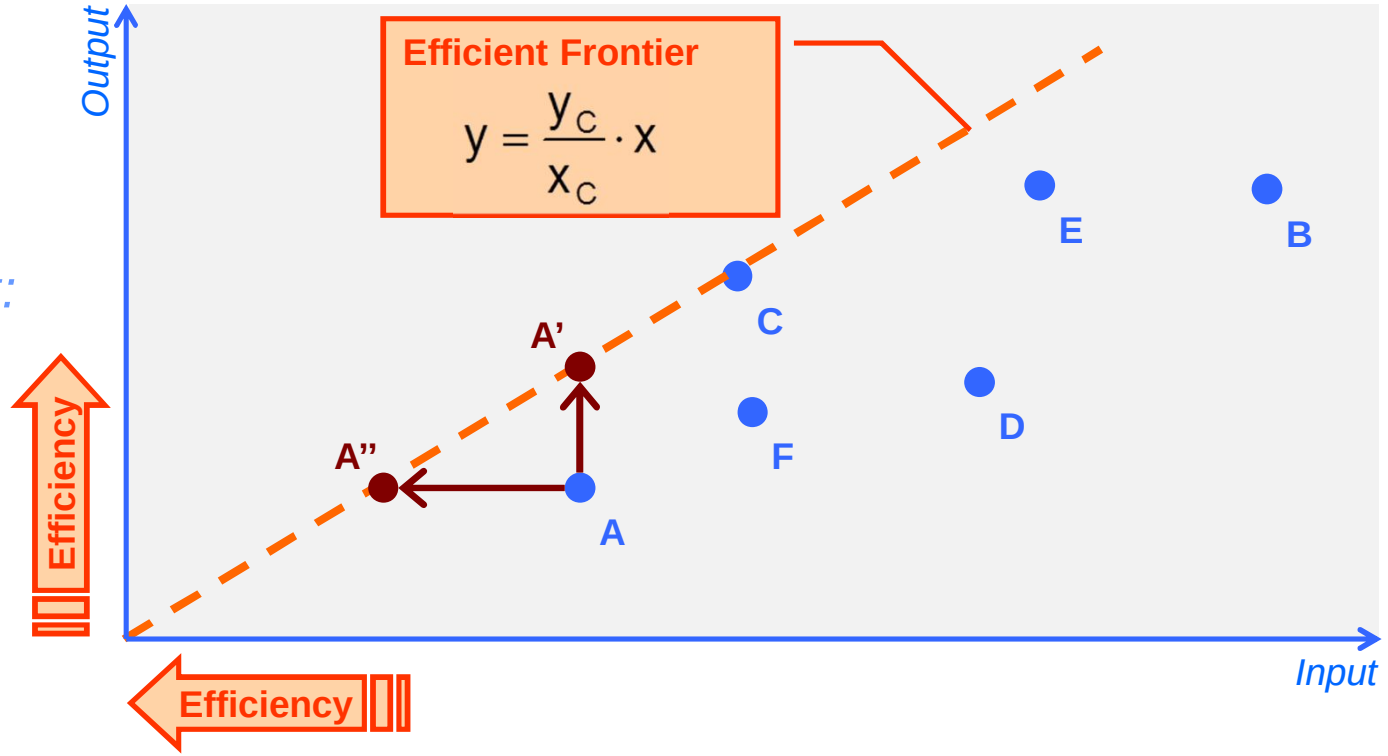
- *Very prompt measures and easily applicable;*
- *Transparent results and easily interpreted;*

Disadvantages:

- *The greatest difficulty of their application is related to the choice of the formula that enables the aggregation of inputs and outputs;*
- *They ignore technical efficiency, as well as allocative efficiency so that the results interpretation should be carried out carefully;*
- *They do not allow for the decomposition of productivity and admit that the operators are technically efficient.*

Data Envelopment Analysis (DEA)

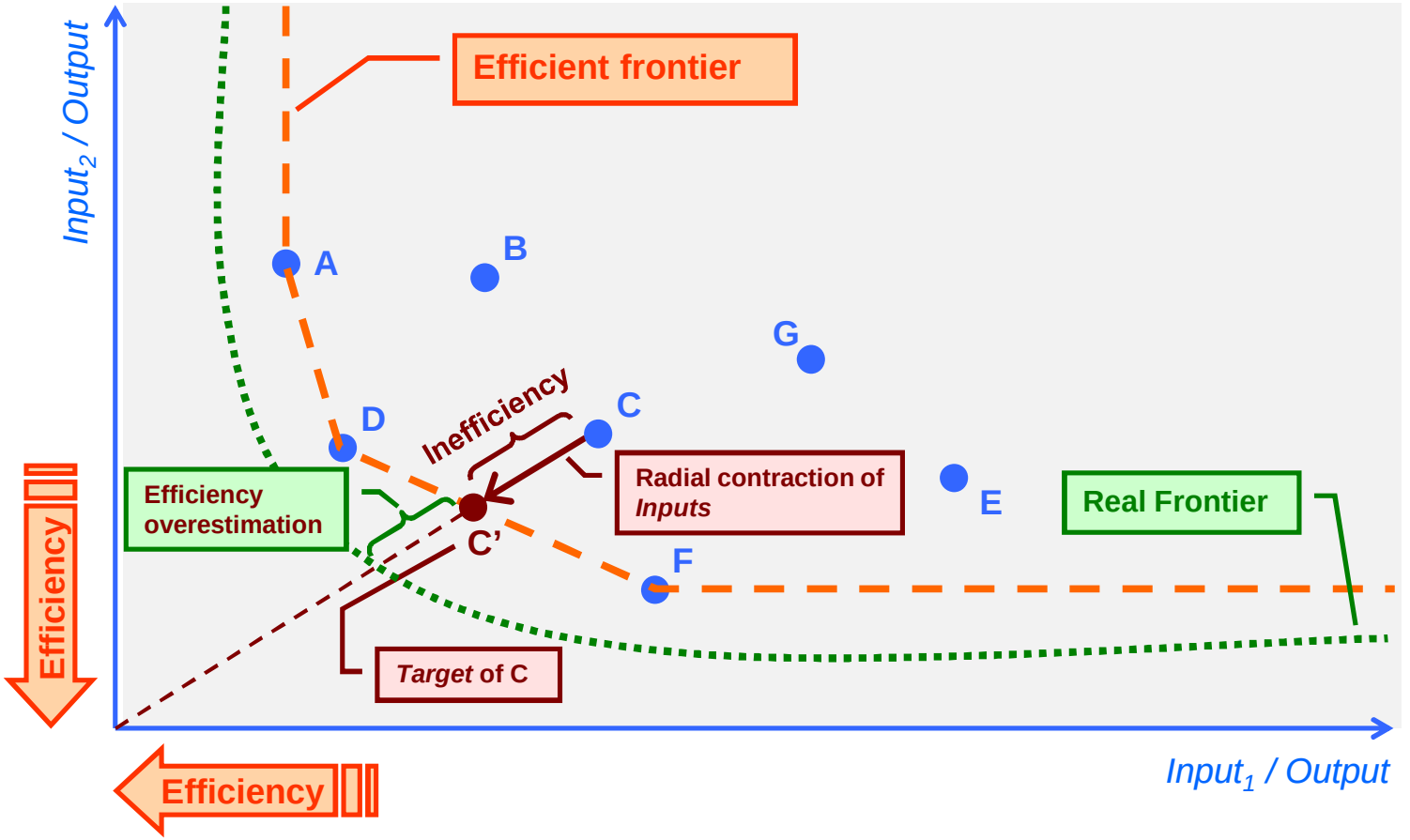
DEA Technique with 1 Input and 1 Output:



- ***A*** *can raise the number of output produced and consume the same quantity of input, until A' (Output orientation);*
- ***A*** *can reduce the consume of input, for the same level of production of output, until A'' (Input orientation);*
- *Segment A'A'' represents the possibilities that* ***A*** *has to improve.*

Data Envelopment Analysis (DEA)

Example of the CCR model as Input oriented

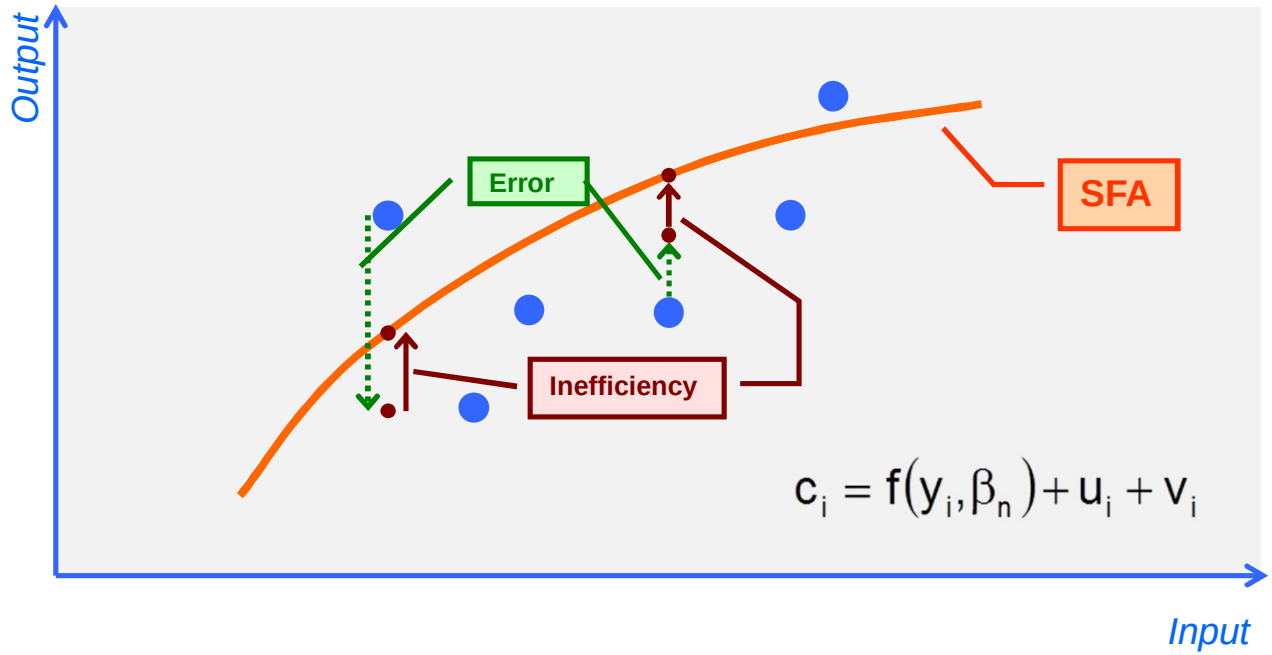


- *Operators **D** and **F** are comparison peers of **C**;*
- *The projection of **C** in the frontier (target) is a **linea**r combination of **D** and **F**.*

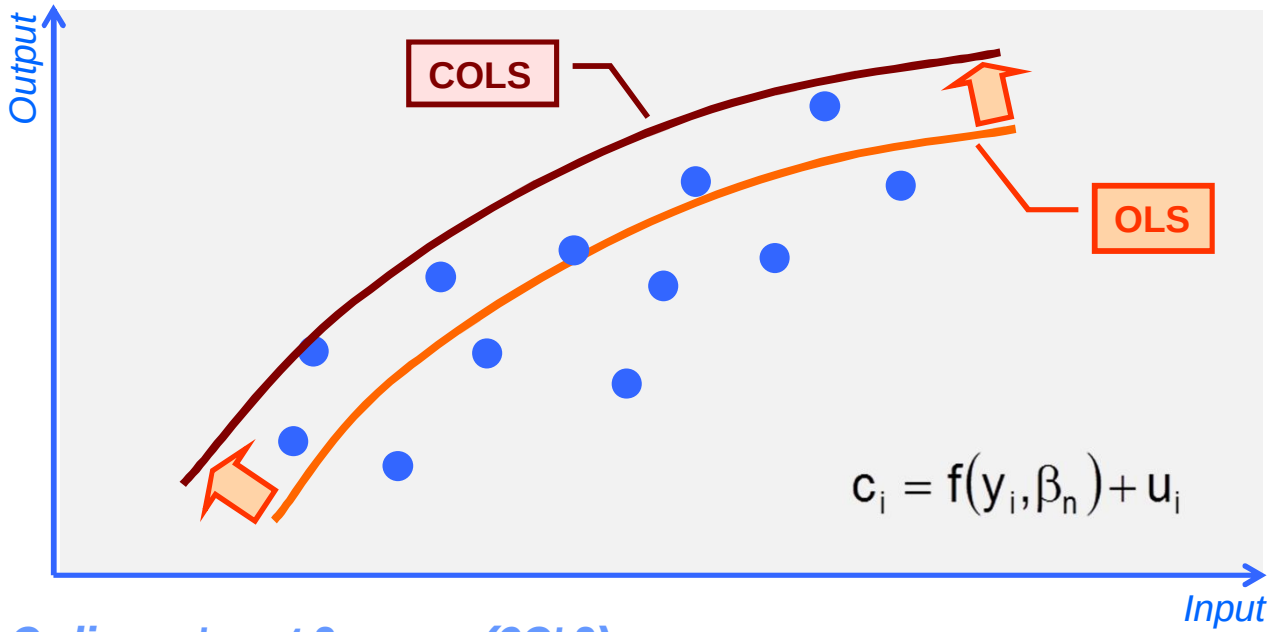
Stochastic frontier (SFA)

Characterization:

- *It is the main technique that compete with DEA;*
- *The determination of the frontier is done based on the method of maximum likelihood;*
- *Differs from other methodologies by separating the statistical error term from the inefficiency term.*



Regression models



Corrected Ordinary Least Squares (COLS):

- *Consists in a parallel movement of the average adjustment curve, determined through a OLS method, by encompassing the sample and passing at a single time to the farthest operator (best practice);*
- *Compute the efficiency, depicting similar characteristics to the OLS, aggravating the harmful consequences of the possible existence of outliers.*

Features of Major Metric Techniques

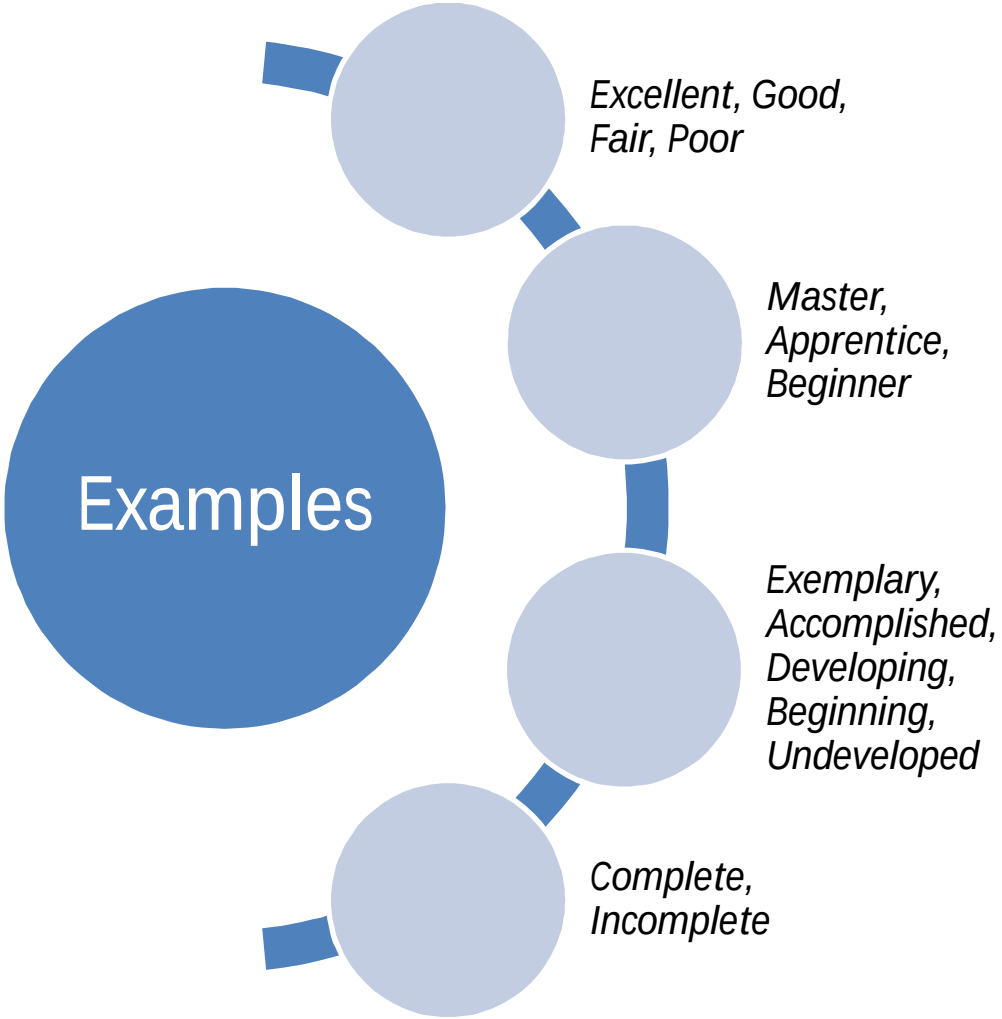
Features	DEA	SFA	COLS	OLS
Specification of the functional form	No	Yes	Yes	Yes
Integration of multiple inputs and outputs	Yes	Difficult	Difficult	Difficult
Identification of best practices	Yes	No	Yes	No
Detail of efficiency measures	High	Low	Low	Low
Statistical inference	Difficult	Yes	Yes	Yes
Adjusting for operational environment	More difficult	Multico-linearity	Multico-linearity	Multico--linearity
Accounting for noise	No	Yes	No	No
Sensitivity to outliers	Very	Sensitive	Very	Little

PERFORMANCE LEVEL

Performance Levels...

- *...are often labeled as adjectives, describing the performance levels;*
- *...determine the degree of performance which has been met and will provide for consistent and objective assessment and better feedback;*
- *... reflect expectations;*
- *...can be used without descriptors but descriptors help in achieving objectivity;*
- *... are particularly useful for customers to assess the service provided when the quantification of the measures is troublesome.*

Performance Levels...

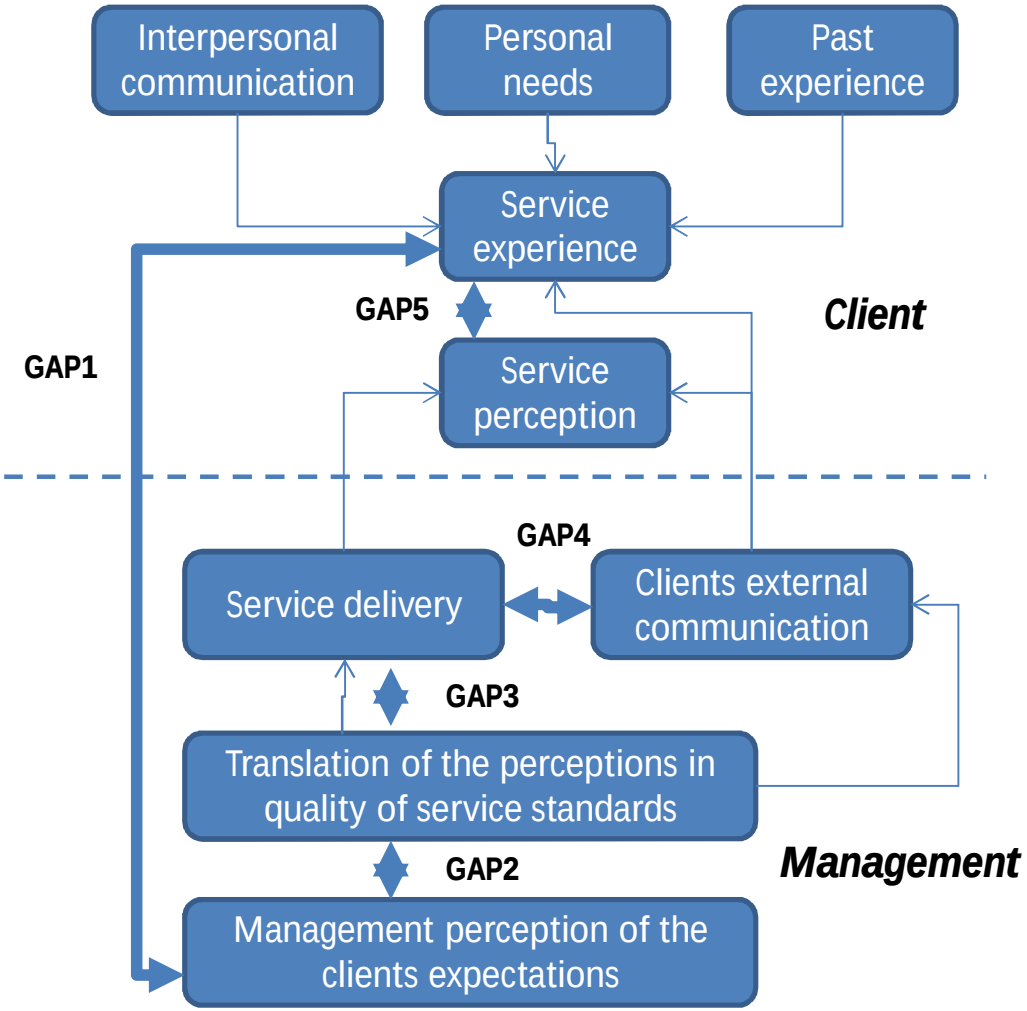


SERVQUAL

SERVQUAL encompasses the quality of service, defining that the client satisfaction is the difference between the expectation and the perception performance.

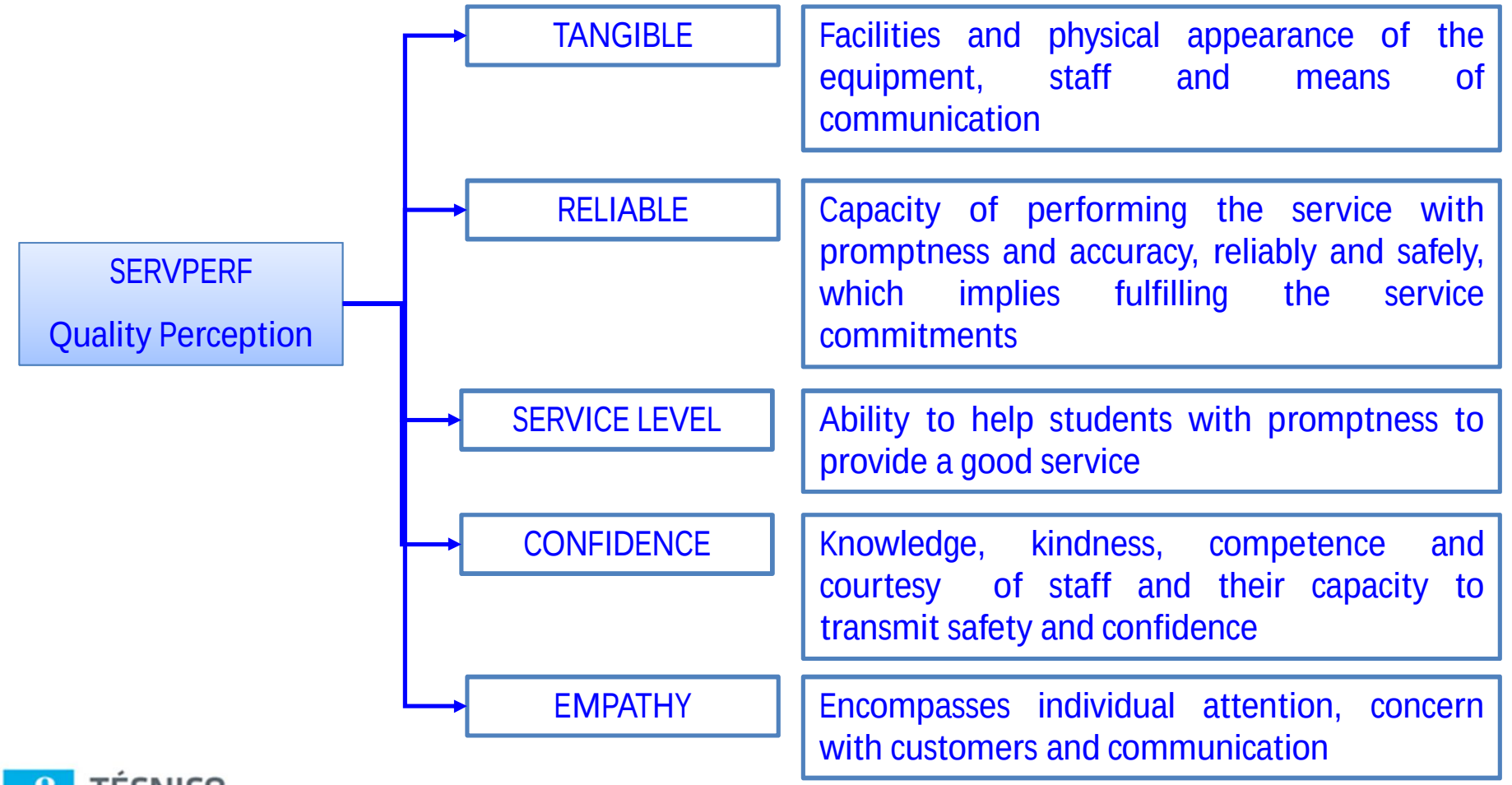
$$Qj = Dj - Ej \quad (1)$$

Which:
Dj = Value of measure of performance perception for the service j characteristic;
Ej = Value of measure of performance expectation for the service j characteristic; and
Qj = Service quality evaluation related to the j characteristic.



SERVPERF

SERVPERF is based only on service performance perception.



KEY-IDEAS

Key-ideas

Even more important than the results evaluation is the awareness that the measurement processes promote regarding the quality, continuous improvement, focus on the passengers/users and objectives.

The process of benchmarking should comprise all the structure

Key-ideas

Benchmarking allows for a knowledge and a real interpretation of the way it works.

Reduction of the probability of the status quo maintenance!...

Understand your own performance

Key-ideas

Only by knowing better the counterparts can the gap that might exist be mitigated!

Know better the other operators

Key-ideas

Awareness that the process of improvement is continuous and time consuming!...

Need for continuous improvement

Key-ideas

Answers must be looked for!

Benchmarking provides more questions than answers

Key-ideas

Ranking by itself should not be an end to the process of evaluation.
On the contrary, it should be a tool to change towards excellence.

Evaluation should focus and provide evidence of the aspects that the managers control

Key-ideas

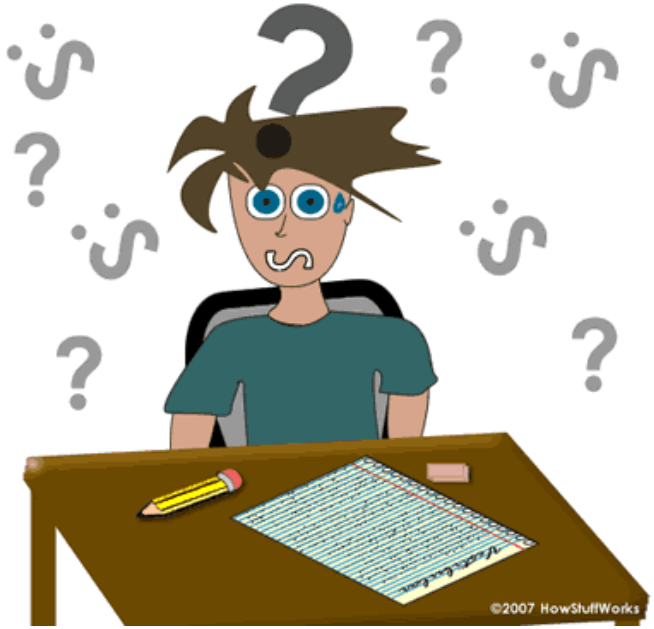
The identification, understanding and implementation of best practices should not be seen as an occasional and solitary task, but as an activity that is entangled in the organizational culture.

Benchmarking is a cyclic and permanent process.

Key-ideas

Performance evaluation should always be regarded as an opportunity and not as a burden or a criticism;

Questions



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