Application of performance indicators in water utilities management – a case-study in Portugal

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Abstract This paper presents some issues concerning water supply systems assessment through performance indicators, based upon research work recently carried out in Portugal about water utilities. A proposal of 50 performance indicators divided into five different groups is presented here, namely structural indicators, operational indicators, water and service quality indicators, personnel indicators and economic indicators. These indicators were associated with a hierarchical structure of knowledge or development according to different levels: basic level, development level and strategic level. The performance indicators, structure, their implementation and assessment methodology and examples of some indicators, use concerning the characterisation or assessment of a water utility are also presented in the paper.

Keywords Assessment; benchmarking; indicators; performance; water utilities

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Introduction

In Portugal, in the past few years, the water supply sector has been characterised through a high development in the building of infrastructures and consequent increase in the level of service coverage, and in the water utilities management.

The need for sustainability in the water market, allied to the growing concern with the water resources and its preservation, as well as the growing interference of the consumers in its management, demand new requirements in the way a water utility works.

The monopoly characteristics of the water supply system make its management peculiar. Due to this reason and to the fact that water utilities are different from one another, it is not an easy task to define procedures, measures and management routines that will enable the improvement of the service delivered, nor to evaluate it.

Performance indicators are an answer to the sector needs, being one of the methodologies with more credibility, allowing water supply systems assessment and management. Among the several aims and advantages of using performance indicators according to the entity they are directed to, one is that they can be used to promote benchmarking between different water utilities. The research study carried out in Portugal, which is presented here, had as one of its main goals to provide a tool for benchmarking application.

In order to collect data and to obtain reliable results for the application and use of the indicators suggested, an inquiry was distributed to 25 water utilities. A description of this inquiry is presented in Marques and Monteiro (1998). The information obtained through the inquiry, even though sparse in some points, allowed the setting and comparison of those indicators among the various water utilities.

Description of the indicators proposal

The aim of this study was to develop a proposal of 50 indicators divided into five groups, which are structural indicators, operational indicators, water and service quality indicators, personnel indicators and economic indicators.

In the definition of the indicators above, both the development level of the Portuguese water utilities and their particular characteristics were taken into account. It was also aim of this study that the proposal could be feasible and relatively easy to adopt at short or medium term.

Structural indicators enable the description of the water utilities physical structure, putting into evidence the main characteristics of the distribution system: customers and consumption. This group of indicators includes the supply coverage (%), water abstraction capacity (%), water abstraction (%), customers density (no. km^{-1}), storage tanks capacity (days), materials (%), diameters (%) and age (years) pipes, volume per type of customer (%), *per capita* consumption (l day^{-1} $cu.^{-1}$), water consumption peak factors (–), customers enlargement (%), network rehabilitation (%) and public taps density (n. km^{-1}).

Operational indicators are suitable to describe the water utilities' behaviour and working characteristics, such as the way their operation and maintenance are carried out and their main problems. The operational indicators group includes the meter reading frequency (no. $year^{-1}$), billing per meter reader (no. $year^{-1}$), inspection and maintenance of systems (–), water billed (%), network efficiency (m^3 day^{-1} km^{-1}), replaced meters (%), pipe length per vehicle (km $veh.^{-1}$), losses per pipe length (l h^{-1} km^{-1}), losses per customers (l day^{-1} cu^{-1}), failures per pipe length [no. $(10^2$ km$)^{-1}$ $year^{-1}$] and interruption of supply (–).

The third group of indicators is related to water quality and quality of service delivered. These indicators can describe the extent to which the water supplied affects public health and reveals the customers satisfaction degree with the service delivered. This group comprises the indicators: disinfected water (%), treated water (%), number of yearly quality analysis (%), violations of water quality analysis (%), customers' complaints [no. $(10^{-1}$ cu.$)^{-1}$] and response to complaints (days).

Personnel indicators try to assess the performance and productivity of the water utilities staff. The indicators that belong to this group are the following: employees per activity (%), qualification of employees (%), absenteeism (%), training (h. emp^{-1} $year^{-1}$), employees per water produced [no. $(10^5$ $m^3)^{-1}$ $year^{-1}$], employees per customer [no. $(10^3$ cu.$)^{-1}$] and employees per pipe length [no. $(10^2$ km$)^{-1}$].

Finally, economic indicators are related to the water utilities' economical and financial characteristics. This group includes the following indicators: average water charges (\$ m^{-3}), average income (\$ m^{-3}), income per type of customer (%), cost composition per type of cost (%), running costs composition per type of cost (%), income per employees (\$ emp^{-1}), investment per pipe length (\$ km^{-1} $year^{-1}$), O&M cost per water produced [\$ $(10^5$ $m^3)^{-1}$ $year^{-1}$], O&M cost per customer [\$ $(10^3$ cu.$)^{-1}$], O&M cost per pipe length [no. $(10^2$ km$)^{-1}$], debt equity ratio (–), liquidity indicator (current ratio) (–) and return on equity (–).

Application methodology

Implementing the methodology for the water utilities management and assessment indicators must be progressive and adapted to the development level of each water utility. This study, directed to the Portuguese water utilities, suggests the application of this methodology according to three levels of knowledge or development: basic level, development level and strategic level.

A particular number of performance indicators is associated with each level. Thus, 20 indicators are associated with the basic level, 15 with the development level and 15 with the strategic level.

The indicators belonging to the basic level provide the general features of the water utilities, according to the several perspectives of each class of indicators. These indicators are generic ones and do not allow, in most situations, benchmarking with other water utilities.

Development level indicators enable the clarification of important issues about water utilities operation and maintenance, namely the performance of tasks carried out in its scope and its cost composition. This level also includes some indicators that characterise water utilities in terms of water quality and personnel.

The indicators included in the strategic level evaluate the performance of operational management, the quality of service delivered and the economic and financial health of the water utilities. These indicators are especially useful to benchmarking between water utilities.

The application methodology for performance indicators is represented in Figure 1.

The indicators belonging to each group can be classified according to their confrontation characteristic if their results enable benchmarking between different water utilities. For instance, the indicator customer density does not allow confrontation, whilst the indicator pipe length per vehicle does. The former indicator constitutes an intrinsic quality of a particular utility, while the latter depends on the vehicles management within the water utility.

Indicator assessment

Taking into account the Portuguese water utilities characteristics, performance assessment of the indicators suggested considers the values recommended as reasonable targets in the cases that the indicators allow confrontation. If for a specific indicator the performance is superior to 90% of the recommended value, it will be classified as excellent. If the value varies between 70 and 90% the performance will be considered acceptable. If the recommended value is inferior to 70% the performance will be weak, and it will need urgent improvement. Performance assessment criteria were defined for each indicator allowing confrontation, taking into account, simultaneously, several possible aspects that can change or justify the performance obtained.

The assessment criteria of the proposed indicators are represented in Figure 2.

An example of the assessment criteria for the storage tanks capacity is shown in Table 1.

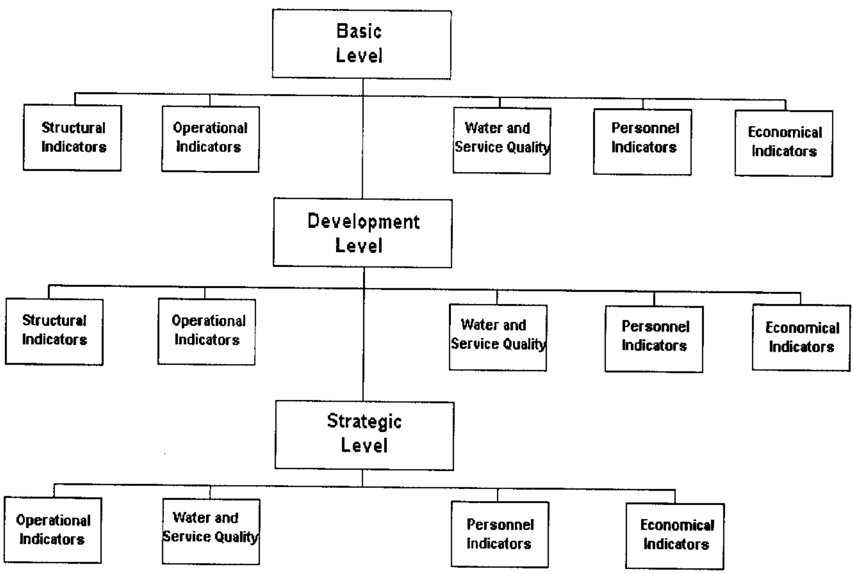

Figure 1 Application methodology for performance indicators (Marques, 1999)

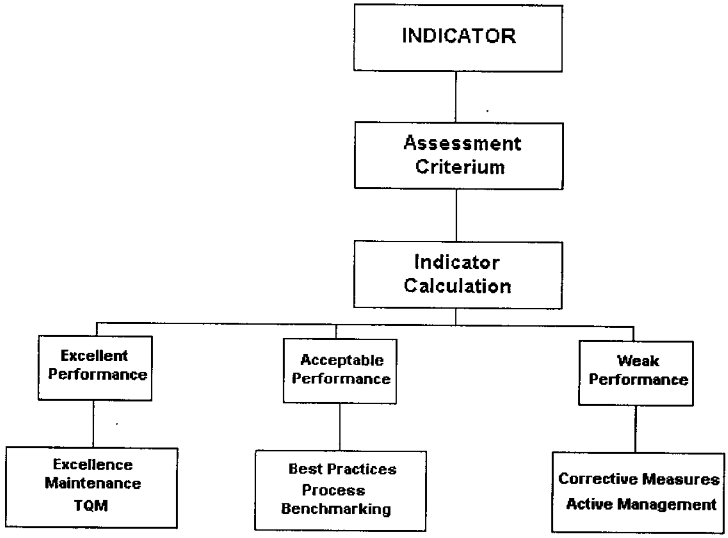

Figure 2 Assessment criteria of the proposed indicators (Marques, 1999)

Table 1 Performance assessment criteria for the indicator storage tanks capacity (Marques, 1999)

Indicator	Performance			Factors that change criteria
	Excellent	Acceptable	Weak	
Storage tanks capacity (days)	> 1.8	> 1.3 and < 1.8	< 1.3	Peak factors, transmission and distribution capacity

Some application examples

Network efficiency

Network efficiency is defined as the relationship between the daily average water volume produced and the total network length. This indicator characterises the population dispersion within the water utility. As this indicator increases, the higher is the populational concentration and, as a consequence, the higher will be the consumption and more profitable will be the water utility.

Figure 3 presents the relationship between the customer density in a water utility and the network efficiency. This picture shows that in the water utilities studied these two indicators are correlated. The correlational curve that best describes this relation is given by:

$$Y = 0.3358\, X^{1.0796} \; (\rho^2 = 0.8311)$$

where:
X represents the customer density (no. km^{-1});
Y represents the network efficiency ($m^3\ km^{-1}\ day^{-1}$).

Violations of water quality analysis

Violations of water quality analysis is an indicator given by the relationship between the number of water quality analyses that violate the legal standards and the total number of analyses taken. These analyses must be performed taking into account several groups of parameters, respectively, aesthetic, bacteriological, physical, chemical, and others. This is an indicator that concerns the water supplied quality and the effectiveness of the treatment taken. An optimal performance of the water utility would correspond to an indicator that would present a 0% value.

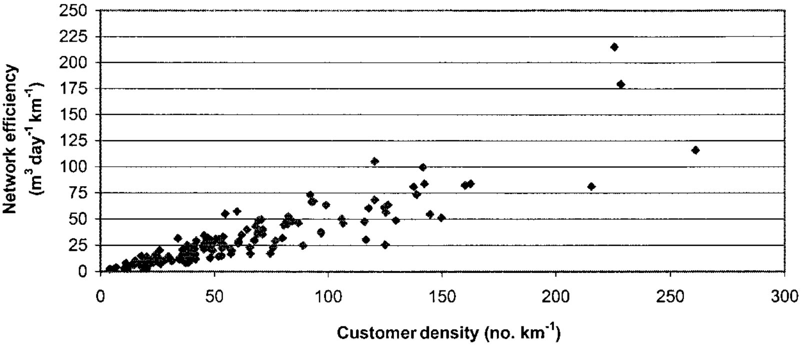

Figure 3 Relation between customers density and network efficiency [Marques, 1999, (Data: APDA, 1997)]

Figure 4 shows the number of violations of water quality analysis in growing order of water production volume for the water utilities studied. As the figure shows, there is an inferior percentage in the violations of water quality analysis in the larger water utilities. Table 2 shows the performance assessment criteria of this indicator.

Network losses per pipe length

Network losses per pipe length is given by the relation between the losses per hour and the pipe length. This indicator, from the economical, water quality and environmental points of view, is extremely important to decision making when doing leak survey. Accounting for the losses in terms of percentage of the volume produced is significant to the efficiency of the system but does not allow conclusions about the profit possibly obtained with their detection and depends on the water utility characteristics under analysis. The implementation of leakage surveys is related with the lost volume, with the pipe length and with the customer number of each water utility (more precisely with the number of connections).

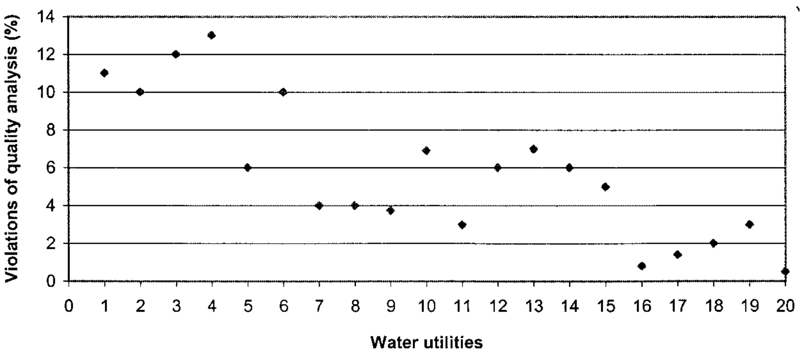

Figure 4 Number of violations of water quality analysis (Marques, 1999)

Table 2 Performance assessment criteria of the indicator violations of water quality analysis (Marques, 1999)

Indicator	Performance			Factors that change criteria
	Excellent	Acceptable	Weak	
Violations of quality analysis (%)	< 1	> 1 and < 3	> 3	Failures, raw water quality, level of treatment, network dispersion

The different kinds of water losses both of physical and commercial origin must be taken into account in the analysis of this indicator, such as the water public and its own consumption.

The correlational curve to the Portuguese water utilities was established in relation to the customers density (Figure 5) and the result was:

$Y = 2.4214\ X^{1.198}$ ($\rho^2 = 0.5376$)

where:

X represents the customers density (no. km^{-1});
Y represents network losses per pipe length ($l\ h^{-1}\ km^{-1}$).

The performance assessment criteria of this indicator are represented in Tables 3 to 5.

Employees per pipe length

The indicator *employees per pipe length* is defined through the relation between the total number of employees in a water utility and each one hundred kilometres of pipe network.

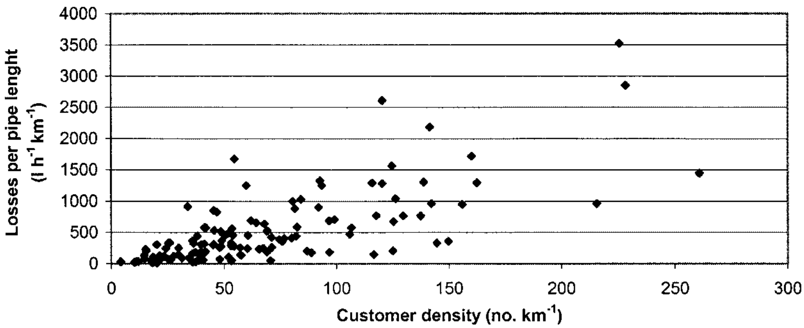

Figure 5 Relation between network losses and customers density
[Marques, 1999, (Data: APDA, 1997)]

Table 3 Performance assessment criteria of the indicator network losses in rural systems (customers density inferior to 50) – (Marques, 1999)

Indicator	Excellent	Performance Acceptable	Weak	Factors that change criteria
Losses per pipe length ($l\ h^{-1}\ km^{-1}$)	< 100	> 100 and < 300	> 300	Water public, metering differences, own consumption, age, pressures, materials and diameters of network, type of soils

Table 4 Performance assessment criteria of the indicator network losses in semi urban systems (customers density between 50 and 125) – (Marques, 1999)

Indicator	Excellent	Performance Acceptable	Weak	Factors that change criteria
Losses per pipe length ($l\ h^{-1}\ km^{-1}$)	< 200	> 200 and < 500	> 500	Water public, metering differences, own consumption, age, pressures, materials and diameters of network, type of soils

Table 5 Performance assessment criteria of the indicator network losses in urban systems (customers density superior to 125) – (Marques, 1999)

Indicator	Excellent	Performance Acceptable	Weak	Factors that change criteria
Losses per pipe length ($l\ h^{-1}\ km^{-1}$)	< 500	> 500 and < 1000	> 1000	Water public, metering differences, own consumption, age, pressures, materials and diameters of network, type of soils

This indicator enables the assessment of personnel in a water utility and depends on the customer density. Regarding the Portuguese water utilities (Figure 6) the correlational expression that best represents this indicator is:

$$Y = 0.3753\ X + 1.604\ (\rho^2 = 0.6431)$$

where:

X stands for the customers density (no. km^{-1});
Y stands for the number of employees for one hundred kilometres of pipe network [no. $(10^2\ km)^{-1}$].

In this study the criteria for the performance assessment of the indicator employees per network length were also established, following the same procedure.

Discussion and conclusions

From the study presented here, the following conclusions may be drawn:

The application of a reduced number of indicators always leads to losses of knowledge about relevant aspects in the water utilities management. Fundamental issues such as leaks or water losses, personnel, or operation and maintenance costs, among others, will be difficult to know and hard to understand without using more than one indicator with a similar meaning.

It is essential to have a homogeneous group of common indicators internationally accepted upon which a deep study can be made, relying on a great diversity of statistics from different entities, so that the results can be generalised.

It is not possible to point out an optimal value to most of the indicators, mainly because when this one exists it depends on the particular characteristics of each water utility and it varies over time. The values suggested for the indicators are characteristic or reference

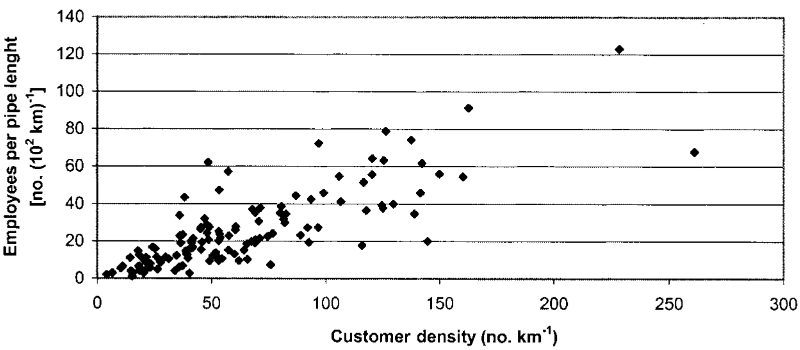

Figure 6 Relation between the number of employees per network length and customers density [Marques, 1999, (Data: APDA, 1997)]

values and do not correspond to optimal values. The intervals were established considering the obtained results from the inquiry developed near the water utilities, the experiences of the inquired entities and the bibliographical references. In the future, on the basis of additional information, the intervals presented can be readjusted.

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