

# Use of performance indicators and performance benchmarking in the North American water industry—findings from studies recently completed for AWWA and WEF research foundations

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**ABSTRACT:** In this paper the author sets out the experience gained while undertaking two milestone performance benchmark studies in the US water industry: *Performance Benchmarking for Water Utilities*, funded by the AWWARF (American Water Works Research Foundation); and *Benchmarking Wastewater Treatment Plant Operations*, funded by the WERF (Water Environment Research Foundation)

The paper identifies two separate, but complementary components, to benchmarking, i.e. metric benchmarking and process benchmarking. The former comprises a range of quantitative assessments and comparisons including performance ratios and performance models. The latter focuses on how to make improvements in existing work processes by mapping current activities and then comparing to similar activities in 'best in class' service providers.

The paper concludes with a summary of the key results from the two studies, including the presentation of performance ratios, performance models and good management practices.

## BACKGROUND

This paper reports on the work of two benchmarking projects undertaken by the WRc in North America. The projects are complementary, in that they separately address the water and wastewater industries. They are also complementary in that the wastewater project followed the water project and was able to further develop concepts identified in the earlier project. In summary, the two projects are as follows:

*American Water Works Research Foundation (AWWARF): Performance Benchmarking for Water Utilities.* This project established the different forms of benchmarking (i.e. metrics and process), used available data to prepare a range of performance ratios, univariate and multivariate cost models, and undertook a case study of process benchmarking. This project commenced in the Summer of 1994. The report was published in Autumn 1996.

*Water Environment Research Foundation (WERF): Benchmarking Wastewater Operations—Collection, Treatment and Biosolids Management.* This project collected raw data from over 100 wastewater utilities and used the information to determine multivariate cost models for the collection and the treatment functions. In addition, information was collected on management practices in the utilities. This allowed the project to establish any links between the above average performers (from the cost modelling exercise) with their management practices. Case studies of above average performers were

prepared. This project commenced in the Summer of 1996 and the final report was published in the Winter of 1997.

## INTRODUCTION

This paper presents an introduction to benchmarking followed by the key results from the two research projects.

There are two types of benchmarking—'metrics' and 'process'. These can be summarised as follows:

*Metric benchmarking* is a quantitative comparative assessment that enables utilities to track internal performance over time and to compare this performance against that of similar utilities. Areas of relatively good performance compared to that of the other utilities can be identified, as can those where there is particular room for improvement in performance. In addition, through the comparison process, target levels of performance can be established.

*Process benchmarking* involves first identifying specific work procedures to be improved through a step-by-step 'process mapping' and then locating external examples of excellence in these process elements for standard setting and possible emulation. This is also known as 'Xerox-style' benchmarking after work undertaken in the Xerox Corporation from 1979 onwards.

Around the world the emphasis of benchmarking is towards 'metrics'. How do my numbers compare with industry averages, industry best practices, how are the numbers trending, etc? Metrics are important to provide trending information

within an organisation but can often only give a sense of relative performance. This is because it is rare for inter-company reporting to be consistent. Numbers in one company are rarely put together in the same way as in the comparison companies. Thus, differences in reported performance may be caused by differences in cost allocations rather than differences in efficiency.

In addition, there are often genuine reasons why one company's headline performance numbers might be quite different to that of its peers, not because of any efficiency differential but because the operating environment faced by one company impacts costs differently to that of the others. This is particularly so in the water industry, where the quality of the raw water, the topography of the service area and the scale of the operation, all impact costs to different degrees and are outside the control of management. These are referred to as 'explanatory factors'.

Metrics, used carefully, will however, allow areas of under-performance within an organisation to be identified. Having done so, the challenge is then to make improvements in those areas so that they out-perform their peers. This requires changing the way things are done—and process benchmarking is one vehicle for achieving this change.

## METRIC BENCHMARKING

### Introduction

Metric benchmarking performance assessments identify activities that merit additional study. These additional studies will either determine that there are particular factors outside of management control which explain the apparent poor performance or they will confirm that action can be taken to improve performance. In either case, effective performance measurement requires the following:

- a set of performance measures that captures most or all of the key features of the function or process under review;
- an understanding of each explanatory factor, outside the control of management, that may impact performance;
- accurate, timely, and consistent internal data addressing

these measures and factors. Such data should preferably be gathered over time, in order to allow the detection of trends;

- comparable external data for each of these measures to permit comparisons with other organisations;
- techniques for data analysis.

### Key performance indicators

The starting point in defining the key performance indicators for the organisation is to agree the objectives of the organisation, or the activity or service which is to be monitored. These then need to be ranked in some way in terms of their 'importance'. The measurement framework can then be built around the important objectives. There is inevitably a trade-off between having too many indicators and too few. Typical measures include:

- Average cost indicators (cost per m<sup>3</sup> treated);
- Efficiency indicators (bills processed per staff per hour);
- Time related indicators (time to process a telephone enquiry);
- Quality of service indicators (availability, quality of water, pressure);
- Explanatory factors (scale of operations, inherited assets).

In developing the framework it is also important to recognise that the more detailed the assessment, the more the raw data has to be disaggregated. This leads to a typical performance hierarchy as follows (Fig. 1).

### Types of assessments

A wide range of quantitative assessment methods are available. A number are summarised below:

*Performance ratios:* These are the 'bread and butter' of performance measurement. They are relatively simple to collect and report. Managers can produce trending charts and league tables. The former are helpful at identifying whether things are progressing in the right direction, although they don't show whether the absolute level of performance is good or poor. League tables, on the other hand, generally demon-

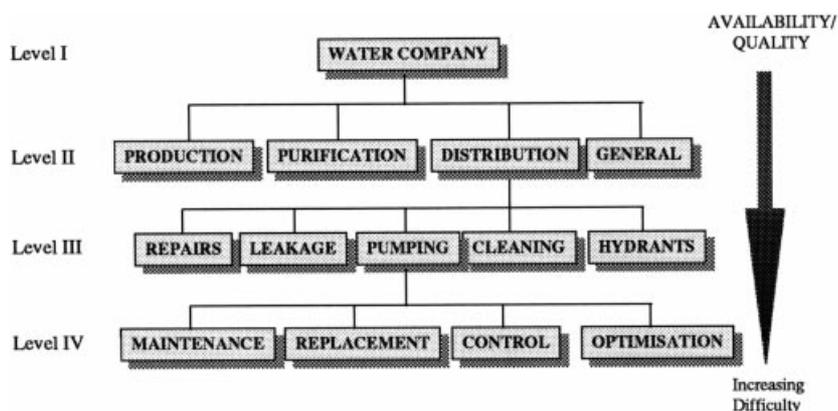


Fig. 1 Typical performance hierarchy.

strate all the weaknesses of performance ratios. They lead to inevitable debates as to the reasons why managers can have apparently good performance in one ratio and poor performance in another—all the explanatory factors then come to the surface. Figure 1, taken from the water treatment sector, also illustrates how ratios do not demonstrate absolute levels of performance.

*Performance models:* Performance models take measurement to the next level of detail and explicitly include explanatory factors in the performance assessment. The models use standard regression analysis to determine a functional equation that links the dependant variable (e.g. costs or staff numbers) with the independent variables (e.g. the explanatory factors such as scale of operations, difficulty of treatment). These are statistical analyses and, as such, do not always reflect what managers would intuitively assess as the relationship between the dependant and independent variables. They are in widespread use in the water industry. OFWAT have developed a whole series of models for the UK water industry, and WRc has produced a range of models for the North American and Italian water and wastewater industries.

*Additional techniques:* Further techniques can also be applied to make quantitative assessments of performance. These include 'stochastic frontier' modelling where, rather than draw a line through the average of all the data (as for standard regression models), the model draws the frontier of good practice. Another alternative is the mathematical programming technique of 'Data Envelopment Analysis' where mathematical cocktails of good performers are compiled, against which the performance of the unit under consideration is assessed.

In summary, there is no one answer to the question 'How efficient am I?'. It is important to use a range of tools to develop an understanding of the situation. Trends, ratios, models, explanatory factors and the others will all come together to give an overall impression of performance.

### Methods of comparison

There are four main types of benchmarking comparisons:

- internal comparisons—comparing two or more units in the same organisation;
- external direct competitor comparisons—comparing your organisation or one of its functions against a competing organisation in your industry;
- industry functional leader comparisons—comparing your organisation or one of its functions against an organisation in your industry which is not a direct competitor but which is thought to be exemplary; and
- generic process comparison—comparing a process in your organisation against an organisation outside of your industry, a part of which has similar or analogous process.

With large organisations such as utilities, internal comparisons are particularly useful. They can be prepared in an environment where the data is relatively consistent between units, making comparisons more robust. The better performers can be identified and their practices analysed. The best practices can then be cascaded throughout the organisation. Clearly, the other forms of comparisons need to be treated with caution, given data differences.

## PROCESS BENCHMARKING

### General approach

Having used metric assessments to identify underperforming areas within the organisation the challenge is to make some change that will lead to an improvement—be that increased quality of service, reduced costs or both.

This can be tackled in a number of ways. This may mean a top-down, business re-engineering, leading to a major reorganisation of the structure of the company. Often there will be a limited involvement of the staff at the sharp end of the business. Alternatively, a bottom-up approach can be introduced that will draw on the detailed knowledge of a full range of staff in the organisation and will lead to improvements at in front line operations. This talk will focus on the latter but is cognizant of the need for both approaches—ideally brought together in one exercise.

The starting point is to identify the full range of business units that contribute to the process being improved. Suitable representatives from each need to be identified and then the improvement team must be assembled and trained in performance benchmarking. The training not only introduces the technical approach to benchmarking but is also a powerful team-building exercise which will be of great value later in the project when change programmes are prepared.

Part of the training includes the preparation of process maps. These maps are flow charts of the activities that comprise the process. Generally, these maps are extremely detailed and are quite different to the maps that managers have prepared as a precursor to the exercise. The mapping process can often lead to immediate changes in the process as the team identify activities that do not add value.

The collection of data, and its analysis, further improves the understanding of the team so that they know their process inside out. They are then in a position to visit other organisations and gain insights into alternative ways of achieving their goal.

### Finding suitable partners

The utility industries are traditionally conservative. Many of the staff have been in the business for long periods, and working methods have evolved over time. When looking for benchmarking partners, it is important to challenge this conservative

thinking. Inevitably the team will initially focus on peer utilities as benchmarking partners, but with some coaxing a much broader range of partners is always possible. There is little if anything that is unique to any utility. Take a water treatment plant. This is a combination of activities such as flow control, chemical dosing, pump and equipment maintenance, dealing with hazardous chemicals and so on. Each of these activities can be found in other industries. A benchmark water treatment plant is therefore unlikely to be another water treatment plant but the summation of best practices in each of these activities—as found by looking at other industries.

Finding best practice partners is mainly detective work. Comparative utilities or ‘benchmarking partners’ should be identified as early as possible to ensure that the ‘best of the best’ are interested and available to participate in the study. Benchmarking partners do not have to come from the same industry but should share similarities in the processes being benchmarked. Before setting up visits to prospective benchmarking partners, it is important to investigate all available information sources.

Information available in the public domain, such as previously published work, industry journals, Total Quality Management (TQM) associations, industry associations and benchmarking organisations, may lead to other sources of information. Reviewing the available information is a cost-effective way to increase the number and quality of choices when selecting benchmarking partners. This helps identify the most appropriate partners to maximise the benefit of the investigation.

## SUMMARY

Metric benchmarking is not a precise science. A range of tools need to be used to assess performance and to take into account explanatory factors that impact performance but are outside the control of management.

Data quality is important. Inconsistency of data reporting will lead to apparent differences in performance which have nothing to do with real efficiency differentials. In-house data are likely to be more consistent than that collected externally, so inter-unit comparisons are a valuable benchmarking resource.

Process benchmarking is one vehicle for change. It looks at how things are done in other organisations and, by learning from this experience, new approaches can be applied to improve the performance of the host organisation. Looking outside the industry will expand the horizons of the organisation.

Process benchmarking can be applied at a range of levels in the organisation, from top-down to bottom-up. The bottom-up approach gains support and commitment from those on the front line of service delivery – improving the likelihood of a successful implementation.

## RESULTS FROM THE STUDIES

### AWWARF

#### *Metrics*

A range of performance ratios were developed using information available for the investor-owned water companies in the USA. These included the following:

- Total operation and management (O&M) cost (US\$) per thousand gallons sold;
- Production O&M cost (US\$) per thousand gallons produced;
- Purification O&M cost (US\$) per thousand gallons produced;
- Production and purification O&M cost (US\$) per thousand gallons produced;
- Transmission and distribution O&M cost (US\$) per thousand gallons sold;
- Transmission and distribution O&M cost (US\$) per mile of main;
- Customer accounting cost (US\$) per account;
- Administrative and general cost (US\$) per account.

A typical output from the ratio analysis is presented in Fig. 2.

Univariate regression analysis of the investor-owned water company data was carried out to develop models of operating costs as a function of the scale of the operation. An example of the univariate analysis is presented in Table 1.

In the early 1990s the American Water Works Association (AWWA) and AWWARF jointly compiled a cost and performance database from over 1000 utilities in North America. This was called the Water Industry Database (WIDB). While the data was not current, it was used to demonstrate how multivariate regression analysis was also possible in the water industry. Models linking costs and staff numbers to the range of explanatory factors facing a water utility were developed. The cost model is presented below:

$$\text{OpEx} = 36.86 \times \text{accounts}^{0.434} \times \text{WDel}^{0.4327} \times 0.995\% \text{gw}$$

where: OpEx = annual operating costs, Accounts = Number of accounts, WDel = Total water delivered, %gw = % of raw water from groundwater sources.

#### *Process benchmarking*

The process benchmarking case study clearly established that process benchmarking is applicable to the water industry. Our conclusions focus on the key learning points derived from the work.

Establishing a team with members across all the activities that comprise the process to be benchmarked is essential. It ensures that the process is properly mapped, while the team's detailed, ‘hands-on’ knowledge of working methods means that any changes to the process resulting from the work are practical and will find support when exposed to a wider audience.

Process mapping is invaluable as a means of team building and enabling the multifunctional team to see the whole process and their individual parts in it, often for the first time.

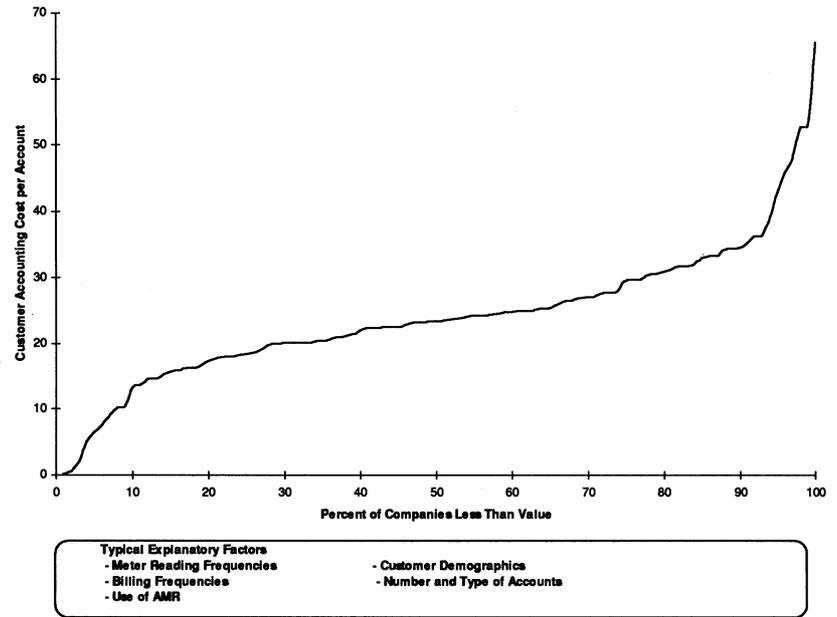


Fig. 2 A typical output from the ratio analysis.

Table 1 Results of univariate analysis

Dependent variable (A) (\$)	Independent variable (B)	Model	% v.a.f.*	Minimum value of independent variable	Maximum value of independent variable
Production & purification Operation & maintenance Expenditures	Total annual water Produced (millions of gallons)	$A = 1036 B^{0.911}$	88.9%	141.4	95 297
Transmission & distribution Operation & maintenance Expenditures	Miles of main in service	$A = 1395 B^{1.093}$	90.0%	23.5	5102
Administrative & general cost	Total number of customers	$A = 329 B^{0.862}$	92.4%	1664.0	373 198

\*% v.a.f. = Variance accounted for = Adjusted  $R^2$  statistic.

While the topic of the investigation was refined considerably during the course of the project, it is essential to keep the subject to a manageable size so as not to become burdened by excessive complexity and data collection needs. It is not recommended that an organisation should attempt to benchmark broad areas of the operation; instead, it should focus on specific processes and allow the team to refine that focus as needed.

Although data analysis is important, the case study quantitative analyses demonstrated that some perception is based on fact, some on fiction. It is important to know which it is.

The use of out-of-industry benchmarking partners should

form part of a benchmarking study wherever possible. It allows the benchmarking team to better understand the strengths and weaknesses of its own process, while establishing an environment where more innovative solutions can surface.

**WERF project findings**

Building on the outputs from the AWWARF project, the project team set out to collect raw data from the wastewater utilities and to derive a set of more complex, but more relevant, multivariate regression models. Thus the team successfully

developed models for the collection system and the treatment operations. The results are summarised below:

#### *Collections systems model*

Several forms of the equation were considered. The preferred model takes this form:

$$\text{OPCSTCOL} = e^{0.898} \times (\text{MILES}^{0.539}) \times [(\text{PCINSP}/100 + 1)^{-0.084} \times (\text{PUMP} + 1)^{0.285} \times (\text{COLWAGE}^{0.897}) \times (100 \cdot \text{KWH})^{0.15}]$$

where: OPCSTCOL = Total cost of collection operations, excluding depreciation (US\$), MILES = Miles of sewers, PCINSP = Percentage of sewers inspected each year, PUMP = Number of pumping stations, COLWAGE = Average annual wage of a collection worker (US\$), KWH = Cost per kWh of electricity (US)

The wastewater and biosolids cost model take the form:

$$\text{OPCSTWET} = e^{6.43} \times (\text{MGD}^{1.354}) \times (\text{WBPLA}^{-0.493}) \times \{[(\text{ASOXY}/100) + 1]^{0.442}\} \times \{[(\text{ASMEC}/100) + 1]^{0.404}\} \times (\text{BIOPROD}^{0.408}) \times (\text{WBWAGE}^{0.499}) \times (\text{KWH}^{0.432})$$

where: OPCSTWET = Total cost of wastewater and biosolids operations (US\$), MGD = Average daily flow (Mgal/day), WBPLA = Average daily flow per plant (both wastewater and biosolids) operated (Mgal/day), ASOXY = Percentage of influent treated by the activated sludge process using an oxygenation aeration device (pure oxygen), ASMEC = Percentage of influent treated by the activated sludge process using mechanical aeration, BIOPROD = The quantity of biosolids produced per unit of influent (dry tons/Mgal/day), WBWAGE = Average wage of a worker in wastewater and biosolids operations (US\$), KWH = Cost per kWh of electricity (US).

In addition information was collected about the management practices of the utilities, and summary information was prepared showing the extent of the use of such practices. Some typical results are presented in Tables 2 and 3.

The team used a range of statistical techniques to establish if there was any valid relationship between the above-average performers (identified through the cost models) and the management practices they used. The results were positive, and statistically valid correlations were found. Case studies were undertaken on a selection of above average performers. The utilities that were selected demonstrated many best practices, such as:

**Table 2** Methods for transferring service requests

Method	Per cent using method	<i>n</i>
Paper	77.9	86
Computer link	41.9	86
Fax	38.4	86
E-mail	33.7	86
Dial-in	2.3	86
Cell phone, pager or other	45.3	86

**Table 3** Factors influencing promotion and/or salary adjustment decisions

Category	Mean	Median	Max	Min	<i>n</i>
Longevity	15%	10%	100%	0%	97
Performance review	35%	25%	100%	0%	97
Certification	7%	0%	50%	0%	97
Meeting performance targets	7%	0%	70%	0%	97
Collective bargaining	26%	0%	100%	0%	97
Other	11%	0%	100%	0%	97

- Sharing the workforce with other utilities or other parts of their organisation.
- Proactive influencing of regulatory outcomes based on good science (and thus cost avoidance).
- Efficient communications technology and work order generation.
- Understanding asset condition, flow monitoring and process modelling to optimise asset sizing (cost avoidance, both capital and operating).
- Managed competition to challenge the work force, and outsourcing where this reduces costs.
- Extensive training and cross-training.

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