Assets Inspections—A Real Knowledge for Risk and Asset Management

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Abstract: Empresa Portuguesa das Águas Livres (EPAL) is a capital intensive company, in which the operational infra-structure assets represent the basis of customer service whilst being a great consumer of capital. In this context, the asset management function plays a key role in optimizing the return on infrastructure usage, and at the same time guaranteeing adequate levels of service. With a view to an effective and efficient management of investments to be made in a rational and sustained way under technical-scientific criteria, implementing a systematic inspection program was considered as the best approach strategy. The main purpose of the inspection program is to obtain, in a systematic, coherent and comparable way, relevant information to support decision making, in particular for supporting intervention priorities and identification along with asset maintenance requirements, whether preventive or curative. This methodology is revealed as a key tool in the management of risk of failure associated with the management and operation of EPAL’s building infrastructure.

Key words: Knowledge, risk, management.

1. Introduction

The Empresa Portuguesa das Águas Livres (EPAL), SA, founded in 1868, is the oldest and largest water supply company in Portugal. Initially, it was a privately owned concession to supply water to Lisbon and became a state owned company in 1974. Since 1991, EPAL is a public limited company, wholly owned by Águas de Portugal group.

EPAL provides drinking water up to 2.6 million people in 35 municipalities, including Lisbon. Water comes from a range of different sources (reservoirs, rivers and underground sources), prior to treatment and bulk supply to municipalities. In Lisbon, EPAL is also responsible for the distribution to around 350,000 customers’ homes and businesses.

With 635 staffs, EPAL has assets with a net fixed value of more than 700 million EUR.

In a water supply company, the assets represent a large consumer source of capital, both in the construction phase or during the life cycle.

In this sense, to ensure sustainability and profitability levels appropriate to the stakeholders, it will be necessary to manage these assets as effectively and efficiently as possible, whilst seeking to maximize the useful life of these assets and minimize investment levels over the full life-cycle of the assets.

For this, it is essential to obtain systematic and consistent information to allow, at each moment, the most appropriate decision based on reliable and comparable data.

The methodology adopted to ensure this objective was the implementation of a program of systematic inspections of assets, based on a set of predefined criteria, which were revealed as a key tool in the management of risk of failure associated with the management and operation of EPAL’s building infrastructure.

2. Methodology

EPAL has developed a system of systematic inspections to its operational building infrastructure,
with the principal objective of obtaining essential information about the management of risks associated with the operation of its assets [1, 2]. This system was used as the basis for decision supporting in terms of investments and maintenance, and also contributed to the operationalization of the concept of integrated asset management.

The implemented inspection system is based on four fundamental vectors: frequency (maximum of five years), origin (planned or unplanned), level (current, principal and detailed) and condition grades (grades 1-5).

Based on these four vectors, a set of information and support data, which form the basis of analysis and evaluation, have been created and systemized. One such example of this situation covers preparation of inspection reports (per type of asset, such as water tanks, pumping stations, etc.), in which all of the necessary information obtained during the course of an inspection are systemized and classified.

Thus, the final outcome of an inspection, in the first stage, consists of the attribution of a condition grade to the asset (from 1 to 5, to support making decision in the first instance), and also considers another set of relevant information to carry out the analysis and proceed with the general systemization and classification of data. It also allows, on the other hand, support of the development of an effective and efficient maintenance plan for the different operational building structures.

To support and manage all information recorded and developed during this activity, the development of a computer application database has become necessary. Its operating requirements respond adequately not only to the specific needs of the inspections, but also to their own overall management of the whole life cycle of the supply system operational assets.

This application allows the aggregation of data related to the assets to enable the availability of relevant information in a universal, consolidated and integrated form.

3. Objectives and Importance of Inspections

The implemented inspection system was based on the development of a system of evaluation and the physical condition of various assets. Simultaneously, it defines the following partial objectives:

- Proceed to the survey of the current state condition of infrastructure;
- Assess the risks associated with the management and operation of infrastructure;
- Organize the information to support decision regarding the prioritization of investments in maintenance/rehabilitation in a systematic and coherent way;
- Optimize the allocation of available resources and channel them to the highest priority investments;
- Identify and diagnose anomalies, and define possible solutions for intervention/rehabilitation;
- Prepare and develop a program supported by documentary procedures.

The reliability of an infrastructure depends on the physical condition and maintenance actions, to which it has been subject during its lifetime. In this context, the inspections allow to obtain relevant information about this condition and consequently on the effective reliability of the assets.

Hence, the methodology implemented aims to ensure that the systematic inspections help to maintain approximation between the infra-structure condition degradation curve and the green curve represented in (Fig. 1) [3], regarding logical and periodic preventive maintenance. To implement this, various regular maintenance interventions need to be implemented over the asset life-time, including those recommended following completion of inspections cycles.

With the information obtained and developed through the implemented inspection system, it is thus possible to:

- Determine the baseline and evolution of the assets;
- Develop risk ranking for the various infrastructures;
• Select, prioritize and schedule investments wisely;
• Conduct a transversal and integrated infrastructure management;
• Support and develop a new strategic approach to preventive maintenance;
• Study and develop models for the degradation of materials and structures.

4. Inspections System

4.1 Definition of Inspection

Inspection activity by definition corresponds to “implementation of a formal procedure—the control of conformity accomplished through measurements, observations, comments, tests or calibrations of the significant characteristics of an asset (in writing rule), which are registered to enable the decision makers to assess the effectiveness of infrastructure and take appropriate actions.”

The implemented inspections system on EPAL is based on the following four fundamental vectors: frequency, origin, level and condition grades.

4.2 Frequency of Inspections

Given the number of assets generally labelled as “visitable”, each asset has to be passed no more than five years before it is again inspected and proceeds to the respective risk reassessment.

In cases that the physical condition of the infrastructure recommends a short-term improving intervention (about two years) and that intervention does not occur due to restrictions of any nature, a new inspection must be carried out within two years.

4.3 Origin Inspection

Inspections may submit the following types according to their origin:
• Systematic inspection—inspection performed at intervals of predetermined time corresponding to the schedule provided in planning inspections;
• Conditional inspection—inspection due to a poor physical condition of an infrastructure or any of its components.
4.4 Inspection Level

The inspection program comprises three levels of inspection:

- **Current inspection**—visual inspection based on check lists pre-defined in the context of monitoring and maintenance routines, which triggers the completion of a main inspection in the event of a malfunction.
- **Main inspection**—visual inspection, supplemented where possible by non-destructive tests, performed or coordinated by a team of skilled technicians (engineers) with valences and specific training in this area; at least every five-year implementation or whenever triggered by information from a current inspection.
- **Detailed inspection**—it was performed by a specialist company, in conjunction with the main inspection team that supported a specific test campaign, to prepare a detailed report on the physical condition of the infrastructure or a particular component, indicating the possible causes for the anomaly occurring, and if possible, referring to alternative approaches to solving/minimizing these situations. The detailed inspection is performed, if the result of a main inspection justifies its need or if the condition/criticality of the inspected assets requires some complementary data.

4.5 Main Inspection Grades

In order to support the definition of interventions priorities, a scale was developed for assessing the condition of the assets (and its components), with grades from 1 (very good) to 5 (very poor). Join this to an action calendar, depending on the anomalies and the associated risk.

An abridged version of the condition grades and the associated timing of intervention are shown in Table 1 [4-6].

5. Information Organization

5.1 Inventory of Assets

In order to inspect the various infrastructures of any utility entity networks or company, it is essential, at first, to identify and characterize the different types of existing assets. It is therefore necessary to update the respective inventory, through the survey/review of all operational infrastructure as well as its main features. In Fig. 2, the inventory (number and extension) of assets in EPAL and the print screen of software application is shown.

5.2 Assets Inspection Planning

The planning of inspections is a dynamic tool that enables the management of the inspection cycle, through a temporal distribution. It tries to reflect the constraints arising from the normal operation of the system. It also allows key dates for the timely gathering of relevant information as a basis and rationale for decision making at predetermined dates.

Taking into account the physical condition of assets and the date of last inspection, the application almost automatically assigns all the inspection schedules and the inspectors responsible for the work. In Fig. 3, an excerpt of the five-year plan inspections is presented.

<table>
<thead>
<tr>
<th>Condition grades</th>
<th>Physical condition description</th>
<th>Recommended intervention calendar</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-very good</td>
<td>Component in good condition (structural, physical and functional)</td>
<td>Only regular observation</td>
</tr>
<tr>
<td>2-good</td>
<td>Component in acceptable condition (structural, physical and functional)</td>
<td>Small interventions, not priority</td>
</tr>
<tr>
<td>3-fair</td>
<td>Component with some relevant deterioration and durability affected</td>
<td>Intervention in medium term (3-5 years)</td>
</tr>
<tr>
<td>4-poor</td>
<td>Component with some relevant deterioration and affected durability</td>
<td>Intervention in short term (1-2 years)</td>
</tr>
<tr>
<td>5-very poor</td>
<td>Component with critical failure detected or possibility of imminent failure (collapse)</td>
<td>Immediate intervention</td>
</tr>
</tbody>
</table>
Fig. 2  Number and extension of assets of EPAL/Print screen of software application.

Fig. 3  Inspections annual planning.

Fig. 4  Support manuals.
5.3 Preparing Manuals Support for Conducting Inspections

As a support tool and reference to the whole inspection system and its related activities, a set of manuals (Fig. 4) have been prepared in order to systematize the information and procedures:

- Management manual—inspections system details;
- Inventory manuals—administrative, technical and training data for various types of infrastructure;
- Inspection manuals—procedures, standards and methodologies for conducting inspections.

6. Methodology of Inspection

6.1 General

Conducting an inspection to an asset, in essence, involves the fulfillment of a number of sequential steps which are of fundamental importance. It should be associated with the need to provide inspection teams with a specific set of equipment (cameras, rebound hammer\(^1\), ferro scanner, thickness gauges\(^2\), etc.).

Thus, a simplified way to conduct a main inspection consists of three steps: (1) preparation in office; (2) inspection of infrastructure; (3) compilation of information and preparation of inspection report (Fig. 5).

6.2 Visual Inspections

A visual inspection, naturally, is an act of engineering involving a high degree of function of civil and criminal liability, since technicians who inspect and assess the structural issues (and thus the risk) in infrastructures, are taking responsibility in their respective reports by the opinion about the reliability (or lack thereof) of certain component/asset.

In fact, it is crucial to the success of an inspection system. The implementation of the various inspections is undertaken by a team of technicians with specific training in this area, and led by a technician with a degree in civil engineering. Another important aspect that should be provided, relates to the consistency and uniformity of assessments. Therefore, for the overall analysis of a infrastructure to be as consistent as possible, the team that performs this activity, should not be too broad, whilst the rationale for assigning grades for the various infrastructure criteria components should be clear and with possible objectives in order to ensure assessment uniformity by various technicians.

For this purpose, a set of supporting information and records that assist and support the analyses/assessments, were created and systematized. An example of this concerns the preparation of inspection reports (by asset type—reservoirs, pumping stations, etc.), where it systematizes all the necessary information during an inspection.

So the end result of an inspection, at first sight, is to assign a rating to the inspected asset (in the first instance, support decision making), still contemplating another set of relevant information to support the analysis which is performed and proceeds with the general systematization of the data. It also allows, on the other hand, the support for the development of a plan for efficient and effective maintenance of various operating structures.

7. Inspection System Application

For all this data collection, EPAL developed an application to capture complete asset inspection report information, including photos, evaluations, characteristics, etc.

In this “user-friendly” application, which allows easy and fast development of new features, the assets constitution information, condition assets and its evolution, the inspection planning process, collecting and managing inspection data, are fully integrated holistic.
Fig. 5 Main inspection report.

The application supports and offers (Fig. 6):
- Historical asset and inspection data;
- Typified lists and drop-downs for inspectors works, through an intuitive and logical process;
- The support and assembling data, such as photos, dimensions, characteristics, anomalies and all relevant inventory and inspection information of assets;
- Fully integrated data for automatically generate of inspections reports;
- Obtaining global and critical information to support decision-making with systematic knowledge about the risks associated with the existing infrastructure of the supply system;
- Characterization of anomalies and repair works, allowing evolution to an integrated system (inspection/maintenance);
- Global and comparative knowledge about the evolution of the behavior of structural materials and construction solutions.

For a water utility, the losses in infrastructures are a permanent concerning. In order to have global data and information of losses in reservoirs, the application has a specific module, where the results of leakage tests are registered and allows to have global vision of losses in EPAL’s reservoirs, to help to define priorities of inspection and consequently interventions. The ranking of losses in EPAL’s reservoirs during 2013 is shown in Fig. 7.

8. Information Management

As mentioned, the implemented inspection program, on the one hand, allows the obtaining information which is extremely relevant for the reasoning and supporting for decision making and for the assessment of the physical condition of the structures. In this sense, it was considered equally important to identify performance indicators of the process itself as well as the actual physical condition of the various structures.

The system implemented allows a coherent and consistent overview of infrastructure physical condition (ranked by the inspection grades) (Fig. 8) and identification of the most critical situations. This information, in association with the strategic importance of each asset in the supply system, allows EPAL to undertake the ranking and prioritization of intervention actions, as well as allocation of investments for assets with a more significant business risk.
9. Risk Analysis to Support Decision-Making

As mentioned above, the operating assets of a water supply utility represent a great source of consumption capital. As this resource is limited, it is necessary to have decision on the highest priority investment tools. Thus, the inspection program provides systematic and consistent information, in order to establish a hierarchy of risk associated with asset utilization and to support management decision-making at all levels [7].

One of the most commonly used formulas for calculating the risk \( R \) is given by the expression: \( R = P \times C \), where, \( P \) is the probability of an event or failure and \( C \) is the consequence (or cost) of that event or failure.

Once the inspection grades are related with the physical condition supported by technical and objective criteria, the assessment are also directly linked to the probability of asset failure. In this context, the higher is the score assigned by inspection, the greater is the probability of failure or interruption.

Thus, to calculate the risk of a given asset failure, the main factor is given by the inspection score of the asset. So in this context, information obtained from inspections becomes essential to the entire structures, which are associated with other factors related to consequence (relevance, redundancy, etc.), allowing the calculation of the risk associated with the availability of different supply structures.

In this sense, based on the result obtained in the inspections, the result of the risk matrix was developed for defining EPAL’s multiannual investment plan. The particular case of pumping stations is presented in Fig. 9. It is possible to quantitatively and qualitatively assess the appropriate risk to make the decision process more robust and coherent.
Fig. 8  General information about the general state of conservation of structures.

**DEFINITION OF MULTICRITERIA MATRIX**

<table>
<thead>
<tr>
<th>OBJECTIVE</th>
<th>METRIC</th>
<th>INDICATOR</th>
<th>WEIGHT</th>
<th>CRITERIA</th>
<th>VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASSESSMENT OF CONDITION (Probability)</td>
<td>Inspection</td>
<td>Structural Evaluation</td>
<td>1.00 (0.80)</td>
<td>Very Good</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Good</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Fair</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Poor</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Very Poor</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Operation impact</td>
<td>Severity of impact</td>
<td>0.06 (0.20)</td>
<td>Low severity</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Relevant severity</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>High severity</td>
<td>5</td>
</tr>
<tr>
<td>ASSESSMENT OF CRITICALITY (Consequence)</td>
<td>Relevance</td>
<td>Annual pumped volume [M3]</td>
<td>0.50</td>
<td>100,000 &lt; V ≤ 1x10^6</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1x10^6 &lt; V ≤ 5x10^6</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5x10^6 &lt; V ≤ 10x10^6</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>V &gt; 100,000,000</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Redundancy</td>
<td>Alternatively pumping</td>
<td>0.50</td>
<td>Total</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Total/Partial</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Partial</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>None/Partial</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>None</td>
<td>5</td>
</tr>
</tbody>
</table>

Fig. 9  Risk matrix (excerpt).
10. Development of Maintenance Plan

Buildings

Alternatively, identifying defects through inspection also led to the characterization of anomalies and the systematization of corrective actions to be implemented towards the deficiencies [8]. This practice led to the development of a more selective and effective assets maintenance plan. With this consistent methodology, it was possible to systematize asset assessment interventions and develop a database of items and unit prices for the tasks.

The implementation of these planned low-cost interventions, encompassed within a preventive and periodic maintenance, seeks to improve the physical asset condition, as well as to extend the useful life of infrastructure (Fig. 1).

11. Results and Discussion

EPAL’s fundamental mission (extraction, production, transport and distribution of water for human consumption) combined with the wide geographical dispersion and variable age of assets, leads to the existence of a significant number of critical infrastructure assets supporting the water supply system.

In this sense, the risks associated with any water supply company must be particularly well managed. Adequate and correct decision-making, along with definition of priority investments and regular maintenance intervention, are essential to ensure supply security as well as the company’s sustainability and business integrity. So the invested capital permanently has fair and adequate profitability for all involved stakeholders.

On the other hand, considering the fundamental objectives of asset management to the permanently seek of maximizing the useful life of assets, minimizing investment and maintenance costs and manage the risk, it is essential to have factual, real and comparative knowledge of the physical condition and performance of the assets.

In this sense, with the implemented approach in the EPAL (regular and systematic inspections, based on established criteria), it is possible to evaluate, in permanent and comparable basis, the most critical situations in terms of probability of failure, allowing thus the actual knowledge of risks.

Thus, currently the investment plan is developed with the support of the result produced by the inspection team, which combines with information about the strategic importance of assets. And then the selection of investments is allowed to be focused primarily in situations where the risk is higher.

Moreover, in addition to the asset condition grade, which supports intervention ranking, another inspection output is the identification of maintenance action’s needs, to ensure good physical condition and performance levels in accordance with function requirements. In this sense, a typed list of anomalies and actions was created, which also allowed the creation of typified price lists for supporting the reference for maintenance contract tenders.

After the release of the tenders, the unit price assigned to each of the activities by competitors, is then statistically treated and loaded into the inspection system application. The inspection results can be a set of maintenance tasks, which is valued at current prices market. Thus, with the completion of the inspection, it is possible to know the cost of the necessary interventions.

The implemented approach allows the overview of the physical condition of EPAL’s assets, in order to manage the risk and priority setting and also to enable significant financial gains, once the investment plans and maintenance become more surgical and consistent.

12. Conclusions

The current economic situation highlights the urgent need to reduce and rationalize costs. Thus, the
decisions about investments should always seek to the adequate service levels to clients, although a certain levels of risk can be accepted. Indeed, decisions based on updated, transversal and coherent information provided by inspections, are able to improve the efficacy and efficiency of the asset management system.

In this sense, the inspections, supported on effective and systematic knowledge of the assets physical condition, are a fundamental tool for the balance among performance, cost and risk of infra-structure, which is the base of an asset management system [9].

In fact, the implementation of a inspections program and the development of a computer application decisively contributed to the improvement of service levels to clients, through minimizing the number of failures and simultaneously ensuring the profitability and sustainability of the business. On the other hand, the implementation of an inspection system equally contributed to the optimization of the performance of assets and to the minimization of acquisition, operating and maintenance costs throughout the life cycle of the assets.

Implementing an inspection system in EPAL allowed the company to obtain significant gains in different areas, in particular:

- Technical—robustness and consistency of information, allowing adequate risk management through duly substantiated decision;
- Economic and Financial—rationalization and optimization of investments (becoming more selective and surgical);
- Environmental Sustainability—maximizing the useful life of assets to enhance the rationalization of resources consumed and thus make the activity more sustainable;
- Social—increase in efficacy and efficiency of the company, with net gains and added value for the consumer/customer, through moderating the tariff.

References


