The Importance of Rehabilitation Planning for the Waste Management in Water Supply Systems

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EXECUTIVE SUMMARY

Water supply system rehabilitation is an activity of the utmost importance for waste management, given the new regulatory context: the Portuguese legislation concerning the public works launched in 2008 (New Code for Public Contracts – DL 18/2008). This legislation states that civil construction and demolition waste should be given a specific destination still in the early stages of development. The rehabilitation of water supply systems is a potentially large producer of waste that has to be adequately handled and transported to a final destination, which is established and implemented taking environmental issues into account. The application of an integrated methodology to rehabilitate the piping system allows a more economical and sustainable process to treat the resulting waste.

The objective of the current research is to develop and implement a rehabilitation plan for water supply systems concerning waste management. The proposed methodology is organized in four levels and eight phases, starting in the macro-scale of the council level and ending in the detailed component of the system to rehabilitate (e.g., pipeline, storage tank, devices or equipment). This methodology is based on the calculation of performance indicators for water supply systems. This paper begins with an overview of waste management in the new regulatory context as well as with a presentation of the main concepts associated with water supply system rehabilitation. The methodology to develop a rehabilitation plan, main conclusions and recommendations for the implementation of the proposed plan are also presented. This is a relevant new research, at both scientific and technical level, which challenges the rehabilitation method of water supply systems that is currently carried out by many water utilities in Portugal. This methodology highlights the importance of having an integrated system of information to define a rehabilitation plan.

KEYWORDS: rehabilitation, waste management, water supply, performance indicators.

INTRODUCTION

In European and North-American developed countries, most water supply systems were designed and built some decades ago. Therefore, water utilities are currently challenged to keep their systems operational, efficient and reliable so that water is provided in sufficient quantity and quality to the populations. The ageing of water infrastructures and related equipment (comprising source and consumers) is a normal and inevitable consequence and, as these mechanical components approach the end of their lifespan, leaks increase, supply breakdowns and interruptions become increasingly more frequent and maintenance costs rise. As a result, water utilities are forced to repair, replace or reinforce their systems. Consequently, questions like what, where, when and how to rehabilitate these systems arise. Utility engineers are required to make a series of decisions based on information of the underground pipeline that is often inaccurate, incomplete and out-of-date. Attention is now moving from reactionary strategies ("repair only after failure"), which hardly involve any long or short-term planning, towards proactive approaches based on predictive analysis to achieve long-term economic sustainability and efficiency (Covas, 2006).

Several rehabilitation models have been developed such as CARE-W (Alegre *et al.*, 2002; Conroy *et al*., 2002; Alegre *et al.*, 2003, 2004). These models, which are conceptually robust and well-designed, are one step ahead in rehabilitation planning, though they still have to be modeled to acknowledge Portuguese reality and simplified in order to be applied to available data in Portuguese water supply systems (Covas, 2006).

The Strategic Asset Management (SAM) aims to balance performance, costs and risks during the lifespan of infrastructures. SAM requires coordinated intervention at strategic, tactical and operational levels as well as at the existence of competences in four main areas: management, engineering, information and social sciences (Alegre, 2006; 2007). SAM of water supply systems is of the most importance in Portugal since, in the last years, a huge amount of money has been invested in the construction of new infrastructures. Furthermore, new necessities have emerged recently such as operation and maintenance, as well as the rehabilitation of those infrastructures.

Until recently, there was not a procedure to guide the decisions made by water utilities in terms of rehabilitation of their systems as well as in the establishment of short, medium and long term goals. Borda d'água (2008) has presented a new proposal of methodology to develop rehabilitation plans in small water utilities and implemented it in the water supply system of Vila Franca de Xira. This method is believed to be more appropriate to the Portuguese water system. Alegre and Covas (2009) have published guidelines to implement the Strategic Asset Management in water supply and distribution systems; this manual was published by the Portuguese Water Regulator (IRAR).

The objective of the current paper is to present the research made by Borda d'água (2008) (development of rehabilitation plans) concerning waste management and acknowledging Portuguese regulation. Rehabilitation and waste management are current issues that reflect economical, environmental and social concerns. Recent Portuguese legislation concerning waste management is an example of such concerns. The new regulation of residues of construction and demolition works (RCDW) - Portuguese law n. 46/2008, of 12th March 2008, which that took effect on the 11th of June of 2008 - emphasizes the responsibilities of the different parties in the waste management. Additionally, the new Portuguese law n. 18/2008, of 29th January 2008 – Public Contracts Code – requires more transparency and a specific destination to civil construction and demolition residues, being this a requirement to the temporary hand-over of construction works.

WASTE MANAGEMENT AND REHABILITATION

Throughout the last decades and after the construction of infrastructures in European and North-American developed countries, water utilities have been challenged to keep their systems operational, efficient and reliable.

Nowadays, the strategic asset management gives water utilities a better integrated overview on how to act before the degradation of their infrastructures becomes unbearable. It is not manageable for a water utility to intervene after its infrastructures have collapsed, but it is if the intervention is gradually done. This not only extends the components' lifespan as also the lifespan of the whole infrastructure (Alegre 2007).

As the concept of rehabilitation of water supply systems is intrinsically related to a process that will certainly generate residues, either by avoiding breaches or anomalies or even in the works' implementation, it always has an ecological footprint associated.

Actually the Portuguese regulation of the administration of construction and demolition works residues (RCDW) obeys to a specific legislation, namely to the Portuguese Law n. 46/2008, of 12th March. This law establishes the regime of the operations in the management of RCDW, including the prevention and reuse of the residues as well as the operations of collection, transport, storage, selection, treatment, valorization and elimination.

This law establishes a chain of responsibilities that spans owners, contractors and city councils, including the following aspects:

- the possibility of reusing the soil and rocks that do not contain dangerous substances, preferentially in the construction works that generated them; if that is not possible, then its reuse should be considered in other civil works as also in the environmental recovery of quarries, in the covering of land waste sites intended for residues or in other places for residues waste allowed by the city councils (Portuguese Law n.139/89, of 28thApril);
- define methods and processes to be implemented during the development and construction phases of the civil works that privilege the application of the hierarchy principle to the processes of residues' management;
- define minimum technical requirements for the sorting and spalling facilities;
- establish a management hierarchy in civil works that privileges the reuse of residues in them, followed by sorting the residues whose production is unavoidable in the original site. The residues should be sent to special facilities that are licensed to handle them;
- require that the residues are sorted before they are placed in landfills.

Currently, the legislation of the RCDW is included in the Code of Public Contracts (CPC) - the Portuguese Law nº18/2008, of 18th January - and in the Legal Regimen of the Urbanization and Edification (RJUE), Law n. 60/2007, of 4th September. As a consequence to these laws, it is now necessary to develop Plans of Residues Prevention and Management. It is then a responsibility added to the decision of what, where, when and how to rehabilitate.

In this context, as a main part of the residues management model, it is proposed to privilege the residues prevention through the reuse of these materials in the original construction works (as long as they are not contaminated with dangerous substances) and to adopt constructive methods that aim to prevent the production of these residues. Depleted the reuse possibilities, the sorting and suitable storage of the residues shall take place in the site so that they are valued and not destroyed, such as disposed in landfills. This case should only be adopted if it is the last management option, that is, when the materials' lifespan is technically or economically unbearable.

Recently, a System of Information of the Licensing Operations of Residues Management was created by the Portuguese Agency of the Environment (SILOGR), which consists of a computer application with a database of licensed waste utilities. This database can be accessed through the European List of Residues codes (LER), referred in the Portuguese Law n. 209/2004, of 3th March as well as by using their geographic locations.

REHABILITATION TECHNIQUES

Currently, the selection of a rehabilitation technology should not be carried out considering only technical-economical factors, but also taking into account the volume of residues produced. It aims to minimize the residues production by creating sub-products. Therefore, it is possible to achieve a sustainable rehabilitation at an economic, environmental and social level if the order of the following priorities is respected:

(i) Prevention – the reuse of materials and sub-products that minimize the production of residues and dangerous substances.
(ii) Recycle – the use of recycled and recyclable materials.
(iii) Elimination – place residues in an appropriated site such as landfills.

Techniques to rehabilitate water supply and distribution piping can be classified in two main groups (Alegre and Covas, 2009):

- **Renovation** techniques that consist of rehabilitation works in a component using its function and without increasing its original capacity.
- **Replacement** techniques that consist of rehabilitation works in a component with its inactivation and construction of a new component.

Table 1 presents the classification of rehabilitation techniques used in pressurised pipe system, particularly in water supply and distribution systems, as well as the respective classification in terms of residues production.

Table 1 - Classification of rehabilitation techniques for pressurized pipes and respective residues production (Alegre and Covas, 2009)

Type	Family of techniques	Technique	Residues production
Renovation	Repair	*Internal joint seal*	+
	Coating or spray-lining	*Cement mortar spray-lining* *Epoxy spray-lining)*	+
	Conventional slip linning	*Lining with continuous pipes or sliplinning*	+
		Lining with discrete pipes	+
	Modified sliplining	*Close-fit pipe lining*	+
		Cured-in-place pipe lining	+
		Lining with adhesive-backed hose)	+
Replacement	Conventional Method	*Conventinal open trench*	+++
	Unconventional Method	*Narrow trench*	++
	Steerable technique	*Pipe bursting*	+
		Pipe crushing	+
		Pipe splitting	+
		Pipe ejection, pipe extraction or pipe pulling	++
		Pipe ejection with pilot pipe	++
	Non-steerable techniques	*Pipe eating or modified microtunnelin*	++
		Pilot jacking with pipe bore)	++
		Pipe reaming or directional drilling	++

Note: + low volume of residues; ++ medium volume of residues; +++ high volume of residues

INFRASTRUCTURE REHABILITATION PLANNING

Planning procedure

The conception of the methodology consisted on the definition of different scales that allow sorting the intervention depth in different levels of decision.

The proposed methodology is based in four levels of decision, beginning in Level 1, which applies to the supplying system as a whole applicable (e.g., county); Level 2 that is associated to the analysis of the system/sector and the detailing of the component to rehabilitate; Level 3 is related with the implementation and finally, Level 4 explains the evaluation of the implementation plan:

Level 1 – diagnosis and analysis of the overall system (*direction*);
Level 2 – diagnosis and analysis of the subsystem/sector (*localization*);
Level 3 – Plan implementation (*implementation*);
Level 4 - Evaluation of the results (*evaluation*).

Each level allows a definition of direction, the location of the system or the component to rehabilitate defines the priorities' hierarchy, the implementation method defines the intervention and respective schedule. To conclude, evaluate the effectiveness of the rehabilitation plan by monitoring, controlling and revising (see Figure 1).

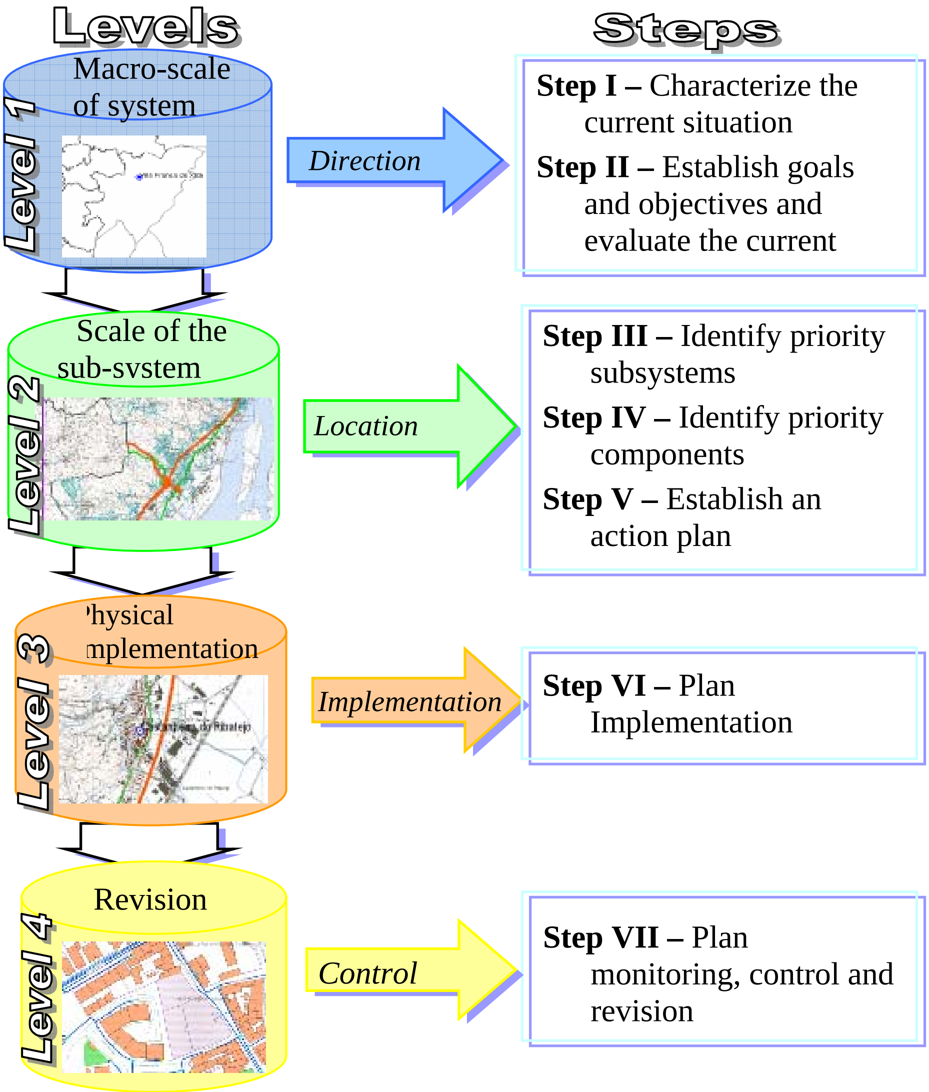

Figure 1 – Different levels and action steps of the proposed operational methodology to rehabilitate water supply systems.

The rehabilitation plan consists on the development of Levels 1 and 2. The plan is implemented in Level 3 and the evaluation of the results of such plan is done in Level 4. Although the planning of any activity includes the strategic, tactic and operational levels, the rehabilitation plan as approached in this work is a tactical plan that defines the rehabilitation tactics and establishes guiding lines for the development of operational plans.

The proposed methodology, which is organized in four levels, consists of seven steps presented in the following paragraphs (see Figure 1). In each of these steps, methods are defined to collect information on each subsystem. Its monitoring and analysis is used to evaluate if the subsystem's performance can be improved.

Step I – Characterization of current situation

In order to carry out the system diagnosis it is necessary to know it, organise the existing information and proceed with the characterization of the current (reference) situation at the different subsystems level. These subsystems can be defined based on the water's origins (i.e., delivery points or sources), existing reservoirs or pressure levels (reducing valves of pressure), topology of the network or on the number of consumers.

Step II – Establishment of objectives and evaluation of current situation

After characterizing the current situation, it is necessary to define the most relevant points of view, tactical objectives and respective performance measures, as well as the goals to achieve at short, medium and long term. A strategical plan at the global level of the utility should be defined by its top administrators. This plan sets the guiding lines and strategical objectives that are to be reached by the utility in medium/long term (e.g., 10 to 25 years).

The tactic level is defined as an intermediate level that sets what to do (the tactics) to reach the established strategical targets. Finally, the operational targets, which are directly related with the actions to implement, are established (Ambio *et al.,* 2007).

The tactical objectives and the respective goals should be assessed based on performance indicators (PI) presented by the IWA (Alegre *et al.*, 2004). The chosen indicators are considered to be the most appropriate in the context of the rehabilitation, namely: Operational PI (Op2, Op3, Op16, Op20, Op25, Op26, Op27, Op28, Op29, Op31, Op32, Op39), quality of service PI (QS28, QS29, QS31), economical and financial PI (Fi25, Fi27, Fi46, Fi47), water and energy resources PI (Ph5, WR1). For each performance indicator, intervals of bad, average and good performance are established to evaluate the objectives.

Step III – Identification of priority systems

This step identifies the priority systems or components and also establishes rehabilitation priorities that are based on the performance assessment results and on the physical condition of the systems.

Step IV – Identification of priority components

a) Inspection of the system

Once the priorities are identified, it is necessary to specify which components are to be rehabilitated in each subsystem. In this context, a set of criteria has been established in order to produce alarms within the subsystems so that it is easier to identify the component that requires an urgent rehabilitation and to set priorities.

The identification of the priority components is based on:

(i) *Direct observation of the system*;
(ii) *Indirect observation of the system*;

(iii) *External constraints* (e.g., civil works in other infrastructures or political decisions).

For the direct observation of the system, it is necessary to establish inspection routines in order to get a first diagnosis of the problems in the different components. These routines should be focused on main components and critical sites, for example reservoirs, pumping stations and control and security valves (e.g., pressure reducing valves or air valves). On the other hand, the inspection depends of the type of component and it should be performed based on periodic inspection surveys and on the registration of all the occurrences in data bases (e.g., inspection forms).

Whereas in the direct observation of the component the type of intervention needed to improve its performance is visible and identifiable, this does not happen in indirect observation. For example, a pipeline that appeearently does not have any problems can hide leakages or other type of patologies that only are you identifieable when flow or pressure measurements are analyzed.

In the case of the rehabilitation motivated by external constraints, the rehabilitation is almost mandatory and can be raised by two unavoidable occurrences: intervention in other infrastructures or political decisions. Interventions in other infrastructures require the replacement of the supplying network because the subsoil is often saturated with different infrastructures, which makes it very difficult to carry new construction works there (e.g., sewers, gas, telecommunications, EDP) without damaging the water supply system. These interventions can sometimes postpone real rehabilitation needs as the water utility cannot afford too many rehabilitation works.

b) Identification of priorities based on multi-criteria analysis

It is necessary to proceed evaluating and establishing priorities of rehabilitation. For this purpose, a multi-criteria analysis can be applied to each individual component. This analysis can be summarized in the following steps:

(i) definition of the individual component or elementary unit to evaluate;
(ii) establishment of evaluation criteria and the respective weights;
(iii) evaluation of each component or elementary unit.

In the current research, the evaluation criteria have been established based on three factors: the component lifespan, the operation and maintenance needs and the importance of the component in the system (defined by its influence area or size). The evaluation of the component must take the value of each criterion into account and the respective weight in the decision process. The calculation of the index is proposed in the following:

$$RN_j = \sum_{i=1}^{N_C} P_i * W_i \quad (1)$$

where RN_j = index of the need of rehabilitation of component j; P_i = value attributed to the criterion i (being i= 1, 2, 3); W_i = weight of criterion i; N_c = total number of criteria for the evaluation of the component.

c) Prioritization of actions for each type of component

After the multi-criteria analysis, the prioritization of the components to rehabilitate should be carried out taking the following items into account:

- the condition and the importance of the component based on the multi-criterion analysis (indicated by the index *RN*)
- the internal priorities (*IP*) of the water services due to complaints or to future expansions;
- the external priorities *(EP)* due to civil works in adjacent infrastructures.

Priority components are those with lower rehabilitation indices that require intervention at short or medium term. In order to incorporate not only the need of rehabilitation of the component as well as the internal and external priorities, the proposed calculation of the index priority of rehabilitation is similar to the one suggested by Barata *et al*. (2007). The following formula represents the priority of rehabilitation (*PR*) of each component:

$$PR_j = RN_j * W_{RNR} + IP_j * W_{IP} + EP_j * W_{EP} \quad (2)$$

where RN_j = index of the need of rehabilitation of component *j*; IP_j = index of internal priority of the component *j*; EP_j = index of external priority of the component *j* (low priority=1, medium=2 e high=3); W_{RN} = weight associated to the rehabilitation needs (%); W_{IP} = weight associated to the internal priority (%); W_{EP} = weight associated to the external priority (%).

Step V – Establishment of an action plan

After identifying the main components or parts of the system to rehabilitate, it is necessary to develop a short and medium term planning. This step begins by establishing a schedule of actions that guarantee the service's objectives initially established for the water supply system. This schedule is divided in two types of actions:

- *global actions that affect all the subsystems of the water utility;*
- *specific actions associated with specific interventions in components or parts of the system.*

To close the cycle of the rehabilitation procedure, it is necessary to analyze the alternative solutions of rehabilitation and the respective costs. The solution that is usually adopted is the one that presents lower costs. However, when taking waste management into account, the best solution might not be the one that presents lower costs, but the one that does not generate residues although it is more expensive (e.g., using a pipe bursting instead of an open trench solution).

Once the rehabilitation priorities are established, the plan schedule must be carried out. Further details of this step can be found in Borda d'Água (2008).

Step VI – Plan implementation

In the actual implementation of the plan, it is important to promote the "information to the population", in order to raise the consumers' awareness of the nature of the civil works and to inform them about the water shortage that they will experience during some of the civil works.

Step VII – Plan monitoring, evaluation and revision

The last stage of a rehabilitation plan consists on the monitoring and evaluation of the results, as well as in the annual revision of the plan, including the established objectives and results reached by the implementation of the established set of actions. This stage allows to evaluate the efficiency of the affected resources and the effectiveness of the actions, comparing the initial situation to the final one within the period in analysis.

FINAL REMARKS

The methodological approach presented in this paper for the development of a rehabilitation plan of the water supply system is relevant at both scientific and technical level as it challenges the way rehabilitation of water supply systems is currently carried out by many water utilities in Portugal. Additionally, it not only takes the efficiency of the hydraulic system into account but also the improvement of the waste management that is associated with its civil works and repairs.

Considering only technical and economical points of view in the decision making process is no longer viable. Currently, other concerns associated not only with technical and economic aspects, but also with environmental and social factors make the sustainable operation of water supply systems possible. When developing a rehabilitation plan, the main concern in terms of waste management is to transform waste, which is typically an eco-deficiency, in a reusable material in the civil works where it was generated.

This paper and the several steps of the proposed methodology aim to make water utilities aware that they must consider the waste management in their rehabilitation process in order to:

i) produce less waste in the civil works associated with the reparation of leakages;
ii) take the volume of waste produced by each rehabilitation technique into account in the decision making process;
iii) create a more adequate plan to reuse by-products generated in rehabilitation works, instead of generating more useless waste.

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