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Aligning financial and technical procedures for the determination of urban drainage assets' current and replacement values

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ABSTRACT

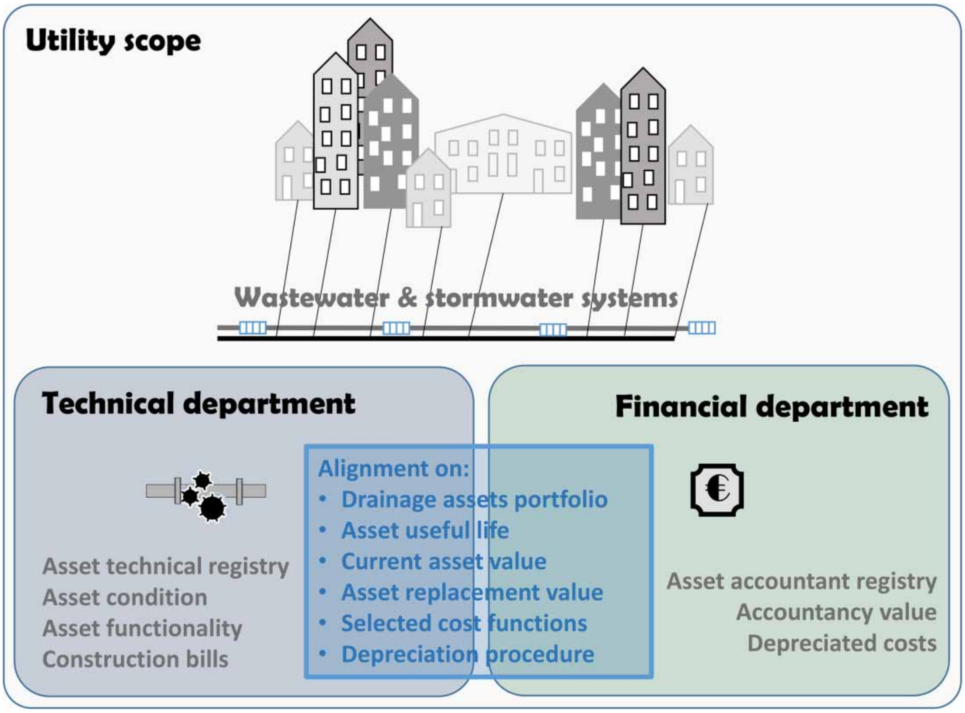
The paper presents a method for aligning the relevant financial and technical procedures for determining drainage assets' current and replacement values. This alignment is especially pertinent when actual construction costs are unavailable and records in different utility departments (technical and accounting) do not correspond. The current asset value is grounded in estimated construction costs, considering accounting and technical useful lives. Asset portfolio considers the assets providing adequate service quality, regardless of their age. The methodology relies on the update of the assets' registry (updating the assets' value), the increase of the accounting useful life in line with technical practice (reducing annual depreciation), and the accumulated depreciation reversion (increasing net current value). In the case study, the need to update information exchange and align technical and financial procedures in Lisbon Municipality was triggered by internal policy requirements concerning the simultaneous development of the urban drainage asset management plan and the requirement to standardize the accounting system. The application of the methodology led to an increase of approximately five times the assets' current value. The results, their implications, and replicability opportunities are discussed.

Key words: Current value, Depreciation methodology, Replacement value, Urban drainage, Useful life

HIGHLIGHTS

- Procedure for aligning financial and technical procedures.
- The current asset value assessed based on estimated construction cost curves.
- Consideration of every asset providing good quality service, regardless of their accounting useful life.

GRAPHICAL ABSTRACT



INTRODUCTION

Asset valuation is essential for water infrastructure management, as a requirement for financial and regulatory reporting, pricing, and funding planning, or asset management decision-making (NAMS, 2006). Common valuation approaches for public infrastructure are the depreciated replacement cost (Baik, 2003) and a modified approach that relies on the asset management analysis (GASB, 1999). The Infrastructure Asset Management (IAM) is the strategic and sustainable management of infrastructure assets. In drainage systems, IAM focuses on tangible assets directly associated with service provision (e.g., sewers and pumping stations, Alegre *et al.*, 2013). The IAM process (ISO, 2014) has implicit financial and infrastructure sustainability. Although revenue from taxation and tariffs is generally the foundation of public finance, they are typically insufficient to finance large investments as those needed for infrastructure works (Humphreys *et al.*, 2018). After the initial investment, it is important to ensure the longest potential life of the components, to increase asset value for the service and the long-term financial efficiency. The deferral of rehabilitation investments can compromise this sustainability.

To address this issue, all assets related to service provision must be recognized and investment in rehabilitation must be planned, which requires good articulation between the financial and the engineering departments. The financial department is not always aware of every asset associated with the service. This might occur because not all assets were incorporated in the asset portfolio (eventually because they were passed on from other utilities or were aggregated with other infrastructure, in the bill of quantities) or because they are fully amortized (even though still providing an adequate service). For the engineering department, disaggregated technical and financial information allows planning for future rehabilitation interventions more adequately. Only an overall assessment of the patrimony enables estimating the complete expected investment volume, which is also reflected in the tariff. Both departments are interested in providing a fair tariff and in guaranteeing financial and technical sustainability.

Most water utilities inherit independent practices for technical and accounting processes, resulting in a lack of alignment between services about assets valuation. It is crucial to agree on shared processes and terminology, when referring to the same assets or groups of assets, opting for using different terms when adequate. This approach is also beneficial for the information exchange between departments and policy in internal alignment. The international technical specification ISO/TS55010 (ISO, 2019) guides this alignment.

The starting point to determine the current asset value is the information from the construction bills of quantities, when available (Johnstone, 2003). The careful analysis of the bills is essential, as not all parcels are relevant (e.g., land expropriation or external funding for construction). This method is not applicable when construction bills are not available, often the case for older infrastructures. Several national regulatory bodies mandate utilities to report on their asset values (e.g., the Canadian Public Sector Accounting Standard Board, the New Zealand International Financial Reporting Standards, and the USA Government Accounting Standards Board (GASB, 1999; Alyami, 2017)). The Portuguese Accounting Standardization System for Public Administrations (SNC-AP: Portuguese Government, 2015), which recently took effect, establishes how to categorize and value assets.

Globally, different approaches can be used to estimate the value of assets, namely the accounting or book value method, the replacement cost method and the market value method. From an asset management perspective, the determination of the asset value can also be derived from the future income generation potential of the asset (ISO, 2018). The accounting method relies on the difference between the acquisition cost and the sum of the accumulated depreciation and other accounting deductions (ISO, 2019). Infrastructure assets are particularly challenging to valuate, namely given their heterogeneity and the lack of evidence of their fair market value (Comisari *et al.*, 2011), as the selling price of similar assets. The replacement cost is supported by the monetary value associated with the substitution of the existing asset by a new one and can be calculated by using different approaches. Water utilities currently rely on methodologies based on detailed analysis of *in situ* costs, on cost functions ((Maurer *et al.*, 2010; Samra & Abood, 2014; Walski, 2012; Marchionni *et al.*, 2014; Cabral *et al.*, 2019) and on the engineering modern equivalent asset replacement (Johnstone, 2003; Cullen, 2009).

The Portuguese regulator (ERSAR) issued a technical guide (GT23: Covas *et al.*, 2018) including construction cost functions. These allow to estimate construction costs using assets' characteristics and are acknowledged by the national water sector. This guide is based on the construction costs for works carried out in Portugal between 2005 and 2016 and, for some types of components, since 1998. These cost functions estimate the construction value as of 2016, regarding initial investments. The functions do not include maintenance or operation costs, or rehabilitation activities that do not correspond to new construction. Taxes or costs associated with design projects, inspections, consultancy, land acquisition, or expropriation are also excluded.

Current asset value depends on the useful life of the components. The concept of useful life differs between the engineering and the financial points of view.

From an engineering perspective, the useful life is the period after installation during which the component complies with its intended function (Covas *et al.*, 2018) or the period from installation and commissioning to final deactivation. This concept is applied to a set of components, using statistical analysis of data from a representative set with similar characteristics and subject to identical situations. Given the data available, the calculation of the useful life by utilities is not straightforward. Several factors affect potential life, including the type and nature of the asset, the production, transport and storage conditions, installation procedures, suitability to local conditions (temperature, humidity), and operation and maintenance practices (Burn *et al.*, 2009; Covas *et al.*, 2018).

Historically recognized average values of useful lives are available; the values used for design are conservative, considering the use of new materials and adequate maintenance practices. The average useful lives commonly applied to the wastewater system components vary between 40 and 60 years (Samra & Abood, 2014; Cabral *et al*., 2019). The components' actual life is significantly variable. In this context, an asset's remaining useful life should be evaluated together with information on the actual asset context and its structural and hydraulic conditions (Burn *et al*., 2009).

From a financial perspective, the definition of the accounting useful life of an asset is the period during which an entity expects the asset to remain in service. In Portugal, groups of assets have standard values defined by the government. Alteration of these pre-defined values is not straightforward. After this period, even if still in satisfactory condition to provide the service, the assumption is that the asset no longer provides the lower-cost option available to satisfy the performance requirements. When maintenance costs increase significantly with ageing, the end of the economic life can occur earlier, at a stage when the asset still fulfills its intended function. Obsolescence can also shorten accounting life (Covas *et al*., 2018).

The infrastructure replacement value in a given year is the expected cost of its equivalent built in that year (e.g., 2022). Approaches to determine the replacement value are two-fold: asset-oriented, with the useful life of each asset as the basis for the calculation, using depreciation functions for each asset category; or service-oriented, with the actual condition of the asset as the basis. The former is easier to determine, assuming that the overall system design (e.g., pipe's layout, location of overflows, or pumping stations) is the same in its modern equivalent. It can include the consideration of the components' modern equivalent, for example, when obsolete materials exist and the utility wants to replace them (Cullen, 2009). Whenever data on service provision are available, a service-oriented approach is preferable (Alegre *et al*., 2014). With this approach, the value of the service provided by the asset is considered. In a water system, the service is not provided by individual assets, and an approach looking to the complete system has to be considered. From an asset management perspective, the service provided by the assets ought to be at the center of decision-making (ISO, 2014).

METHODOLOGY

A valuation procedure is proposed to determine drainage assets' current and replacement value, to meet both the common and the specific requirements of technical and financial departments. This methodology builds on the update of the asset portfolio, the application of cost functions, and a depreciation procedure. It relies on replacement cost determination and a market evaluation. It is based on the recognition of the technical characteristics of the components, the specific context of the city, and the service provided, even for infrastructure that already exceeded the expected technical useful life. In this project, as data on service provision are commonly unavailable at the sewer system level for the whole city, an asset-oriented approach is used.

The application of the methodology is doable when actual construction costs (from bills of quantities of previous construction works) are available or not (as shown in Figure 1). In either case, assets are organized previously in component classes with similar typologies. This organization must be defined considering the reporting requirements, addressing the assets' technical function and characteristics, and ensuring the alignment between technical and financial registries. When the construction bills are not available (or, even if they are, when the disaggregation into the component classes is not possible due to merged data), then the construction costs must be estimated.

Validation of asset registers involves confirmation of non-existent or inconsistent data when doubts remain after a thorough inspection was made. The characteristics of adjacent pipes are helpful in the validation, particularly when the data to be confirmed refer to the cross-sections or pipe materials. For instance, if two circular sewers with similar characteristics have a sewer between them of unknown cross-section, the latter can be

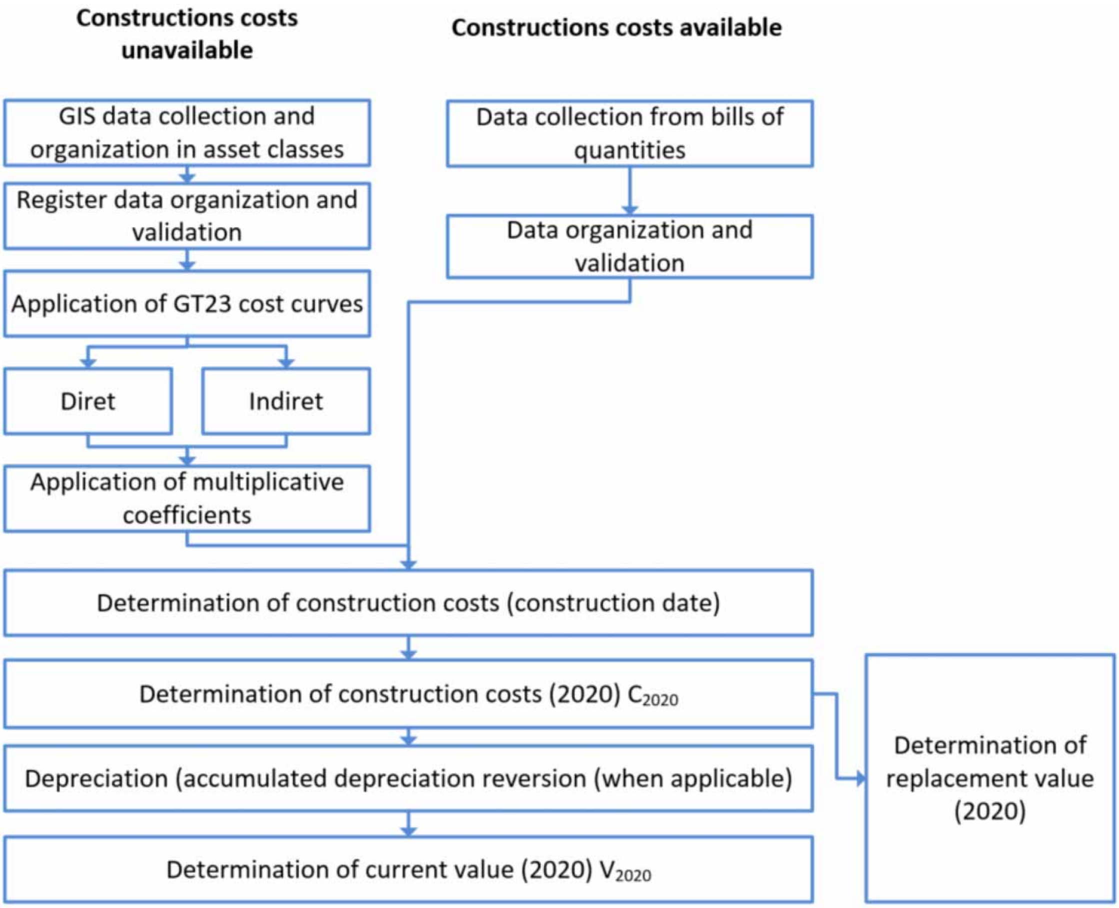


Fig. 1 | Methodology for determination of assets' current and replacement values (asset-oriented approach).

valued as a circular pipe. Another example is a pipe registered as a rectangular vitrified clay pipe; as vitrified clay pipes are only available in circular cross-sections, this register should be corrected, as rectangular cross-sections are not commercially available for this material. The same procedure can apply to the construction date.

In the present work, estimates of construction costs use the cost functions from publication GT23 (Covas *et al.*, 2018). The functions for sewers (Equations (1)–(5)) are for circular pipes and differ depending on their material and dimensions. The construction unit cost excludes road paving (*C*, in €/m) and is defined depending on specific characteristics, such as the type of component, the diameter (*D*, in mm), and pipe material (Table 1).

Application of cost functions uses validated asset register data, directly or indirectly. Whenever the assets' characteristics fit the boundaries of the cost functions, these apply directly. Otherwise, an indirect application for a first cost estimate is proposed, regarding (i) pipe material and (ii) cross-section typology, as explained below.

Whenever a cost function is unavailable for given (i) pipe material, similar listed curves can provide a first estimate. Two approaches can be applied: cost functions from a similar material can be used (e.g., using PVC curves for other plastic pipes); or, if no similar material is listed, cost functions from its modern equivalent (as the material one might use to replace it) can be used (e.g., using the concrete curve for asbestos cement).

Regarding the typology of existing cross-sections (ii), as the cost functions only apply to circular pipes, the equivalent diameter for other typologies can be used. The determination of the equivalent diameter (D_{eq}) was

Table 1 | Cost functions for pipes (Covas *et al.*, 2018).

Pipe characteristics			Construction unit cost	
Component type	**Material**	**Diameter range, *D* (mm)**	**Cost function, *C***	**Eq.**
Trunk sewer	HDPE	200–1,600	$C = 0.00041\ D^2 + 0.1997\ D + 25$	(1)
	PVC	410–1,000	$C = 0.00028\ D^2 + 0.2021\ D + 25$	(2)
	Ductile cast iron	200–1,000	$C = 0.000033\ D^2 + 0.4622\ D + 25$	(3)
Sanitary sewer	PVC	200–400	$C = 0.06946\ D + 25$	(4)
Stormwater sewer	Concrete	300–800	$C = 0.00023\ D^2 - 0.03429\ D + 30$	(5)

based on the similarity of transport capacity, which can be obtained from uniform flow equations. Flow in a pipe can be calculated using empirical equations, such as Gauckler–Manning–Strickler (Equation (6)).

$$Q = K_S \cdot S \cdot R_h^{2/3} \cdot J^{1/2} \tag{6}$$

where Q is the flow (m^3/s); K_s is the Manning–Strickler coefficient ($m^{1/3}\ s^{-1}$); h is the flow height (m); S is the flow cross-section (m^2); R_h is the hydraulic radius of the cross-section (m); J is the unit energy loss; in the uniform regime, J can be assumed as equivalent to the pipe slope (–).

The transport capacity of a non-circular pipe equivalent to a circular pipe (D_{eq}) of the same material (i.e., the same K_s) and slope (i.e., the same J), can be obtained using the equivalence of the term $S{\cdot}R^{2/3}$ in Equation (6). The final value for D_{eq} is the next available commercial diameter since the aim is to determine the circular section capable of, at least, the same transport capacity as the section providing the service.

The cost functions were determined for a context and time frame. Naturally, specific factors (e.g., the geographic, urban and social-economic contexts) can either overestimate or underestimate the resulting average values for the current value. Validation of the cost functions ought to be done with local data, by comparing a sample of bills of quantities of a given component with the corresponding cost estimates and determining whether a multiplicative factor applies. Such factors can also apply to pipe materials or diameters for which cost functions were not available, and a first cost estimate is obtained by similarity.

These equations (Equations (1)–(5)) allow estimating the construction costs for 2016; if using another reference year, it is necessary to deflate to the construction year. When bills of quantities are available, construction costs can refer to a different year. In the next step, construction costs are updated to 2020 prices (C_{2020}), using Equations (7) and (8), based on the Harmonized Index of Consumer Prices (HICP) and the Consumer Price Index (CPI).

$$C_{2020} = C_n \times F_n \tag{7}$$

$$F_n = \prod_{i=n+1} (1 + t_i) \tag{8}$$

Here, C_{2020} is the updated construction cost for 2020 (€), as in Figure 1; C_n is the construction costs on year n (€); F_n is the update factor; n is the construction year; t_i is the annual price index (HICP/IPC) between the following year and 2020.

Update to later years (e.g., 2022) can use the same method, as long as the annual price indexes are available up until then.

For the replacement value, the asset-oriented approach was found appropriate, as the study does not intend to evaluate layout changes. The approach is like the one used to determine the net asset value and, to support possible replacement investments, the replacement costs for 2020 are determined as the construction costs updated from 2016 to 2020 prices (i.e., C_{2020} in Figure 1).

To determine the current value (V_{2020} in Figure 1), depreciation from the construction year until 2020 is deducted. As described previously, depreciation depends on the components' useful life, which can differ between the technical and financial points of view. In the proposed methodology, a preliminary analysis is made, using either the accounting useful life or using the average useful technical life. For older assets, already fully depreciated but still providing an adequate service, the valuation procedure comprises reversing the accumulated depreciation by 50% and assigning half of its useful life as new. This assignment of the remaining useful life can be based on the asset condition, as in Table 2, whenever information on the condition is available. The procedure for assigning the condition class based on the structural status of each component uses the European standard EN 13508-2:2003+A1:2011 (from the European Committee for Standardization: CEN, 2011).

Deactivated assets will not be accounted for in the total current value as it is assumed they have reached the end of their useful life.

CASE STUDY

Lisbon is the capital of Portugal, in western Europe, and has a population of over half a million in 2,892 km². Lisbon Municipality (CML, Câmara Municipal de Lisboa) directly manages the collection system.

Currently, combined and separate sewers coexist in the drainage system. Most of the system is combined (865 km). In developments after the 1980s, the separate systems predominate, with sanitary and stormwater flows collected in separate sewers (278 and 532 km, respectively). It is noteworthy to mention that fieldwork for updating the sewer system register is recent. Compared to the 1,500 km value before this project, the updated values of network length, 1,675 km, represent a significant increase.

A large part of the system comprises assets in service for several decades, with some built before the 18th century. The bulk system (including sewer trunks, larger pumping stations and treatment plants) is owned by Lisbon municipality but operated by another utility. A submarine outfall exists, it is currently out of service, following layout changes to upgrade the wastewater interceptor system to the wastewater treatment plant (WWTP). A few septic tanks exist, but the corresponding registry update is ongoing.

The technical registry is complete and mostly updated, whereas the accounting registers for the drainage system are incomplete. This situation derives from the fact that costs were aggregated, for sanitation, roads, or other

Table 2 | Indicative values for the remaining useful life of sewers depending on their condition.

Structural condition class	Description of the structural condition	Remaining useful life (years)
1	Acceptable structural condition	>50
2	Minimal possibility of short-term collapse, but with potential for further deterioration	30–50
3	An unlikely collapse in the near future, but the continuation of deterioration is probable	10–30
4	Probable collapse in the near future	3–10
5	Collapsed or imminent collapse	0–3

infrastructures, in construction works before 2019. For this reason, the current value of drainage infrastructure in the financial department does not correspond to the actual situation and is underestimated. Using these values for allocating maintenance and rehabilitation funds and to calculate the replacement values has implications on decisions on investments, ultimately resulting in management constraints.

In 2019, the opportunity to develop the urban drainage asset management plan and the transition to the Portuguese SNC-AP triggered the need to align technical and financial procedures in the CML and update the assets' current value. By aligning these procedures, the utility reduces the inconsistencies between accounting and physical infrastructure data. Other main benefits are meeting the regulators' annual reporting requirements and the improved knowledge on assets replacement costs.

The development of this integrated management tool for the city's wastewater and stormwater systems is a step forward for both departments. The current value of the bulk system infrastructure, septic tanks and submarine outfalls is postponed to a subsequent phase, because, as explained, the bulk system is operated by another utility.

APPLICATION AND DISCUSSION

Data collection and validation

The information used comes from the up-to-date data on network components from the technical department's geographical information system (GIS). The number of items not included in the financial registry is significant. After completing the project, the length of pipes is 12% longer than the previously available data.

An important step was choosing new classes for fixed assets; the basis for defining these classes is the function and characteristics of each type of asset, the annual reporting requirements of ERSAR, and the accounting standards in SNC-AP. ERSAR requires information on sewers depending on the type of inflow and information on installations. SNC-AP required information on either buried or over ground infrastructure, and today allows the disaggregation aligned with the regulator requirements. The resulting 11 classes are combined sewers, sanitary sewers, stormwater sewers, drains, pumping mains, pumping stations, septic tanks, submarine outfalls, detention or infiltration structures, wastewater treatment plants, others. The information structure is complete, including the classes not covered in this project phase (such as those relating to the bulk system, which will be included in a subsequent phase).

Older assets have an incomplete construction date in Lisbon's GIS. Some have the year (e.g., 1953), others the decade (e.g., D1970), older ones have a reference year (e.g., A1919, meaning 'before 1919'). For the second case, the simple rule is to use the intermediate year of the decade as the equivalent construction date (e.g., for D1970, the equivalent date would be 1975). In the third case, since the accounting value is null, the simplified rule is adopting the previous decade (e.g., for A1919, the nearest decade is 1910, and the equivalent construction date 1915).

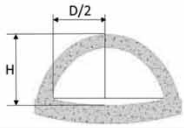
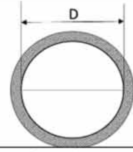
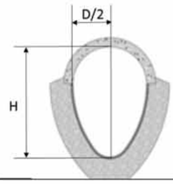
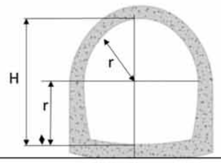
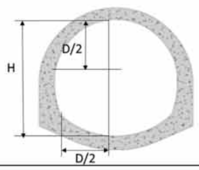
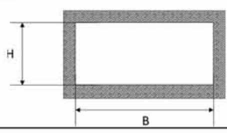
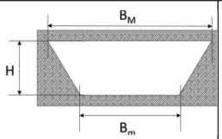
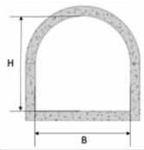
Application of cost functions

For most assets, the direct application of the cost functions is possible (Table 1). For some pipe materials and cross-sections, an indirect application of the cost functions was used, as the best cost estimate.

Regarding the range of pipe materials, the following exist in Lisbon: masonry; concrete; reinforced concrete; vitrified clay; asbestos cement; high-density polyethene (HDPE); polypropylene (PP); fibreglass-reinforced plastic (FRP); polyvinyl chloride (PVC); and cast iron. Curves for similar materials were used as the best estimate for reinforced concrete, using the concrete cost function, and for PP and FRP, using the PVC curves. The cost function used for masonry, vitrified clay, and asbestos cement was the function for concrete.

Regarding the typology of existing cross-sections, the following exist in Lisbon (Table 3): lower arch; circular; oval; ovoid; NOVA I; NOVA II; rectangular; trapezoidal; U and inverted U.

Table 3 | Cross-section similar geometry and hydraulic parameters of sewers in Lisbon.

Cross-section		Cross-section parameters	
		S - section (m^2)	R_h - hydraulic radius (m)
Lower arch	H: maximum height (m) 	$S = 1.208 \cdot H^2$	$R_h = 0.292 \cdot H$
Circular	D: diameter (m) 	$S = \pi \cdot (D/2)^2$	$R_h = D / 4$
Oval/ovoid	H: height (m) 	$S = 0.0496 \cdot H^2$	$R_h = 0.189 \cdot H$
NOVA I (Specific CML design)	Like horseshoe H: maximum height (m) 	$S = 2.889 \cdot (H/2)^2$	$R_h = 0.235 \cdot H$
NOVA II (specific CML design)	Like higher arch H: maximum height (m) 	$S = 0.937 \cdot (H)^2$	$R_h = 0.267 \cdot H$
Rectangular	B: base (m) H: maximum height (m) 	$S = B \cdot H$	$P_m = 2 \cdot (B+H)$ $R_h = S / P_m$
Trapezoidal	B_m: minor base (m) B_M: major base (m) H: maximum height (m) 	$S = (B_m + B_M) /2 \cdot H$	$\mathbf{P_m = B_m + B_M + 2 \cdot \sqrt{H^2 + \left(\frac{B_M - B_m}{2}\right)^2}}$ $R_h = S / P_m$
U and inverted U	B: base (m) H: maximum height (m) 	$S = B \cdot (H - B/2) + \pi \cdot (B/2)^2 / 2$	$P_m = B + 2 \cdot (H - B/2) + \pi \cdot (B/2)$ $R_h = S / P_m$

Despite the information update, some information is lacking because of previous missing data that were not obtainable during the fieldwork (e.g., construction dates). Other information was not reliable and difficult to validate, as the pipe material, the type of cross-section or dimensions when the infrastructure was inaccessible because of covered accesses. In these situations, validation was made using information from adjacent components, for instance, the date of construction.

When the information missing was preventing the application of the full procedure, the construction costs estimation was carried out using an average unit cost for that specific area of the city.

The application of multiplicative coefficients was validated. CML's experience is that, in recent decades, the construction costs in Lisbon are significantly higher than in the rest of the country, even higher in areas with high groundwater levels (along the coastline or in areas adjacent to streams, representing approximately 1.3% of the total sewer length). The indirect application of cost functions to some materials (such as using the concrete curve in vitrified clay pipes with the same diameter) and dimensions (extrapolating the concrete curves outside the application range in Table 1, for larger concrete pipes) was also analysed.

The CML collected data on costs from seven construction works carried out recently, between 2018 and 2020, for large scale construction works, including sewers with varied characteristics. Data included costs for trench excavation; pipe supply and settlement; trench filling; manhole construction (every 60 m; includes an intermediate blind chamber, i.e., a manhole with a non-accessible cover, in stormwater and combined systems) gullies and connections construction (also in stormwater and combined systems); and accessory works. Other costs were not included, namely design and inspection; execution of surveys; CCTV; registry update; local constraints (for example, associated with very narrow streets, reinforcing, monitoring old buildings, or archaeology works).

The unit cost analyses were done on circular pipes in vibrated concrete (with the diameter ranging from 300 to 500 mm), in reinforced concrete (600–1,800 mm), in PVC (200–630 mm) and HDPE (315–400 mm). Additional information was collected from vitrified clay pipe suppliers (200–600 mm). There is some variability in the results, with the actual costs being about three times higher than those estimated by the cost functions, as Figure 2 illustrates. Differences between estimates and real values vary with materials (for the same diameter range), since cost functions were derived using values from the whole country, which can be significantly different from those in Lisbon.

An average multiplying coefficient of 3.0 was applied to developments in Lisbon for construction works after 1980. Based on CML's experience, a multiplying coefficient of 1.3 was adopted for construction works before 1980. For vitrified clay pipes, an additional multiplying coefficient of 1.2 was applied to the concrete cost function. For large diameter concrete pipes (larger than 800 mm), a multiplying coefficient of 3.0 was found by comparing actual costs with the GT23 concrete cost function. Since it corresponds to the one determined for smaller diameters, there is no need for an additional correction. It was also possible to conclude from actual costs that in coastal or areas adjacent to streams, with high groundwater levels, costs are generally increased by 1.5.

The costs for household drains were also analysed by the CML using data from recent construction works. An average cost of €2,610/drain was found. Given the absence of a complete registry of drains, a simplified procedure was chosen for the global valuation of this type of component. Circa 55 000 buildings exist in Lisbon, around 30% were built before 1980, and generally have one single drain to a combined system. Other buildings have separate drains to the sanitary and stormwater systems. This simple procedure can be improved when a more comprehensive survey allows to include these components in CML's GIS.

The application of multiplicative coefficients was proven necessary in the case study. This methodology needs updated validation in locations where construction prices are significantly higher than in the regions from where the cost functions were determined, as for the case of Lisbon, and also where prices change abruptly or in countries with significant fluctuations in the inflation rate.

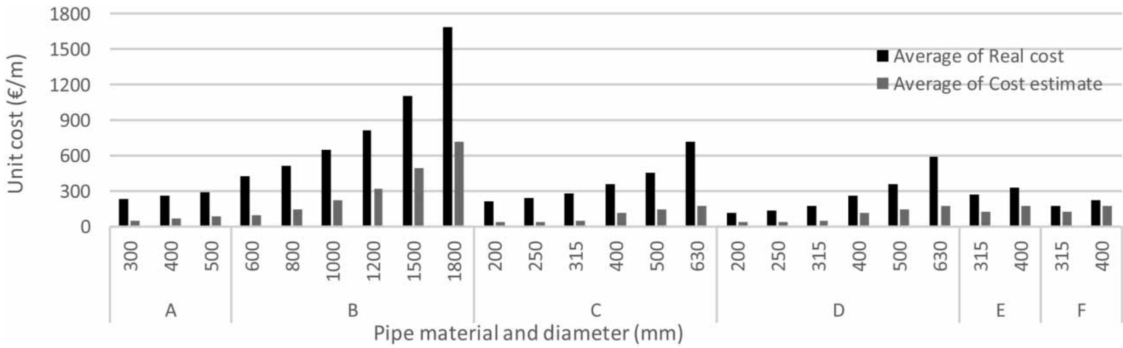


Fig. 2 | Comparison of average real and estimated unit cost for several pipe materials ((A) concrete; (B) reinforced concrete; (C) PVC stormwater and combined sewer; (D) PVC sanitary sewer; (E) HDPE stormwater sewer; (F) HDPE sanitary sewer) and pipe diameters in Lisbon.

Determination of the current value

As discussed, depreciation depends on the useful life, and the pipe's average useful technical life is usually assumed as 40 years in Portugal. In Lisbon, actual information about the assets' useful life is still limited to support a comprehensive proposal. On the other hand, condition assessment is ongoing and there is no structured database allowing the application of methods for assessing the structural condition of components. Therefore, it is not possible yet to assign the useful life remaining based on asset condition as per Table 2. In such context, the generic 40 years of useful life is applied.

For older assets already fully depreciated but still providing an adequate service, the procedure for valuing them builds on the national best practice (FAQ25 of the Public Accounting Standardization Committee): the accumulated depreciation is reversed by 50% and half of its useful life is assigned.

Deflation to the construction year and cost update to 2020 prices were based on the update factors for 2016 and 2020 (F2016 and F2020), which were calculated (using Equations (7) and (8)) drawn on the annual price index in force in Portugal. A few indexes and update factors are presented in Table 4. Portuguese annual price indexes are not available before 1949.

The registry update showed that (Figure 3), of the existing 1,675 km of sewers, 23% of those in service were built before 1949. For these pipes (and for those whose construction year was not possible to determine, which totals 35% of the length), the simplified application of the 1949 factor was applied. For those pipes and to the large extension (47%) of those built in the 1950s and 1970s, their value is only being considered due to the depreciation reversion, as they are already fully depreciated. Had the depreciation reversion not been proposed, only 18% of the pipe length (those built after 1980) would be valued. Moreover, if merely pipes built in the last 20 years (15 km) were to be valued (as in the accounting procedure implemented before), only 0.9% would have been accounted for.

The overall current value for the drainage systems, only regarding sewer system components, determined for 2020 (V_{2020} in Figure 1), is 5 times higher than the previously estimated value before the application of the methodology.

The majority (44%) of the V_{2020} comes from the pipes built in the 1950s and 1970s, as illustrated in Figure 4. Combined system pipes represent much of this value, as these pipes correspond to the bigger cross-sections in Lisbon (up to 5500 mm height and 8,000 mm width). Still, a very relevant value (25%) is

Table 4 | Examples of annual price indexes and update factors for 2016 and 2020 (F_{2016} and F_{2020}) for Portugal.

Year	Annual price index	F_{2016}	F_{2020}
1949	2.81%	94.485	98.606
1950	−1.38%	95.807	99.985
–	–	–	–
1969	8.85%	57.863	60.387
1970	2.76%	56.309	58.765
–	–	–	–
1989	11.61%	2.437	2.544
1990	13.93%	2.139	2.233
–	–	–	–
2019	0.30%	–	1.003
2020	1.20%	–	1.000

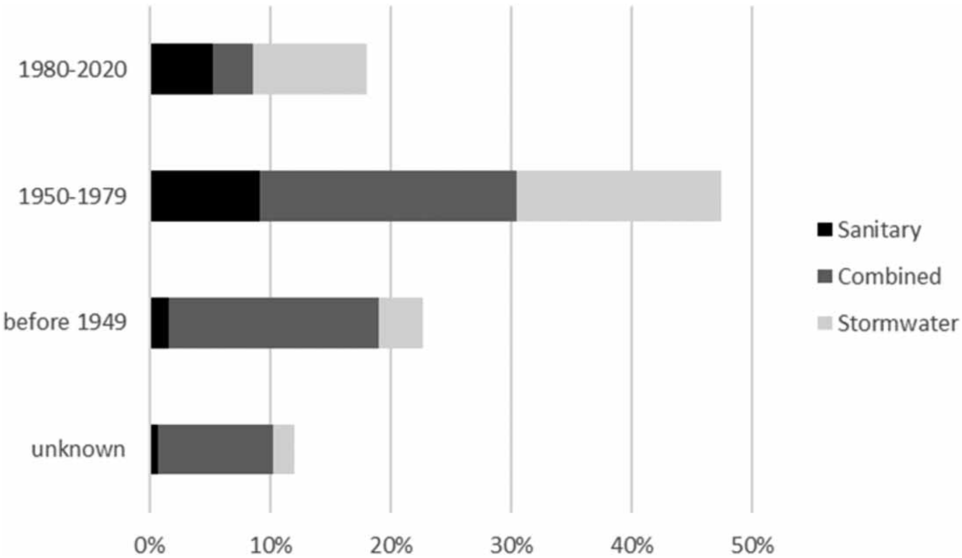


Fig. 3 | Construction dates of sanitary, combined and stormwater pipes and the corresponding relative length.

associated with those built before 1949, highlighting the relevance of giving due importance to the assets providing the service.

Nevertheless, it should be stated that application of this step to assets providing a good service that already reached their expected useful life (reversion of the accumulated depreciation by 50% and assignment of half of the assets useful life) was possible given that it builds on national best practice (FAQ25 as mentioned). In other countries or in situations where concession contracts exist, application of this step may be conditioned by contract requirements or deadlines.

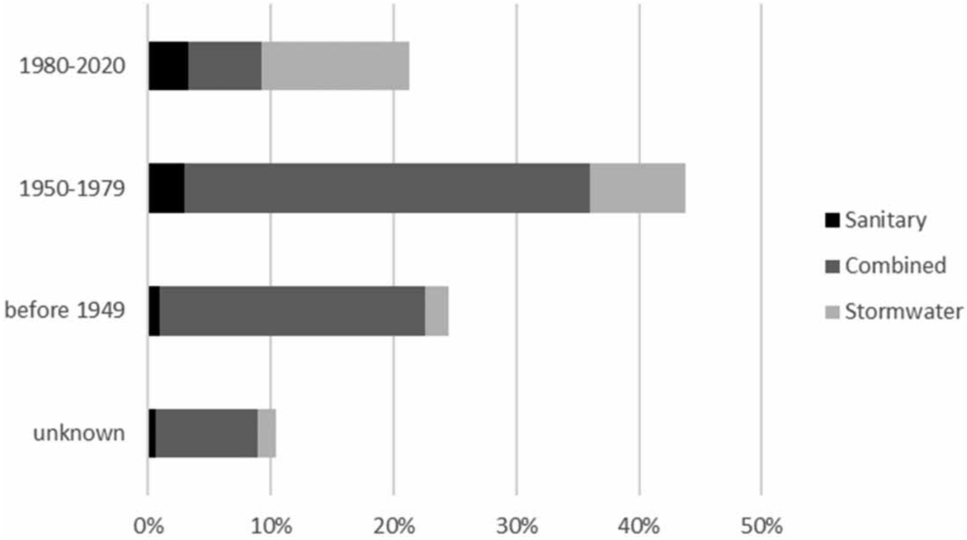


Fig. 4 | Construction dates of sanitary, combined and stormwater pipes and the corresponding relative current values (V_{2020}).

CONCLUSIONS

The phased application of the proposed methodology allowed its gradual validation. The phases included the definition of asset classes relevant for financial and engineering processes; the validation of the asset portfolio; the application of cost functions to out-of-range cross-sections and materials; valuation of assets over 40 years old; allocation of equivalent diameters to non-circular cross-sections; and dealing with inconsistent records concerning material, type of section or dimension.

The alignment of the asset classes used in the financial and engineering processes, and the definition of the asset portfolio, allowed for an unprecedented update in Lisbon's accountancy registry. The length of pipes currently recorded is 12% longer than the data available before this project.

A reflection was made regarding the link between accounting and technical useful lives. The alignment of the previously used accounting life (20 years) with the technical life (40 years) reduces the annual depreciation by half and can affect directly or indirectly the wastewater tariffs. Further developments will allow to study the implications. Given changes in the Portuguese regulatory requirements, tariffs will be revised later in 2022, and the results of this project will be taken into account. With these changes, assets' current values will be closer to their real values, as keeping accounting useful lives of 20 years leads to an almost null asset value today. In addition, a third of the assets are over 70 years old. For those fully amortized but still in service, accumulated depreciation was reversed, increasing the current value.

The combination of these three factors (update of the assets' registry, updating the assets' value; the increase of the accounting useful life, reducing annual depreciation; accumulated depreciation reversion, increasing net current value) leads to an increase of approximately 5 times the assets' current value.

In conclusion, in Lisbon, drainage infrastructures include an old heritage that has already largely exceeded the design useful life. Adapting the conservation and maintenance efforts to the required service quality is an obligation of good municipal management and a commitment to intergenerational sustainability. An unrealistic assessment of current assets' value can compromise financial and technical sustainability. By updating the asset portfolio and the accounting useful life, the balance between future expenses and income is doable, while ensuring good performance and safety for people and property. Further developments are envisaged, namely the consideration of the assets' condition.

The applied methodology is replicable to other assets in the Lisbon region, namely to the bulk wastewater transport and wastewater treatment. In such cases, special care should be given to the treatment solutions, where treatment procedure's obsolescence needs to be considered. Replicability is also envisaged in drainage systems in other regions, considering the specific contextual factors of each region.

DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

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