Águas de Portugal Water and Wastewater assets Re-engineering - System Selection Methodology

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Abstract

Águas de Portugal (AdP) Group plays an important role in the development of the water supply and sanitation services in mainland Portugal, and is currently facing new challenges of optimization and efficient management of its resources, namely its assets. Taking into consideration a sustained planning for the next investment cycle, it is naturally relevant for the AdP Group to structure a re-engineering effort of its treatment systems.

This work arises from such context, aiming to identify the systems that should be targeted for undergoing the said re-engineering, for the different companies of the AdP Group. To fulfill such purpose, a selection methodology was defined based on Multicriteria Decision Analysis models, grounded on three sets of pre-established criteria of different natures. This methodology was applied in an informatics tool, developed on Microsoft Excel. It operates by feeding data regarding every water and wastewater system operated by each company, returning a list with those in need for intervention within this context.

The tool was applied to five different companies of the AdP Group, resulting in an average selection rate of 37% .The results obtained show that the greater the number of analysed systems, the lower the selection rate given by the tool. It was also concluded that in addition to fulfilling its purpose, the developed tool proves itself as a useful means of evaluating the systems of the Group. After some adaption it can be modelled to serve a final goal of identification of the main problems associated with a particular system.

Keywords: Águas de Portugal Group; water and wastewater assets; selection methodology; multiple-criteria decision analysis.

1. Introduction

In Portugal, the supply of drinking water and wastewater treatment are essential activities for the quality of life of populations, the protection of ecosystems and the socioeconomic development of the country [1]. The Águas de Portugal (AdP) Group plays a structural role in the environment sector in Portugal, being characterized as a publicly-owned limited liability company, and whose activity involves the integrated management of the urban water cycle and spanning all of its respective phases. Through its different companies, the Group has a nationwide presence providing services to municipalities that are simultaneously shareholders in the companies managing multi-municipal systems ("bulk" systems), and directly serving their populations through municipal level services ("distribution" systems) for water supply and sanitation [2].

As a result of Portugal's membership of the then European Economic Community, over the past decades there has been a substantial increase in the number of assets in the water sector, due to the hastened pace which was dictated by the availability of the European funds. As a result, many ongoing projects were constrained as the investments and financial supports became the main driver of the sector in Portugal [3].

Albeit the maturity attained over the years, the AdP Group is now facing new challenges. The reality nowadays has significantly diverged from the forecasts, namely in the areas of demographics, technological advances, climatic changes, variations in quality requisites demanded by the regulatory entities and increasing demands on the quality and quantity of the product from the population served. Adding the fact that some of the assets are nearly at the end of their life cycle, an opportunity is created for the AdP Group to carefully study their substitution and other eventual changes in the respective infrastructures, within the modern concepts of sustainability and preservation of the existing resources [3]. Taking into consideration a sustained planning for the next investment cycle, it is naturally relevant for the Adp Group to structure a re-engineering of its water and wastewater systems.

To fulfill such purpose, a series of objectives were established, such as: the identification, for the different companies of the AdP Group, of the systems that should be targeted as possible systems for undergoing the said re-engineering; the development of a user friendly informatics tool to perform the mentioned identification of systems; and the presentation of the conclusions achieved, in regards to the operation of the tool.

2. Current status review

2.1. Activity data of the AdP Group

The AdP Group acts across every phase in the urban water cycle, spanning the withdrawal, treatment, transport and distribution of water for public consumption, the collection, transport, treatment and rejection of used waters, both urban and industrial, including their reutilisation. Through its companies, and in partnership with the municipalities, the Group provides services to around 80% of the Portuguese population, reaching 234 municipalities with "upstream" services of water supply and wastewater sanitation [4]. As of 31 December 2019, the Group comprised 19 companies of which 13 were entities managing the water supply and wastewater treatment systems [2].

It is important to note that the increasing availability of urban water supply and wastewater sanitation services in Portugal is partly due to the vast network of operational infrastructures managed by the Group's companies, represented throughout the mainland by 118 water treatment plants, 980 wastewater treatment plants, 17155 km of water mains and distribution network, 9692 km of sewers, 2106 pumping stations for sanitation and 742 for water supply, 1791 reservoirs and 1216 abstractions [2]. It is only due to such great numbers that it was made was possible for the Group, at the year of 2019, to produce 597.3 Mm^3, acquire 22.3 Mm^3, distribute 71.5 Mm^3 and deliver 613.9 Mm^3 of water and also treat 498.1 Mm^3 and discharge 491 Mm^3 of wastewater [2].

2.2. Multicriteria Decision Analysis

As a means to fulfill the main objective of the present work - identification of water and wastewater systems to be the object of a future study for optimization opportunities - a selection methodology has to be defined. Following this, an analysis will be carried out to each company of the AdP Group individually, gathering data relative to the respective systems as input to feed the tool. It is intended that this tool processes that information, returning a list with the selected systems.

Ultimately, a decision has to be made (the selection of systems from the overall domain of each company of the Group) taking into consideration a set of pre-established criteria, thus introducing the concepts of decision aiding models. In the present work, Multicriteria Decision Analysis (MCDA) is the right approach, being a generic term to describe a collection of formal approaches which seek to take explicit account of multiple criteria in helping people obtaining elements of responses to the questions asked by a stakeholder in a decision process [5], [6]. About MCDA, it is important to retain the following:

- The main focus is on aiding the decision and not on what the decision is or how it is supposed to be made in the absence of a formal support.
- It does not provide such thing as the "right answer" and the concept of an optimum does not exist. The result is merely a recommendation based on the selected criteria.
- It does not provide an "objective" analysis which will relieve decision makers of the responsibility of making difficult judgements. Subjectivity is inherent in all decision making, in particular in the choice of criteria on which to base the decision, and the relative "weight" given to those criteria.

Regarding the MCDA process, three key stages are identified: Identification and structuring of the problem (divergent thinking), model definition and application (convergent thinking) and the development of action plans. Iterations are expected to occur during the process, within and between the different key stages. Each stage is also subject to multiple internal and external influences [6], [7].

Multi-Attribute Value Theory

Within the MCDA models, the Multi-Attribute Value Theory (MAVT) stands out, not only because it is one of the most applied methods and hence better defined, but also because it fits best the context of this work [7]. Basically, MAVT relates to the construction of value functions for each criterion that normalize individual impacts to a common scale of comparison (intra-criteria evaluation). There is also a phase of weighting, where participants are asked to assign weights to the evaluation criteria, or rank them according to their preferences and value judgments (inter-criteria evaluation) [6], [8].

The final outcome of the analysis is the overall value for each alternative reflecting all criteria taken together. In order to obtain such final value, one can use an additive model that multiplies the criteria performance scores with the corresponding weights and then sums them up. The results can later be organized in a ranking so as to show the stakeholders the preferences obtained. [6].

3. Methods

The work of this dissertation derived from a project that was initially proposed by AdP SGPS, S.A. to the Engineering Department from AdP Serviços Ambientais, S.A., consisting of two distinct phases: the first phase, comprising this dissertation, regarding the identification of the systems from the AdP Group to be object of further studies taking place in phase 2. In this second phase (not included in the scope of the present work) a thorough analysis will be carried out to the selected systems in order to make the final decision on whether to proceed to their re-engineering.

3.1. Methodology definition

In brief, the desired informatics tool will select systems for a certain company of the AdP Group based on a pre-established set of criteria, using a MAVT model to normalize the results of each criterion to a common scale of comparison in order to obtain a final and global result.

Besides the multicriteria models, another principle was used to define the methodology. The filter applied in the selection of the systems will be as tight as it can be, in order to maximize the number of systems selected. The reason for this lies with trying to avoid that possibly relevant systems be left out, even if it implies an over selection of systems that later on in the project are not considered for the future studies.

For the selection process, three sets of criteria were established enabling the application of three distinct and successive filters. This way a first selection occurs based on the first set of criteria. The systems that are not selected shall move on to a second selection stage based on the second set of criteria, and following the same logic to the third and final filter.

In order for the tool to be as selective as possible, it will also operate in two slightly different versions: one for water supply systems and another for wastewater systems. This is because these two types of systems have distinct characteristics that justify an individualized analysis. For companies that include the two types of services both versions will be applied separately.

Figure 1 shows a scheme of how the tool will operate through its three filters, displaying all the criteria and distinguishing between the water and wastewater versions.

In all the filters (or sets of criteria) a final rating is generated for every system analysed based on the input data.

Binding Criteria

The first set was named **Binding Criteria** due to their significance justifying the automatic selection of a system, meaning that only one criterion needs to be met in order for a system to be selected by the tool for future study.

This set differs between water and wastewater systems, showing differences in the analysis performed. For both versions the binding set is composed of two criteria (as shown in figure 1). They will automatically select all systems that present direct costs above the system fare (at the year of 2019) or that had, at some point, resorted to alternative emergency means of supply (road tankers) for water systems, or that are not complying with the regulations in the year of 2019 for wastewater systems.

The final evaluation performed in this set is the simplest of the three, attributing a rating equal to the Direct Costs of a system, to all systems that meet at least one of the criteria of this first filter.

Weighting Criteria

The second set of criteria took fully into account the MAVT theory, having been named as **Weighting Criteria**. These are criteria that individually do not justify the selection of a system, but when put together and considering assigned weights, allow the identification of a system for selection. Similarly to the binding criteria, this set also differs between water and wastewater systems, as seen in figure 1. The only difference is in the number of criteria in the set, namely 5 criteria for the water version and 6 criteria for the wastewater one.

The criteria in this filter will be quantified and then normalized to a common scale of comparison, comprising values between 0 and 10, as well as being assigned a weight specific for each criterion (percentages of the weights also shown in figure 1). The final result for each system will be the sum of all criteria products between the normalized value obtained and its corresponding weight, resulting in a final number between 0 and 10 (equation 1).

$$\text{Evaluation}_{\text{system x}} = \sum_{n=1}^{n=N} Weight_n * Value_n \quad (1)$$

Where x refers to the system in analysis, n to the criterion, N to the number of criteria (since it diverges depending on the type of system) and the *Value* to the already normalized value.

However, the attribution of a classification to each system is not enough to cause its selection. In order for this to happen, a threshold value must be established, causing the selection of all systems

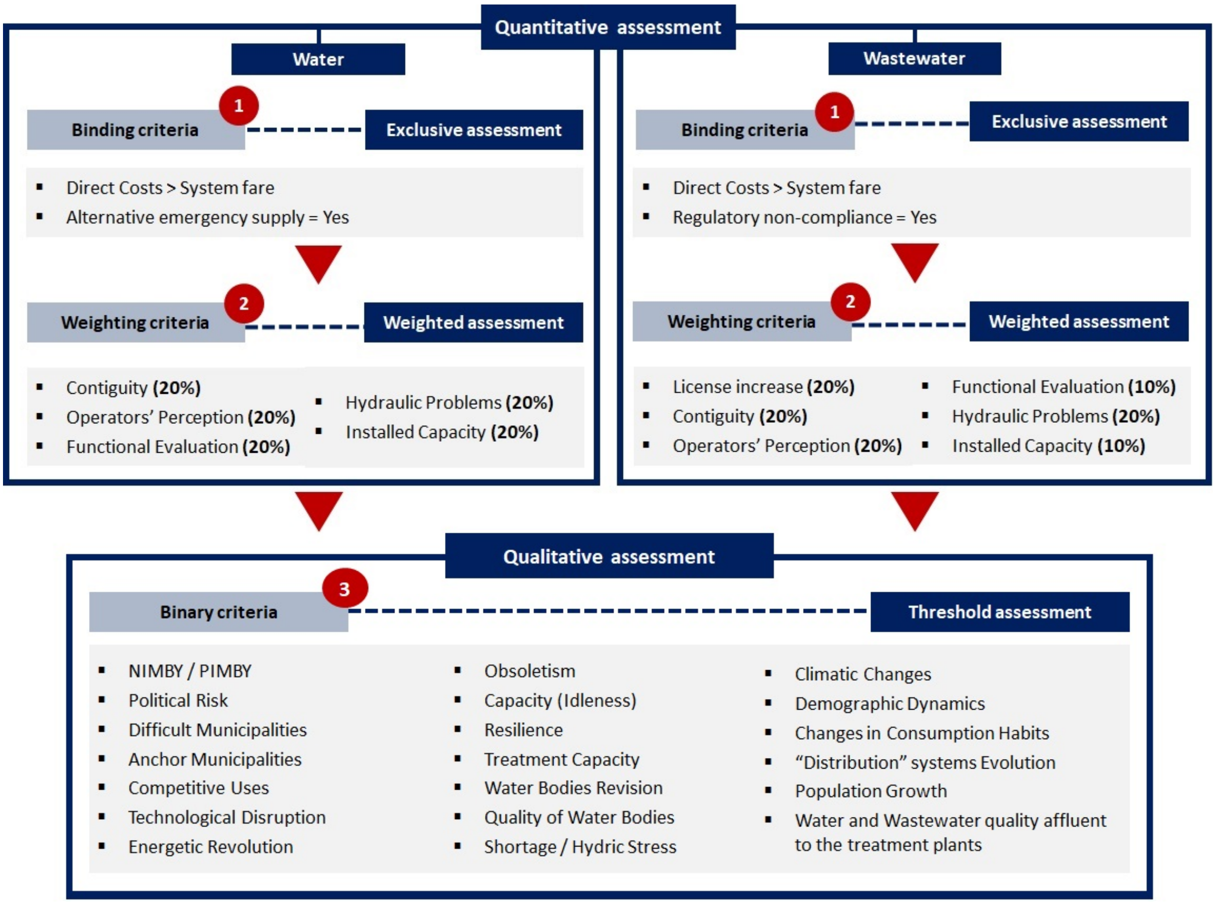

Figure 1: Tool operation scheme, showing the three sets of criteria for both versions of water and wastewater systems.

with an evaluation value equal or higher than the threshold chosen. The choice of this value will vary amongst the different companies of the AdP Group in order to better adapt the tool to each company, resulting in a personalized analysis, as it will be shown in the Results of the present work. The reason for such variations is related to the great diversity within the Group, making it almost impossible to fit one tool to every company without adjustments.

The analysis carried out by the tool on this set is finalized by checking if any of the systems with an evaluation equal or higher than the threshold was not already selected in the previous filter (of the binding criteria). Only then it will produce the list of the selected systems for this weighting set.

Binary Criteria

As the third set there are the **Binary Criteria**. The name derives from the fact that their input is made only with values of 0 or 1. This final set represents criteria that are not quantifiable and that do not necessarily reflect current existing problems on the systems' infrastructures, but instead situations that are foreseen as problematic in the future (for example, equipment obsoletism or the vulnerability caused by extreme climatic events).

The binary set is composed of 19 criteria (all shown in figure 1), related to different indicators which the companies will have to assess if their systems may or may not be propitious to the impacts that may come from such indicators. In the cases that a system is not considered to be affected by the criterion, the value 0 shall be attributed to it, whereas systems that are considered vulnerable to those same effects must be classified with the value 1.

The same set of criteria is applied in both versions of the tool with the only difference being in the types of water. For example, on the criterion relative to the quality of the water, the water version refers to the water withdrawn at the source and the wastewater version refers to the wastewater affluent to the treatment plants.

The final evaluation of the systems will correspond to the sum of the classifications given to each of the criterion, as seen in equation 2. Such evaluation has a maximum value of 19 (which would correspond to total vulnerability of a system) and a minimum of zero (corresponding to a system risk free of any impact caused by the criteria).

$$\text{Evaluation}_{\text{system x}} = \sum_{n=1}^{n=19} \mathit{Classification}_n \qquad (2)$$

Once again, the x refers to the system in analysis, the n to the criterion and the *Classification* to the values of 0 or 1 attributed to the system.

Similarly to what happened on the previous filter (the weighting criteria), the binary set also needs a threshold value in order to establish the limit from which systems are selected. Then, a final assessment is carried so as to understand if any of the systems with a classification equal to or higher than the threshold value were already selected by one of the previous two filters. In this way, the final list of selected systems never shows repeated systems.

Due to the complexity of the criteria in this set (regarding their non quantifiable traits), an auxiliary section within the tool was created in order to help the user with the classification (of 0 or 1). This assistance comes in the answer form on different phrases related to each criterion that can characterize different types of systems. In this way the user can select the phrase that best fits the system under analysis while the tool automatically attributes 0 or 1 according to the chosen phrase.

A final assessment is carried out so as to understand if any of the systems with a classification equal to or higher than the threshold value were already selected by one of the previous two filters. This way, the final list of selected systems never shows repeated systems.

3.2. Tool operation

Software

Since the tool will be operated not only by the Engineering Department of AdP Serviços Ambientais, S.A. (where myself is included during the execution of this work), but also some of the criteria will be answered by the respective companies and inserted directly in the tool, one of the main requisites for the choice of software for developing the tool is for it to be an accessible and user friendly interface for every intervening entity.

The tool also needs to be easily programmable in order to ease changes in its methodology since it has to be adjusted to every company. Such factor is also important in the way that it becomes more available for future improvement actions or other adjustments that may come with alterations within its domain of application.

Taking all this into consideration, it naturally occurs *Microsoft Office Excel* as an adequate choice of software as it is available and known by all and relatively simple to operate once the tool is set up. It also provides some freedom to the user to register relevant notes during its loading.

Operation

The two versions of the tool only differ in certain criteria whereby its design and operation are the same for both versions.

By opening the respective file, the tool presents itself to its users with an introductory page that summarizes all criteria along the three filters as well as providing pertinent information regarding the responsibility and the loading of the data, working as an instruction sheet.

The user can then navigate to the main page which is divided into three sections: one where the results are shown, another relative to the quantitative assessment (binding and weighting criteria) and the last one corresponding to the qualitative assessment (binary criteria). The results section is composed of three tables, each corresponding to a list of the systems selected in each set of criteria.

As a way to facilitate the process of filling the tool with the required data, a color scheme was created. In this way all cells marked white are blocked and non editable cells containing formulae that perform automatic calculations, all cells marked grey are the Engineering Department's responsibility to fill and all cells marked blue are the company's responsibility. Once filled with the data, the blue cells will automatically turn white in order to warn the user that the cell's value is already settled.

Given the large amount and subjectivity of the binary criteria, the tool presents a decision aiding page for the user, in order to help with attributing the values 0 or 1 in the last filter. For each system and each criterion a drop down list with different phrases related to the criterion is shown when the corresponding cell is selected. By choosing the phrase that best fits the system in analysis, the tool automatically fills in the criterion with its corresponding value. There even exists an alternative option to users who want to add their own characteristic phrases to the tool, in case neither of the options listed are considered adequate to the system under analysis.

4. Results and discussion

4.1. Study sample

From the 13 companies within the AdP Group, 8 were selected to take part in this study due their individual peculiarities. These companies secure different services: water supply, wastewater sanitation or even both. Regarding the fact that the developed tool distinguishes between water and wastewater services, for this analysis, it was considered from this point forward that companies which secure simultaneously water and wastewater services correspond to two different and independent entities. Taking this into consideration, during the execution of the present work, 5 companies (2 from water supply and 3 from wastewater sanitation services) gave their contribution by answering and filling all the criteria that were established as their responsibility. Thus, these 5 companies constitute the working sample of the study, having been subject to the analysis performed by the developed tool.

For analysis purposes, the companies were named after a letter of the alphabet (with no correlation whatsoever between their name and corresponding letter). Each of these companies also manages a list of systems. Table 1 shows the list of companies with their coded letter, type of service and respective number of systems that were submitted to this study.

Table 1: Companies participatin in the study with their respective type of service and number of systems in management.

Company	Type of service	Number of systems
Company A	Water supply	27
Company B	Water supply	4
Company C	Wastewater sanitation	161
Company D	Wastewater sanitation	30
Company E	Wastewater sanitation	28

4.2. Results

As explained in the Methods section, a choice of a threshold value has to be made in two of the filters (the weighting and binary sets of criteria) in order to enable the selection of systems. To reduce the arbitrariness associated with this decision, a target was established regarding the fraction of systems selected by the tool. Therefore all decisions made during the process of analysis took into consideration a preferable selection rate of about 25% to 35% of the systems submitted by each company, corresponding to more or less 1/4 to 1/3 of the total systems.

This target is considered only as a guideline, for the results are not always adjustable enough to fit the established values. The reader may find all justifications regarding the choices of the threshold values in the full thesis document, being presented in this extended abstract only the values chosen for each company. It should be noted that all decisions took into account the following:

- How the choice affected the final results in terms of selection rates, knowing the preferable interval is about 25% to 35%;
- Attempt to try to always have at least one system selected at each filter level;
- The principle of maximization of selected systems, whereby it is preferable to result in over selection than in under selection;
- All cases were studied individually.

Company A – Water

Of the **27 systems submitted to analysis** by company A, 7 were selected in the first set of criteria, all to due to having resorted to emergency alternative means of water supply. On the second filter (of the weighting criteria) a threshold value of 4 was established, resulting in the selection of 2 systems. Finally, applying a value of 12 for the threshold on the last filter, 3 more system were selected, causing a total of **12 systems selected** by the tool out of 27 analysed. Such value corresponds to about **44% as selection rate**, which is higher than the preferable interval established.

Company B – Water

Company B constitutes a particular case since in only manages **4 systems that were submitted for analysis**. On the first filter no systems were selected by any of the criteria, opposing the principles adopted. However the binding criteria are neither arbitrary nor they possess freedom of decision, so it is not possible to manipulate this results. On the second set of criteria 1 system was selected through the choice of a threshold value of 3. The last set of the binary criteria caused the selection of 1 more system due to the established value of threshold of 9 (the maximum being 19). All together, the tool returned **2 selected systems** out of the 4 that were submitted to the study, resulting in a **selection rate of 50%**. Even though the value obtained is much higher than desired, it is still very much acceptable regarding the number of systems that were analysed and taking into account the principles adopted in the methodology.

Company C – Wastewater

Completely opposite to company B, company C **possesses 161 systems**, a lot more than the rest of the companies participants in the present study. The first set of binding criteria identified 6 systems (3 of which had direct costs superior to the established fare and the other 3 were not compliant to the regulatory licenses). This value appears to be low regarding the total amount of systems submitted to the study. This is partly because 21 of the submitted systems were given a 0 value in their respective direct costs criterion due to being comprised in an outsourcing system. This way it is not possible to separate the costs evenly regarding the remaining systems, which would result in an inconsistent analysis of this criterion.

On the second filter 14 systems were selected regarding the threshold value chosen of 4. By establishing a threshold value of 8 on the binary set of criteria, 18 systems were selected at this stage, summing up to a total of **38 selected systems** and corresponding to a **selection rate of 24%** (just below the 25% limit of the preferred values). The fact that company C has a much greater number of systems seemed to result in a stronger control of the outcome in terms of selected systems in each filter (keeping in mind that binding criteria are not arbitrary and that 21 systems were not properly analysed, which could have changed the results)

Company D – Wastewater

Company D **submitted its 30 systems for analysis**, of which 3 were selected in the first set of criteria (1 system presented direct costs higher that its fare and 2 other are not in compliance with regulatory licenses). Choosing a threshold value of 5 for the evaluation on the weighting criteria set caused the selection of 4 systems. Regarding the last filter (binary criteria) a value of 11 was established for the threshold causing the selection of 2 more systems. A total of **9 systems were identified** by the tool resulting in a **selection rate of 30%**, right within the preferable interval established.

Company E – Wastewater

Of the **total of 28 systems** from company E, 4 were selected on the first filter ((1 system presented direct costs higher that its fare and the 3 remaining are not in compliance with the regulatory licenses). On the second set of criteria a threshold value of 5 was defined causing the selection of 3 systems at this stage. Finally, applying a threshold value of 8 on the last set of criteria (binary) 4 more systems were identified resulting in a total of **11 selected systems**, which out of the 28 submitted corresponds to a **selection rate of 39%**.

4.3. Analysis of the results

Threshold values

Table 2 gathers all the threshold values established for the five companies analysed, regarding the weighting and binary sets of criteria.

Table 2: Selection threshold values for each company participating in the study, regarding the weighting and binary criteria sets.

	Threshold values	
Company	**Weighting set**	**Binary set**
Company A	4	12
Company B	5	9
Company C	4	8
Company D	5	11
Company E	5	8
Mean	**4.6**	**9.6**

In terms of the weighting criteria, the values chosen do not seem to vary much having only values of 4 or 5. As for the thresholds chosen for the binary set of criteria the values vary between 8 and 12, which appears to show more diversity than the previous criteria, naturally due to using a wider scale as well. Even so, the values are around the number 10 with a variation of 2 units (above and below). In both sets of criteria the results show a tendency towards the choice of values near half scale (mean values of 4.6 out of 10 for the weighting criteria and 9.6 out of 19 for the binary criteria). If this results were to correspond to a bigger working sample, it could mean that even though there is freedom of decision in some of the criteria (regarding the establishment of threshold values), the methodology appears to adjust to a same intermediate value, reducing the existing variability amongst the different companies and standardizing the methodology itself.

Selection rates

Figure 2 shows the overall results obtained from the study, representing the number of selected systems with the number of systems submitted for analysis as well as the selection rate for each company. The same figure shows that only company D stayed inside the interval of selection rates initially established as preferable and company C practically achieved it while the remaining companies all obtained higher selection rates. Such results are mainly due to the lack of control over the binding criteria and also to the freedom of choice in deciding the threshold value for the weighting and binary criteria.

It is also possible to observe in figure 2 that the company with the lower selection rate (company C) corresponds to the company with the higher number of systems submitted to analysis, whereas the company with the higher selection rate (company B) corresponds to that with the lower number of systems. One might speculate about a inverse correlation between the number of systems and the selection rate. This ideia is more or less sustained by the information for the rest of the companies, and a graphic representation can be observed in figure 3.

Figure 3 shows two correlation models: linear (in green) and logarithmic (in red). The coefficients of determination indicate that the logarithmic model is the most adequate of the two, understanding that the linear would always be unlikely taking into account the enormous gap in the number of systems (from 4 to 161). However, the working sample is rather small and not very representative (only 2 companies of water supply and 3 of wastewater sanitation services), making it harder to infer about

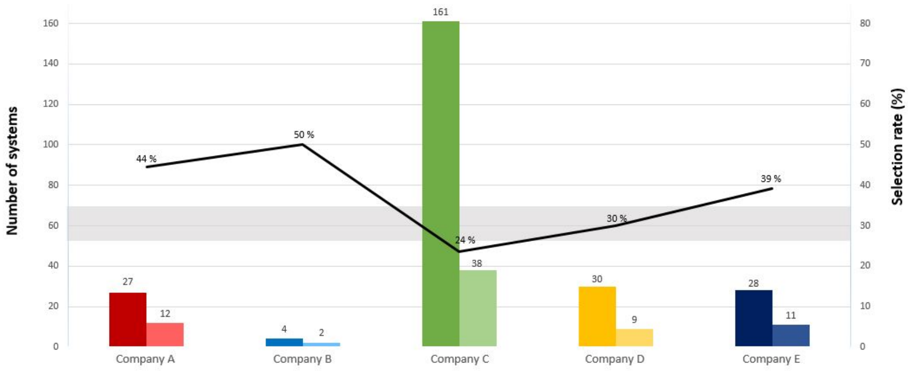

Figure 2: Main axis: Number of analysed systems vs. number of selected systems for each of the participant companies (in the respective order from left to right). Secondary axis: Selection rate of each of the companies (%), with a grey shade showing the preferable interval (25% to 35 %).

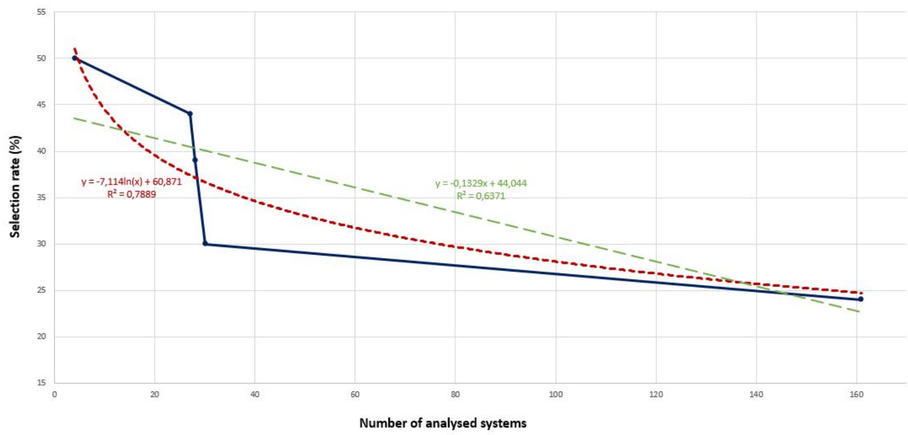

Figure 3: Graphic representation of the correlation between the number of analysed systems and respective selection rate for each company. Linear regression equation: y = - 1329 x + 44,044 and Coefficient of determination (R^2) = 0,6371. Logarithmic equation: y = -7,111 ln(x) + 60,871 and Coefficient of determination (R^2) = 0,7889.

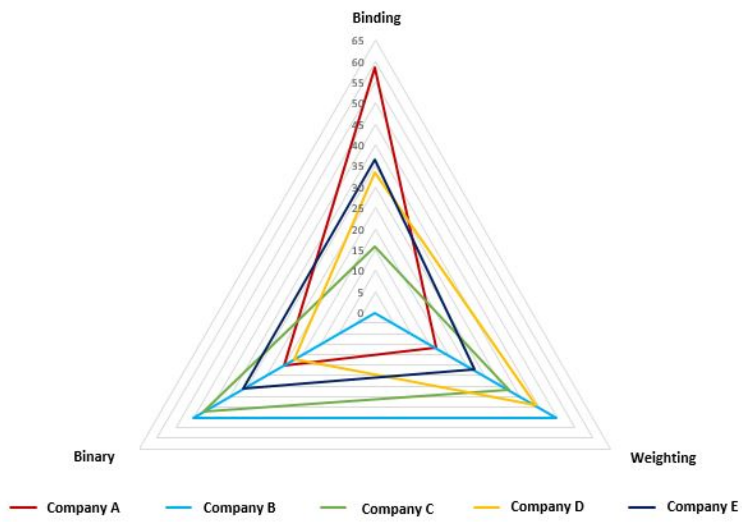

Figure 4: Web representation of the percentage of selected systems in a certain filter (binding, weighting or binary) with respect to the total number of selected systems, for each company.

such type of model. Further data would be needed in order to enable a consistent model proposal.

Selection within sets of criteria

Table 3 shows the selection rates obtained in each filter individually (selected systems in relation to the number of systems submitted to analysis).

Table 3: Selection rates obtained in each filter (binding, weighting and binary) individually.

	% Selected Systems		
	Binding	**Weighting**	**Binary**
Company A	26	7	11
Company B	0	25	25
Company C	4	9	11
Company D	10	13	7
Company E	14	11	14
MEAN	**10.8**	**13.0**	**13.6**

Values show that the selection rate by filter has varied from 0% (no system selected) to 26% (surpassing one quarter of the analysed systems in just one filter). These extreme values contradict some of the principles applied in the methodology, however they all occurr within the binding criteria which is the set in which the results are exclusive and do not offer any freedom of decision, meaning they cannot be changed. Company B also shows values of 25% of selection in both weighting and binary criteria, indicating an overall over selection of systems (if just one set selects one quarter of the analysed systems then almost no margin is left for the selection of other systems in the other filters). However, these values belong to company B, that was already defined as a particular and unique case due to its reduced number of systems. The remaining values of selection rates by filter are considered reasonable, taking into account the final selection objective (the preferable interval established), which corresponds to about 5% to 15% of systems selected in each set of criteria.

In order to compare the different selection profiles within the three filters for the companies, figure 4 shows the percentages of selection within each set of criteria in relation to the overall number of selected systems for one company.

It is observable in figure 4 a higher density of high values in the sets of weighting and binary criteria for they appear to select more systems comparatively to the set of binding criteria, which only shows one high peak (corresponding to company A).

It also appears that there are no companies with similar profiles, making it difficult to group companies by profile, making it impossible to identify any possible pattern. Moreover, figure 4 actually shows two companies with opposing profiles (company A in red and company B in light blue), curiously enough, the only two companies with water supply services.

Since no relation was found for the results obtained, not even within the group of companies working the same type of service, it is only possible to conclude about the high diversity of the results and their unpredictability, no trends being identified in values, filters or type of service. Such results may be linked in a certain way to the existing freedom of choice in the decision on the threshold values for the weighting and binary sets of criteria, confusing possibly existing trends. It should be reinforced that the study sample is small. Upon a bigger sample more results would be obtained, increasing the probability of finding a pattern or a trend. However, it may also happen that the companies analysed in this study are actually very representative of the status and condition of the rest of the systems of the AdP Group.

5. Conclusions and future perspectives

It is important to initiate this section with the note that the sample used in this work was small, comprising only 5 companies within the AdP Group. For this reason, the conclusions drawn from this study are sustained only by the data obtained from the said companies which may not be fully representative of the rest of the Group. Amongst many reasons, the operational situation caused by the SARS-CoV-2 pandemic stands out as significant in justifying the reduced number of participants.

Regarding the results obtained it was found that the greater the number of analysed systems for a certain company, the bigger the control over the respective selection rate, resulting in lower values comparatively to companies with smaller numbers of systems.

The weights assigned to each criterion in the second filter were, for this work's purpose, left untouched. However, these might be reviewed according to a company's necessities or challenges. After obtaining the results, a company may wish to include other systems that are not in the final selection list provided by the tool. This way they can adjust the weights in order to give more or less importance to different criteria according to the characteristics and priorities of that company.

In regards to the accessibility and operationality of the decision tool that was developed, it was considered that it served its purposed correctly. The responsibility assigned to the companies is relatively simple, involving the attribution of scores to its systems in well defined places in the tool as well as being provided with an introductory page with operational instructions and an auxiliary page for assistance in the binary criteria. Even so, the high number of criteria multiplied by the number of systems within a company may result in a time-consuming task.

Therefore, the high number of criteria to assess is regarded as a limitation to the pursuit of this work. Nevertheless this is a factor difficult to change since the tool has to take into account as many criteria as possible so as to fit all the systems comprising all the infrastructures of the AdP Group. On the other hand, the creation of a static and unique tool (without the freedom of choice in the thresholds and weights) would also be impractical due to the wide diversity within the Group, culminating in weaker results and increasing the risk of leaving out systems for which further study could be relevant.

Another possible limitation lies with the subjectivity affecting the assessment of the criteria. It exists in every criteria with freedom of decision and in every criteria assessed by the companies, which may produce very different results amongst the companies. However, another approach would not be as adequate since every opinion aims to be accounted for, regarding the company and the operation of its infrastructures. To try to counteract to this subjectivity, the tool applies normalization principles in the weighting set of criteria, and in the binary set it provides several pre-defined phrases as a means of assisting the user in attributing a classification for the systems analysed.

As a final comment, it was also concluded that in addition to fulfilling its purpose, the developed tool proves itself as a useful means of evaluating the treatment systems of the Group. After some adaptation it can be suited to serve a final goal of identification of the main problems associated with a particular system, serving also as evidence for the companies looking to justify existing problems in their systems.

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