Doctoral School of Business Administration

SUMMARY OF THESES

Károly Kovács

REPLACEMENT NEEDS OF WATER UTILITY INFRASTRUCTURE

Social responsibility – needs for solidarity

of doctoral (PhD) dissertation

Supervisors:

Sándor Kerekes, PhD
Professzor Emeritus
and
Ágnes Zsóka, PhD
Professor

Budapest, 2021

Doctoral School of Business Administration

SUMMARY OF THESES:

REPLACEMENT NEEDS OF WATER UTILITY INFRASTRUCTURE
Social responsibility – needs for solidarity

Károly Kovács

of doctoral (PhD) dissertation

Supervisors:

Sándor Kerekes, PhD

Professzor Emeritus

and

Ágnes Zsóka, PhD

Professor

Table of contents

I. Subject of the research

The principal topic of the 3rd Budapest Water Summit held in 2019 was **preventing the global water crisis.** According to the author of the closing document, (Szőlőssy Nagy and et al, 2019 p.1), **"we are already off the track in implementing the water related SDG targets". Water professionals have been sending warnings to society for a long time, the worries present in professional circles have not, however, triggered a response in society at large. Social dialogue has not given the necessary attention to and has thus failed to recognise the natural and economic significance of water, primarily "fresh water".**

The closing documents of the water summits attempt to make up for the lack of public awareness and set the task of "developing cooperation at all levels" and designate, as their first pillar **"making water-related information on policies, processes and data transparent and accessible to all people"**.

An important document from the perspective of my research is the National Water Strategy published in 2017 (Government of Hungary). The chapter on settlement water management of the document stresses that *"the single greatest challenge of water management of settlements is the lack of reconstruction of water utilities*". According to the document, "*the backlog in reconstructions is accumulated and water tariffs do not generate funds for the reconstruction of the infrastructure."*

Economic problems related to the operation of water utilities are present outside of Hungary, as well. A comprehensive study prepared in 2010, assessing the sustaining and development challenges in the United States concludes that a three-fold increase in service charges would be necessary because of the increasingly urgent renewal and development needs. (American Water Works Association, 2010) The studies cited in my work, as well as my own research outcome demonstrate that the situation of the replacement of water utilities varies greatly in time, by sector, settlement and settlement size groups. It is in settlements with a smaller number of inhabitants in the first place where service charges do not generate sufficient funds for replacements. Based on the current tariff system, the maintenance of the infrastructure cannot be secured using service charges, and developments can be funded only from external sources. In 2018, the Hungarian Academy of Sciences defined special tasks in consideration of the equal opportunities criteria of water supply.

These research tasks are the following:

- *The development of solutions for the simultaneous fulfilment of the principle of full cost recovery and of the affordability of drinking water*
- *Universal, in the long-term sustainable access to drinking water, including socially marginalised people – identification of legal, engineering and financial solutions* (MTA, 2018)

It was in consideration of the above documents, reflecting the position of the Hungarian professional circles that I formulated the research questions and tasks for my thesis. Within the empirical research I studied the following issues:

- The extent of the difference in urban settlements of different sizes, grouped by size, between specific costs per capita or per single unit of consumption of the development and upkeep of infrastructure on which water utility services are based, and to what extent is funding provided for these through the tariffs used in the various urban settlement groups,
- The factors influencing per capita replacement needs and the correlation between the size of the urban area, specific costs and the income level of the inhabitants,
- The extent to which the polluter pays and the cost recovery principles and the right to healthy drinking water and sanitation are enforced under the current framework of affordability/willingness to pay, and how these can be reconciled with the requirement of sustainability,
- The social engagement needed and solidarity requirements arising out of ensuring universal and sustainable in the long-run access to drinking water, including to those socially marginalised and those living in small villages, in light of the considerable differences and disparities in water infrastructure development and replacement needs, manifest by urban settlement size groups,
- The extent to which people living in urbans settlements of different sizes perceive the difference in the costs of water utility services and to which people are willing to engage in or expect society's engagement and solidarity in the interest of ensuring universally accessible and sustainable water services,
- What asset management measures can be taken to ensure that the planning of the development and replacement of water utility infrastructure and thereby the fee structure is more balanced and more sustainable among the various urban settlements and settlement groups,

Answering the questions above, in addition to economic consequences, there are other pressing issues to be addressed in terms of the supply of healthy drinking water as is highlighted by the Challenges and Research Tasks of the Hungarian Water Research Programme issued by the MTA:

Primarily following the introduction of water tariffs, a major shift occurred in consumer habits, leading to a continuous decrease in drinking water consumption in the last 30 years (it halved to an average of about 110 l/capita/day). The change is even more significant in small rural municipalities, partly due to urbanisation, partly because of the use of private wells (daily utility consumption is a mere 60-80 l/capita). The distribution system is oversized throughout the country for the current level of water consumption and generally of deteriorated condition. The water loss resulting from the leakage from the obsolete pipeline network is considerable (20-30%).

Reconstruction of the pipelines is both a public health, as well as an economic concern because the breach of pipe integrity is one of the primary causes for the microbiological contamination of drinking water.

Decreasing consumption leads to higher stagnation time in the distribution system, which may trigger unwanted processes (deposition of inorganic substances, leaching, biofilm formation). This is the so-called secondary deterioration of water, the risk of which is likely to increase in consequence of the increase in mean summer temperature caused by climate change (especially in distribution systems inside buildings more exposed to ambient temperature). Asbestos cement pipes make up more than half of the mains pipes. The health impacts of asbestos fibres released through the abrasion of asbestos cement pipes is yet to be clarified and the lifecycle and potential problems of plastic pipes used to replace asbestos are not yet known. (MTA, 2018)

Based on the above documents and my research questions, I defined the following hypotheses:

1. The replacement costs per inhabitant, of infrastructure on which water utility services are based show significant differences in urbans settlements of different sizes, with the difference being of orders of magnitude at the extreme values, where the value in smaller settlements is a multiple of the value in larger settlements.
2. The average (spread evenly over time) cost requirements of sustaining and replacing the water utility infrastructure are considerably higher than the funding afforded in the current service environment (tariff structure). To make matters even worse,

replacement needs vary greatly over time because of the age distribution and technical condition of the water utility infrastructure. For drinking water supply systems, this value is extraordinarily high for the near future (next 15 years).

3. The distribution over time of replacement needs varies by sector and settlement type, meaning that such needs are more concentrated in time, with higher outlier values in smaller settlements, and can in time become more balanced and as such better manageable in the tariffs through the consolidation of asset management among the sectors and through the regional management of municipal assets (regional consolidation of water utility systems).
4. The replacement values of the infrastructure are reflected in the service charges, which thus are significantly higher in smaller urban settlements than the service charges in cities.
5. Groups of society living in smaller and large urban settlements are aware of the significant differences in the cost of municipal water and sewerage services depending on the size of the settlement and feel the need to renew the infrastructure and on the one hand require, on the other hand are willing to provide compensation and offer solidarity and social engagement.

II. Bases and research of results of empirical research

The basis for the research was, on the one hand, the set of data for the 714 settlements where there is both water and waste water utility infrastructure, within the Multipurpose Infrastructure Assessment Database (MIAD) software (Kovács and et al, 2010), which supports valuations and was developed under my professional guidance.

The database can be queried for structured economic data summarised by sector and object group, showing the annual replacement needs, which can then be used for further statistical evaluation and analysis. I then coupled these data with the number of inhabitants in the given urban area, the water and wastewater service charges levied there, as well as the length characteristics of the supply pipeline, as well as their county (regional) affiliation and additional identification codes together with other data facilitating evaluation and analysis. In addition to the research into the infrastructure forming the basis for urban water utility service and exploring issues related to asset management, I focus on the attitude of society towards Water-Value, more specifically the willingness for social engagement in vertical solidarity (overarching multiple generations), as well as the horizontal solidarity attitudes of those living in the different individual settlements and regions.

To substantiate the hypotheses, I had the data from the Data Matrix table in the doctoral thesis at my disposal: settlement, county, number of inhabitants, service provider, aggregate replacement, water-waste water sectoral replacement costs, per capita Aggregate Replacement Costs during the life cycle studied, per capita length of pipeline, population density in county, number of dwellings connected to the drinking and waste water network, total – 2018, average price of used dwellings sold (million HUF/dwelling) – 2018, amount of personal income tax base (1000 HUF), monthly personal income tax base per taxpayer, 2018, combined amount of household water and sewerage tariff (HUF/m3) – 2019, water volume supplied per person (m3)-2018, volume of waste water discharged in the public utility waste water collection network (household) per person (m3) – 2018, Total replacement value – OPÉ/person (HUF/person), Total asset value - OVÉ/person, average Consistency index – OVÉ/OPÉ, Annual depreciation – OÉCS1 (HUF/person/year), Annual eligible depreciation – OÉCS2 (HUF/person/year), per capita replacement cost incurred between years 1-15 – OPK15 (HUF/person), as well as top-heaviness indicator (ratio of opk15/opk35)

My questions intended to measure willingness for solidarity were incorporated into the focus-group based research "HWA WATERVALUE - Water in the household, domestic perception of water supply and water treatment" and into a survey conducted on a sample of 5000 people. The databased thus generated (MASZESZ, 2020) was used for further research and analysis.

In my research, the data matrix summarised per settlement is examined in two principal steps. The research focuses primarily on the analysis of the per capita replacement costs per settlement, the OPK/person indicator and of the underlying factors, substantiating the related hypotheses 1-4. In the second step, I analyse the combined database supplemented by the data of the Water Value research, partly to substantiate hypothesis 5, partly in an attempt to identify possible solutions for the financing problems surfaced in the course of the research.

In the next and final phase of the analysis, my aim was to create a common ground between the results identified in the household consumer survey and the settlement-geographical and water utility network operational data included in the MIAD database and to interpret them together.

Since the former is a research database resulting from an individual sampling procedure, while the basic units of the MIAD database are settlements, the condition for bringing the two databases to a uniform level was to first obtain settlement-level data from the household consumer survey data.

First of all, I defined the variables that I wanted to include in the settlement-level database of MIAD, and for which data input and transformation from the individual level to the settlement level was a realistic option. These were the following variables:

Variables describing status - income

- average monthly net household income per capita
- income quintiles based on monthly net household income per capita
- income segments based on per capita income and subjective well-being
- segments formed on the basis of the estimated value of a residential property by category and its relative value within its category
- income segments based on per capita income and subjective well-being; gaps in responses are estimated on the basis of real estate value and educational attainment variables

Variables describing the willingness to material sacrifice related to water

- sensitivity to price increases of water
- sensitivity to the increase in wastewater charges
- making financial sacrifices for the renovation of water supply networks versus passing on the burden of network renovation to future generations
- Cluster of sensitivities related to price increases of water and wastewater charges and financial burdens undertaken for network development
- the importance of introducing a single water tariff
- support for a nationally uniform water tariff, similar to electricity and gas supply
- Attitude cluster related to water and wastewater public load bearing

Variables describing material sacrifices related to water supply

- Attitude-based segments formed on the basis of concerns about drinking water supply, as well as about its quality and stability and the importance of sanitation

Variables describing water consumption

- segments formed on the basis of the average monthly total water consumption of the household

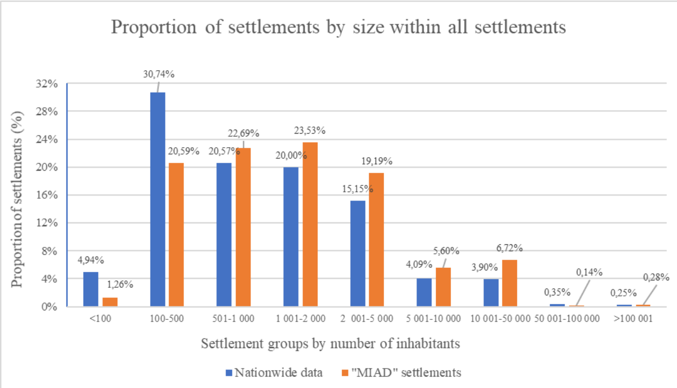
I refer to these variables as key variables, which are contained in the MIAD database with data input described in the dissertation.

Subject matter of the study: total replacement cost per person (OPK/person) during the lifecycle examined (HUF/person) and examination of funding sources for the costs.

Study units: Urban settlements

Number of units (N): 714

Clustering the size of settlements studied (714) and its representativeness at national level (3.155) are shown on the following figure:



III. Presentation of methodologies applied

The data of the water utility objects related to the subject of the research (714 settlements) *Groundwater abstraction,… Waterworks,… Water treatment facilities,… Drinking water network,… Water reservoirs,… Pressure boosters, (gravity) sewer, sewage pipes (force mains) …wastewater lifting plants,… Sewage treatment plant,… Individual wastewater treatment plant,… Semi-natural wastewater treatment plants,… Individual closed wastewater storage,… Individual water utility facilities: water utility elements not to be classified in the above types…, and all of them to be categorized according to: building, structure; machinery, equipment; control technology, energy supply."* (NFM, 2013).)

stemming from the valuation and aggregated by settlement (50-year replacement timelines) formed the basis of the research unique on an international scale as well.

The data base supporting both asset management and the research of social engagement allowed for a nationwide representative, quantitative research.

The statistical methodology applied during the research included the following methods:

- Descriptive statistics, to reveal the asset and tariff management situation by settlement or settlement groups, to substantiate hypotheses 1-4
- Correlation analysis to determine the closeness and direction of the relationship between the dependent variable and potential explanatory variables

- Linear regression, to establish the links determining the replacement value of the per capita infrastructure
- Cluster analysis to identify the most homogeneous groups of settlements within the clusters using cluster variables reflecting the water utility tariff and asset management situation of the individual settlements and settlement groups, the social and economic situation of the inhabitants and their willingness and position to engage socially, in order to identify the possible coping strategies for the settlement clusters devised.

IV. Summary of scientific findings

Results are summarised in line with the validation of the individual hypotheses.

To validate **Hypothesis 1.,** based on the following chart it can be concluded that the replacement costs per inhabitant, of infrastructure on which water utility services are based show significant differences in urbans settlements of different sizes, with the difference being of orders of magnitude at the extreme values, where the value in smaller settlements is a multiple of the value in larger settlements.

It can be established that in accordance with the hypothesis, the per capita average values by settlement group of the total replacement cost incurred during the 50-year cycle analysed (as a sectorial total OPK, as well as broken down by sector (water) OIPK and (wastewater) OSZVPK) **exceed the values of the settlements with a population in excess of 100.000 inhabitants by a multiple of about 5 in the case of settlements with a population of less than 100 people and by a multiple of 2, even in settlements of between 1.000-2.000 people. The per capita average values by settlement group of the total replacement cost is calculated as the average of the per capita values of the settlements within the given group of settlements**

Settlmenet group	OIPK/person average (HUF/person)	OSZVPK/person average (HUF/person)	OPK/person average (HUF/person)	OPK/person/year average (HUF/person/year)	Average water-sewerage tariff (HUF/m^3) - 2019	Average per capita annual tariff payment (HUF/person/year)
1	859 404	1 813 714	2 696 426	**52 871**	786	**28 315**
2	589 255	904 379	1 517 845	**29 762**	778	**23 145**
3	397 812	671 727	1 089 382	**21 360**	781	**21 258**
4	449 543	558 037	1 016 006	**19 922**	775	**24 238**
5	357 322	476 027	839 391	**16 459**	723	**22 515**
6	272 390	460 820	737 695	**14 465**	678	**23 229**
7	235 845	412 541	651 232	**12 769**	662	**22 764**
8	287 750	264 051	566 621	**11 110**	695	**23 721**
9	213 248	368 352	501 330	**9 830**	622	**20 825**
Grand total average of groups 1-9	**428 862**	**639 060**	**1 081 082**	**21 198**	**753**	**22 892**

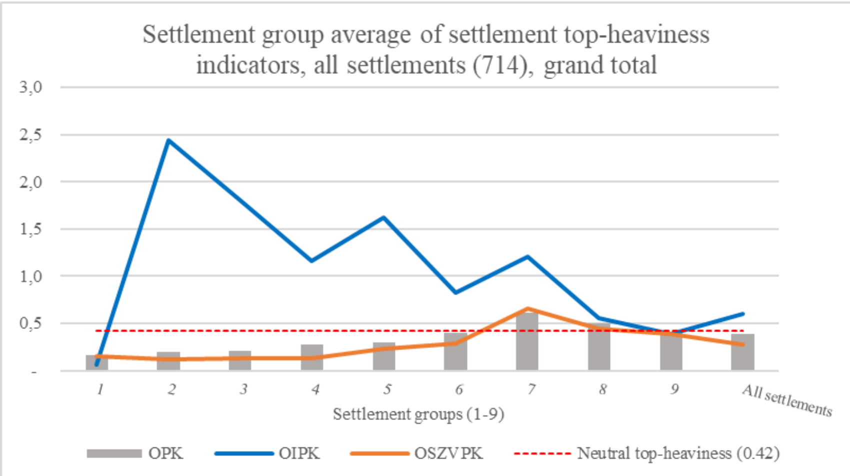
The per capita average values by settlement group of the total replacement cost is calculated as the average of the per capita values of the settlements within the given group of settlements. It is important to note that the grand total average values of groups 1-9 were calculated as the weighted average the total replacement values and total fee payments of the entire sample (714 settlements) divided by the total number of population of the sample, 2.361.740 people.

Hypothesis 4 is only partially correct, as the figure above shows that service charges are higher in smaller settlements (20-40%), at the same time, looking at it from a different angle, what we see is that it does not nearly provide enough financial cover for the five-fold extra costs needed to cover replacement needs. Especially in light of the fact that the specific costs of operation and maintenance (although not the subject matter of my present research) are also higher in small urban settlements.

The truth of the first statement within hypothesis 2 - *the average (spread evenly over time) cost requirements of sustaining and replacing the water utility infrastructure are considerably higher than the funding afforded in the current service environment (tariff structure)* - **is** evidenced by values summarised in the table above for settlement groups 1-9, on the annual average per capita replacement needs (HUF 21,198/person/year) and the annual average fee paid per person (HUF 22,892/person/year). By way of clarification, it must also be noted that, while replacement needs are net values (excl. VAT), water charges include 27% VAT. The net value of the total annual fee income (HUF 18,025/person/year) of the service provider and, as we can see, in the smaller settlements this fee income does not even cover half of the replacement needs. **Average tariffs fail to cover even replacement needs evenly distributed in time and among the settlements of the entire sample!**

That the statement made in the second half of Hypothesis No. 2., namely that *„to make matters even worse, replacement needs vary greatly over time because of the age distribution and technical condition of the water utility infrastructure. For drinking water supply systems, this value is extraordinarily high for the near future (next 15 years).* "

is illustrated with the indicator introduced during the study, the top heaviness indicatior shown in the figure below:



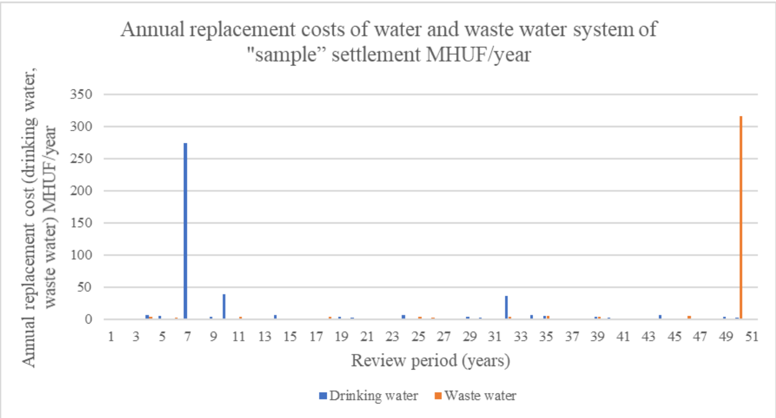
The top-heaviness indicator shows whether it is during the first 15 or last 35 years of the 50-year period reviewed, that higher replacement costs are incurred. Anything above the value of 0.43 (15/35=0.43) showing an even distribution over time, means that the water utility systems are "top-heavy", i.e., a higher-than-average portion of the 50-year replacement costs is incurred during the first 15 years.

Based on the above figure, we can conclude that drinking water systems tend to be "top-heavy", whereas wastewater systems tend to be "bottom-heavy" in almost all settlement groups. Exceptions to the above general observation are settlement groups 1 (0-100 inhabitants), 7 and 8 (10,001-50,000; 50,001-100,000 inhabitants, respectively). In the micro-settlements in group 1., piped water networks and subsequently wastewater sewerage systems were built during the last 35 years, i.e., in the last wave of constriction of urban water supply systems. Consequently, there is no significant replacement need during the next 15 years either in the drinking water or in the wastewater sectors. In the case of settlement groups 7. and 8., the refurbishment needs of the sewer systems built in the 1960's and 70's arise during the 15 years following the valuation, thus those systems are also top-heavy. **To quantify the urgent refurbishment needs anticipated in scientific references, it must be noted: in settlement groups 2-7, water supply infrastructure will require one and a half to twice as much spent during the coming 15 years than during the 35 thereafter in total!**

In group 9, of settlements with more than 100,000 inhabitants, the replacement needs are evenly distributed as a result of the gradual development of both the water and the sewerage networks.

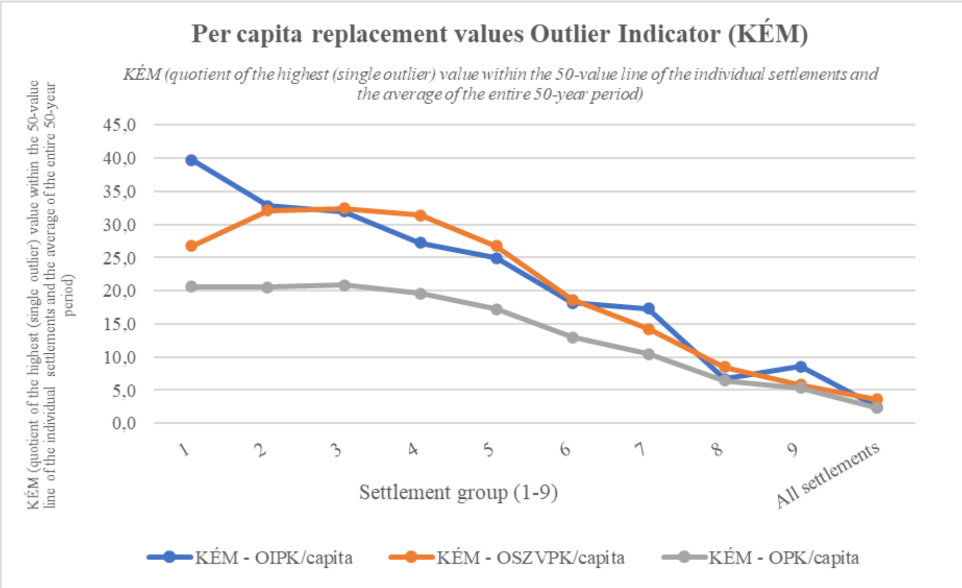
To justify the statement made in the Hypothesis No. 3., namely that the *distribution over time of replacement needs varies by sector and settlement type, meaning that such needs are more concentrated in time, with higher outlier values in smaller settlements, and can in time become more balanced and as such better manageable in the tariffs through the consolidation of asset management among the sectors and through the regional management of municipal assets (regional consolidation of water utility systems)"*

before moving on in analysing the consolidated data of the settlements grouped by size, it is essential to see the replacement timeline for settlements with less than 5,000 inhabitants, which tends to be the more extreme outlier as the smaller the settlement is and tends to follow the following pattern increasingly markedly. The "marked" trend in replacement needs is shown in the following Figure, on the example of a "Sample" settlement (number of inhabitants: 2,500 people) from group 5. (2,000-5,000 inhabitants).



The top-heaviness indicator of the given settlement is 3.97 in the case of water, i.e., the settlement is rather "top-heavy". The amount of replacement costs incurred during the first 15 years is about four times the amount of the replacement costs during the last 35 years. The "top-heaviness" indicator for wastewater is 0.03, i.e., the settlement is markedly "bottom-heavy", i.e., the amount of replacement cost during the first 15 years is minimal, thus the total replacement cost during the last 35 years is some 30-times higher than that of the first 15 years. At the same time, the outliers in each year make up 80-90% of the replacement needs of the total timeline, which, if divided over the years preceding and following the due date, presents a nearly unsurmountable challenge for the asset management of the given settlement.

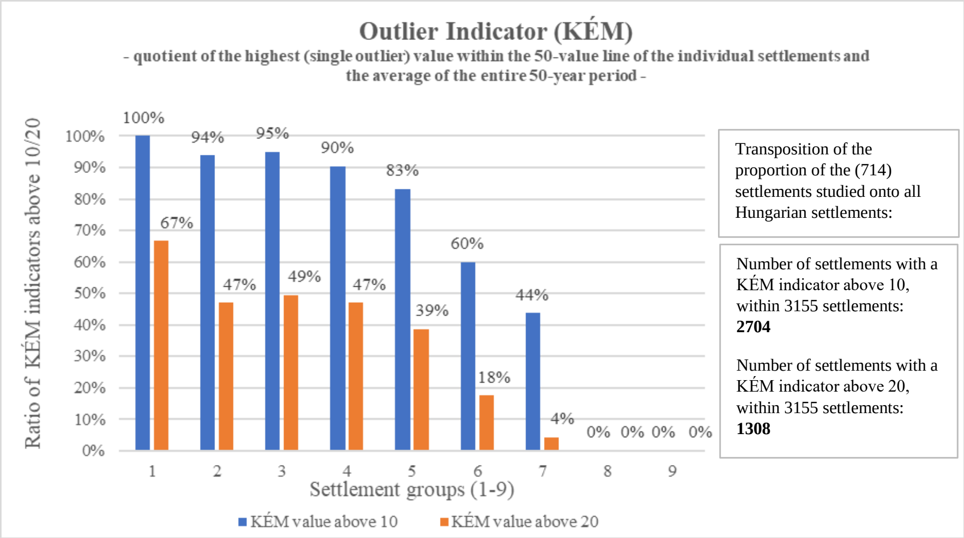
The outliers present at various points in time are characterised as the Outlier Indicator calculated from the quotient of the highest replacement need value presented in the given settlement within a year and the average value of the 50-year data line.



On this basis, we can conclude that:

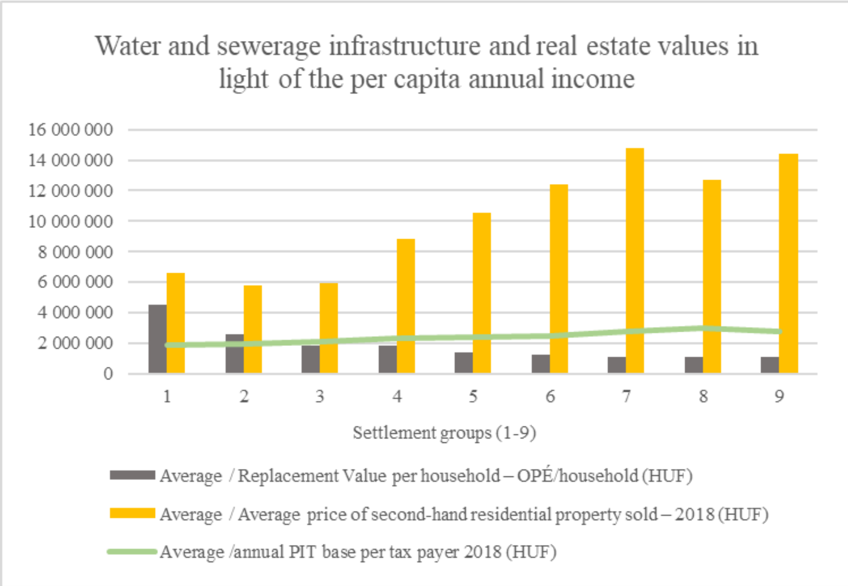
- In small settlements, at a disadvantage also in terms of the per capita replacement needs, (where fees do not provide funding for the average replacement values even)
- The extreme high outlier values (exceeding the average by a factor of 30-40) present sporadically at the level of the individual settlements (as independent asset manager owners and service providers) make asset management entirely impossible at the level of the individual settlement.

An excellent illustration of how common this occurrence is, is shown in the figure below



With small settlements, the reason for the presence of outlier values is primarily that the network was typically established in one year, representing more than 70% of replacement costs. Another reason for the presence of high replacement values is that in smaller settlements larger point-source water utility objects, including water works or wastewater plants are either missing or only available in some, thus their replacement value does not manifest during the 50-year review period either. In cities and larger settlements outlier replacement values are less characteristic, since urban water and wastewater networks were not built in one year and the replacement cost of point-source objects is incurred over multiple years, and in part recurringly.

The negative picture shown above is compounded by the fact that the annual per capita PIT base (income) in small settlements is lower than that of larger settlements. There seem to be surprising correlations between the Total Replacement Value (OPÉ) per real estate per household and the property value of used residential property sold in the given settlements or settlement groups. In the case of smaller settlements (with less than 1000 inhabitants), the replacement value of the water utility infrastructure represents nearly 50% of the market value of the given property, in the case of settlements with less than 100 inhabitants, the ratio is 70%.



The per capita Aggregate Replacement Costs (OPK/capita) indicator, as a dependent variable, was generated using correlation analysis to determine the strength and direction of the relationship between dependent and explanatory variables.

A considerable portion of the potential explanatory variables does not show normal distribution, therefore, in the case of the correlation matrix, I used the Spearman rho value as the basis to present the strength of correlations. I looked at the relationship, extent and direction of potential explanatory variables with the OPK/person, as well as at the strength of correlations with each other of potential independent variables.

The results of the study of variables, the correlation coefficients are shown in the correlation matrix, the relations of which for the OPK/person related principal links are presented below.

My goal is to reveal which explanatory variables are in close relationship with the values of the OPK/person, to ensure that the regression model includes variables that meet statistical and professional considerations.

Explanatory variables (0.7≤rho<1) in a strong positive correlation determine to a significant and determining extent, the per capita Aggregate Replacement Cost (OPK/person) indicator during the lifecycle studied.

There are five explanatory variables in the given Spearman rho value range, and they are related to the OPK/person indicator in the following order by strength):

- Annual depreciation – OÉCSI (HUF/person/year) calculated for the total replacement value established upon asset valuation.

- Total replacement value - OPÉ/person (HUF/person) the cost value per capita excluding VAT established upon asset valuation for the one-off replacement of the water utility system.
- Annual depreciation applicable - OÉCS2 (HUF/person/year) for the replacement value as asset value adjusted by obsolescence.
- Total asset value - OVÉ/person (HUF/person) value per capita excluding VAT adjusted by the obsolescence determined upon asset valuation of the one-off replacement cost of all water utilities.
- Per capita pipeline length (water-wastewater) (rm/person) sum of drinking water and wastewater pipeline length of the given settlement, based on the number of inhabitants, calculated per capita.

Of the variables in a strong relationship, four are indicators stemming from the replacement value established upon the asset valuation of the infrastructure, their different explanatory strength, though, highlights the differences in the expected lifetime (recurring replacement needs during the entire lifecycle) and in the state of obsolescence of infrastructure elements, as well as the differences by settlement, which have a strong influence on the replacement costs incurred during the entire lifecycle.

The only significant, non-value-linked (i.e., replacement value) explanatory factor, with a strong impact on the per capita total replacement costs is the per capita pipeline length, which was present already, in the form of a reference, in the literature review. None of the other factors has a strong explanatory power, either positive or negative.

Explanatory variables ($0.2 \leq rho < 0.7$) in a medium positive correlation again in an order by strength, are the following:

- Per capita replacement cost incurred between 0-15 years - OPK15 (HUF/person/15 years)
- Per capita water-sewerage tariff total (HUF/person/m^3)
- Annual per capita total tariff payment (HUF/person/year)
- The per capita replacement cost incurred between 0-15 years (OPK15) correlates with the Top-heaviness indicator (opk15/opk35) highlighted. As has been shown earlier, although top-heaviness is also seen elsewhere, this indicator tends to be higher in smaller settlements, so coupled with the higher per capita pipeline length characteristic there, it results in in a medium positive relation. Water and sewerage charges per cubic

meter, and the per capita fee payment influenced by water consumption but also related to the tariffs, is higher in smaller settlements.

Explanatory variables (-0.7≤rho<-0.2) in a medium negative correlation again in an order by strength, are the following:

- Number of inhabitants
- Amount of personal income tax base (HUF 1000)
- Number of dwellings connected to the drinking water network, total - 2018
- Number of dwellings connected to the sewerage network (units) - 2018

where the negative direction is due to the higher variables in the larger settlements, and the trend is the reverse in terms of the direction of the OPK/person values, which are higher for smaller settlements.

Explanatory variables (0<rho<0.2) in a weak positive correlation which determine the per capita replacement costs to a lesser extent (weak relation), in an order by strength, are the following:

- Settlement density by county (pcs/100 km^2)
- Average price of used residential property sold (million HUF /property) - 2018
- Volume of water supplied per capita (m^3) - 2018
- Volume of (household) wastewater per capita discharged to public utility sewerage network (m^3) – 2018

Based on the preliminary results, according to my professional opinion and intuition, per capita pipeline length (water-wastewater) (rm/person) is the key independent predictor of the OPK/capita variable, with the single largest influence on its amount.

In the following sections I used linear regression calculation to find the true predictors of OPK/person in order to establish the estimated value and links between the variables and the links determining the replacement value of per capita infrastructure.

By investigating linear regression (key relations defining the value of OPK/capita) I have removed from the analysis potential explanatory variables where the correlation coefficient is 0.3 or less. In cases, where I thought it professionally justified, weak correlation values were also left in the analysis (see consistency index). I have removed two variables from the explanatory variables with a correlation coefficient of ≥0,81 (they cannot be regarded as variables independent from each other).

The strength of the relationship gained in the course of the analysis is 0.967 among the variables examined (square of the correlation coefficient), which proves the high explanatory power of independent variables studied and the predictive capacity of independent variables over dependent variables.

Using the data of settlements within several different size groups, based on the model, I received results within 5-10% accuracy for the per capita total replacement cost values (OPK). At the same time, it must be noted that the wide-ranging application of the model is hindered by the fact that some of the variables used in the model rely upon data generated through the asset valuation, thus it cannot be run without carrying out the asset valuation, important from a number of other perspectives, too. Further simplification of the model, while keeping the predictive capacity, calls for the introduction of the specific unit costs of the object forming the basis of the valuation (pipeline sections, etc.), which could form the subject matter of further analyses and research.

The validation of **Hypothesis No. 5,** on the residential perception of the cost of water supply and on the willingness for social engagement was done by analysing the cluster variables created through the consolidation of the 5000-strong research, “HWA – Water Value – Water in the household, Residential perception of water and waste water supply” and the MIAD asset management data bases.

As for the first statement in the hypothesis, namely that *consumers would be aware of the significant differences in water tariffs according to the size of settlements*, it has clearly been refuted by the survey. While it is quite clear from the examination of the settlements included in the MIAD (Multipurpose Infrastructure Assessment Database, Hungarian abbreviation: TIKA) database that the water tariff per cubic meter is higher (by 20-40%) in settlements with a smaller population, in the household consumer survey, the opposite correlation can be observed: those living in the smallest villages estimated, on average, the lowest water tariffs, while those living in settlements with a population over 1,000 rated the water fees they pay higher.

The second and third statements of the hypothesis, according to which the various social groups *are aware of the significant differences in the cost of municipal water and sewerage services depending on the size of the settlement and feel the need to renew the infrastructure and on the one hand require, on the other hand are willing to provide compensation and offer solidarity and social engagement*” were on the whole substantiated based on the answers given to the questions asked in the 5000-sample The vast majority of respondents, 86%, were in favour of modernization as soon as possible, even with the necessary financial contributions, and 74% of the respondents would support a uniform national water tariff, similar to electricity and gas supply.

At the same time, there were considerable differences among the social groups, in their perception of the questions. Further analysis of the results was all the more justified because, although the targeted questions asked in the residential research suggested additional development costs, as well as the burden for others stemming from the solidarity with the inhabitants of smaller settlements, they were unaware of the extent, especially of the order of magnitude revealed previously.

I used cluster analysis, with the help of cluster variables reflecting the water utility tariff and asset management situation of the individual settlements and settlement groups, as well as the social, economic situation and the willingness and capacity for social engagement of the inhabitants, to study and identify the most homogeneous groups of settlements, in order to be able to offer possible coping strategies for the settlement clusters thus devised.

The purpose of the analysis of the database thus integrated, which will be presented in the next phase, was to be able to set up a segmentation between the settlements, which can help me to more effectively identify the groups of settlements where the financial resources necessary for the replacement and reconstruction of the water utility network can potentially be covered by involving additional resources financed by consumers, and those settlement segments where, even if possible additional charges are expected to meet the disapproval of the population, other potential additional sources can be identified (e.g. higher fees for public institutions), and finally, I can point to those groups of settlements where the situation is really critical, as there is no potential additional source for network development locally.

The need for additional funding sources is underscored by the fact if the current fee payments are considered to be unchanged, 94% of the fee payments would need to be set aside to cover replacement costs in order for the system to be self-financing in the long run.

From this amount that could theoretically be spent on asset replacement, I deducted the value of the need for replacement per capita, and I considered the resulting difference to be a relative surplus, or (unfortunately in the majority of cases) a **deficit**.

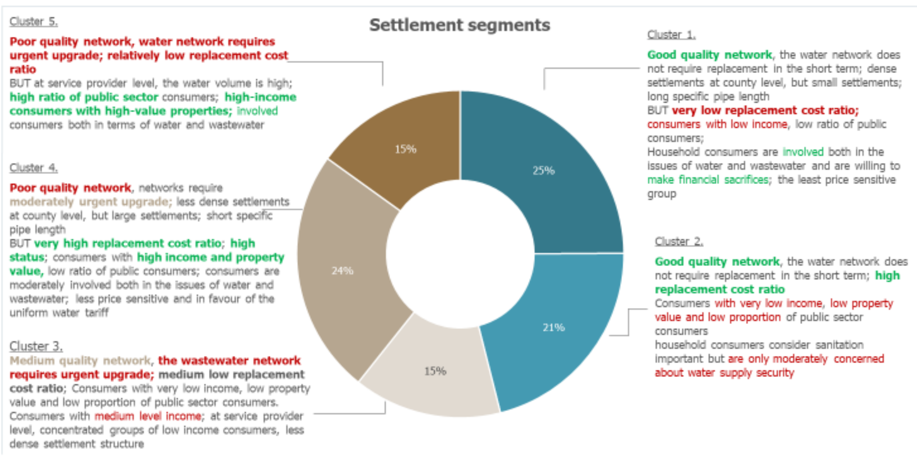
I also prepared the same variable in the form of quotients and absolute values, where I divided the 7.5-80-94% share of the annual per capita fee payment by the annual replacement value per capita. This variable also expresses the extent of the payment deficit compared to the estimated level, but not in absolute HUF value, but in percentage form.

From both continuous variables, I formed a categorical variable that divides the settlements into 5 roughly equal groups, which I categorized as extremely low, low, medium low, medium, relatively high replacement cost share.

I formed also categorical variables from: average quality indicator, “top-heaviness” indicators, per capita drinking water pipe lenght, proportion of consumption in the households-public institutions dimension, county-level settlement density, number of settlements belonging to the service area of a given service provider, number of residents of the settlements, aggregate annual PIT base variable per capita of each settlement, average price of flats sold in the given settlement, status variable input from the household consumer as a variable characterizing the financial situation of people living in a given settlement, cluster segments which describes the attitude related to the security of water supply and sewage disposal, price-sensitivity.

Finally, among the variables input from the household consumer research, **the variable expressing the attitude related to equal burden and the nationally uniform water fee** is included in the cluster analysis, which divides consumers (and thus, indirectly municipalities) into proponents of public burden-bearing and uniform water tariffs, and those generally opposing public burden-bearing and uniform water tariff.

The final result of the clustering was a cluster dividing the settlements into 5 groups. The distribution of the settlement groups was as follows:

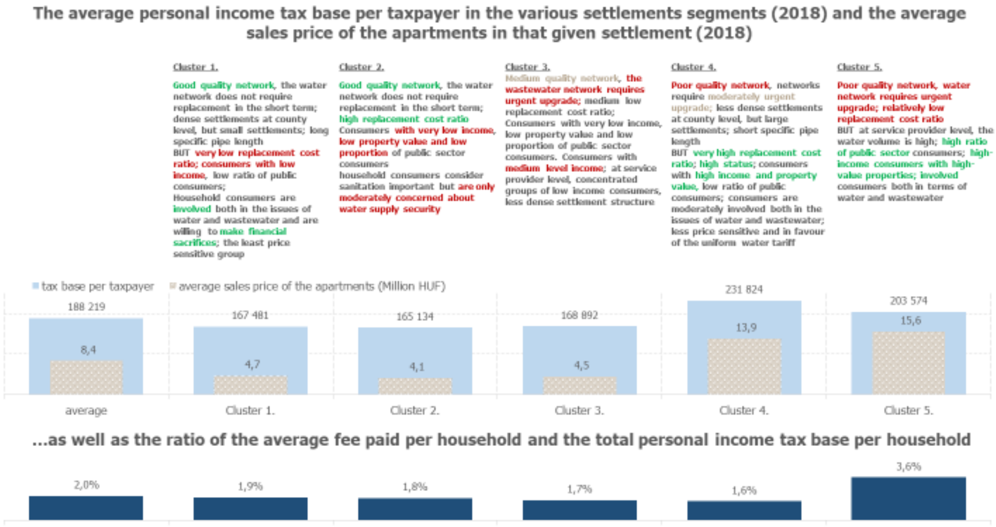


MIAD database after inputting the data of the household consumers online survey, n=710

The above settlement clusters show very strong differences in geographical, regional distribution. The two clusters with good condition networks (1st, 2nd) are strongly over-represented in Northern Hungary, and the 2nd cluster can also be characterized by a medium-level replacement cost share and it can also be found in the Northern Great Plain region. The

settlement segment with a network in medium condition is most typical in the Northern Great Plain and the Southern Great Plain. Settlements with a network in poor condition and requiring relatively urgent modernization are overrepresented in Central Hungary and the Central Transdanubia region. Settlements with poor conditions and in urgent need of renovations of their drinking water networks are located in Transdanubia at an above-average proportion, especially in the Central Transdanubia region.
According to the types of settlements, the two groups with better conditions are small and micro villages, and the settlements with networks in poor condition requiring renovations with moderate urgency (described by a medium top-heaviness indicator) are mainly in towns.

As for the household income situation of the individual settlement clusters, clusters 4 and 5 with the worst infrastructure have the highest income populations.



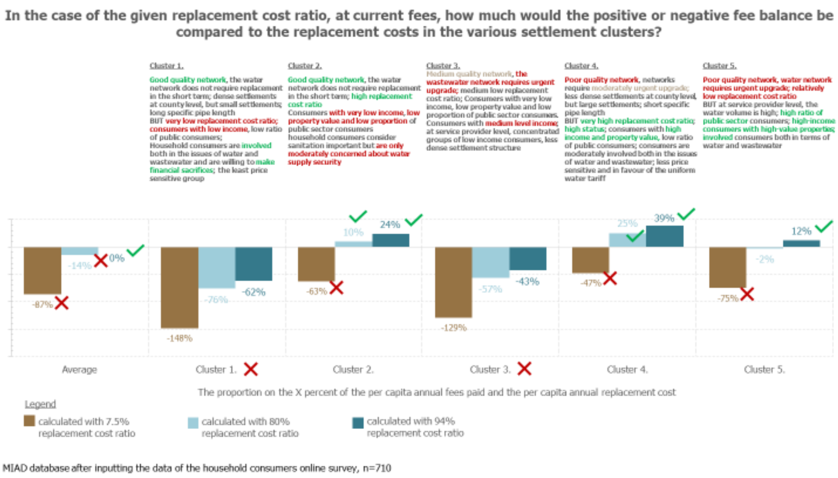
MIAD database after inputting the data of the household consumers online survey, n=710

People living in settlements with an obsolete network with a moderate top heaviness indicator in cluster 4 have by far the highest incomes: the HUF 232,000 personal income tax base per taxpayer exceeds the average value of the sampled settlements by 22%. Consumers living in this settlement are not only considered to have a higher status on the basis of their monthly income, but are also wealthier on the basis of the value of their property. Comparing the water and wastewater tariff payments generated here to the incomes of the local residents, it is obvious that within this group, the ratio of water utility fee compared to the total income of households is the lowest among the 5 settlement clusters. Consequently, if there is room anywhere to raise fees of household consumers, it is in these settlements.

The other settlement segment, where the income of local residents is remarkably high, is settlement cluster 5, where the top-heaviness indicator of the drinking water network within the generally degraded infrastructure is far above average and thus requires urgent modernization, moreover, this is the group of settlements where the current moderately low replacement cost ratio would not provide coverage for network upgrades in the long run. Although, similarly to Cluster 4, the high income of residents would, in principle, allow for higher water charges, on the other hand, comparing the current fee payments to the households incomes, even with the current tariff, this group of settlements pays the highest water and wastewater fees in proportion to income by far. However, what seems to be feasible in these settlements is to incorporate a fee element into the real estate-related taxes to finance the development costs of the water utility network. This can be a tax levied on the sale or inheritance of real estate, it can be a real estate tax, or in the case of real estate (also) operating as a private tourism accommodation, it can even be imposed as part of the tourism tax. As it can be clearly seen that the value of residential real estate in these settlements is far above average, the additional revenue generated, even if it were a negligible annual % fee compared to the value of the property, could represent a significant additional source for service providers or to the owner municipalities or the state responsible for financing the replacements.

An increased tariff is further justified in the latter two settlement segments by the fact that these two segments had the highest proportion of consumers willing to make financial sacrifices in order to modernize the water supply network as soon as possible.

The balance of replacement costs at the level of current fees is shown in the figure below:



The reality of filling the gaps in coverage in all clusters through fees is questionable, even though social research shows that 93% of respondents consider it important for public water supply to provide drinking water quality water. At the same time, we can see that a significant part of the population, 27%, or about 2.5 million Hungarians, do not drink tap water at all. (MASZESZ, 2020b) This astonishing result is supported by a research report on the website of the Blue Planet Climate Protection Foundation, according to which this proportion reaches 47%!, meaning that nearly half of the total population does not hold their glass under the tap, unless it is for washing dishes.

Our total social expenditures on drinking and household water supply are already twice the fees paid for public water services examined in the previous studies. Knowledge of this circumstance provides a double justification for the implementation of the improvements: on the one hand, with the deterioration of the state of infrastructure, alternative expenditures continue to increase, and on the other hand, as conditions improve and consumer confidence and cost awareness increase, current drinking water consumption proportions may change in favour of tap water, also strengthening the safety and sustainability of domestic water supply, which accounts for 97% of citizens water consumption.

V. New findings of the research and potential applications of the results

1. The value of infrastructure replacement costs per capita, which serves as the basis for water utility services, is five times higher in the smallest settlements (HUF 52,871 / person / year) compared to the largest settlements (HUF 9,830 / person / year)
2. The average cost requirement (evenly distributed over time) for the maintenance and replacement of the water utility infrastructure (HUF 21,198 net / person / year) exceeds the current service fee revenues (HUF 22,892 gross / person / year with 27% VAT deducted: HUF 18,025) / person / year) and is almost 10 times higher than the current reconstruction expenditure. This situation is exacerbated by the fact that due to the age composition and technical condition of the water utility infrastructure, the distribution of replacement needs in time shows significant differences (top-heaviness indicator, 2-5 times the average distribution), which means an exceptionally high replacement requirement for drinking water supply systems in the next 15 years, in some settlement groups 40-100,000 HUF / person / year.
3. The time distribution of replacement requirements varies by sector and settlement group, in such a way that in smaller settlements they are more concentrated in time, with higher outstanding values beyond the average (in settlement groups 1-5, 25 times the average and for all Hungarian settlements, for 1,300 settlements, 20 times the average). This outstanding value indicator becomes more balanced in time and can be reduced under the twofold value, and thus become more manageable in fees by merging the

cross-sectoral asset management and the regional management of the municipal asset management (regional consolidation of water utility systems).

4. Infrastructure replacement values are **NOT** reflected in tariffs. Although the service fees of smaller settlements are insignificantly higher than those of larger settlements, this difference is far from covering the replacement needs.
5. People living in small and large settlements realize the need for infrastructure renewal and to 86% they are in favour of their earliest possible modernisation, even if this required a financial contribution from everyone, and although they are not aware of the significant differences in the costs of municipal water and sanitation services depending on the size of the settlement, 74% are ready to compensate for it, to show solidarity and take on social participation.

Based on the above, in accordance with the strategic recommendations submitted by MASZESZ to the sectorial administration (MASZESZ, 2020a) I am making the following general findings and strategic recommendations that can be projected on all of the 3155 settlements:

- In order to fully assess the situation of the infrastructure forming the basis of the water utility service, the water utility property assessments prescribed by the Water Utilities Act (Parliament of Hungary, 2011a) must be performed as soon as possible
- The complete data set must be uploaded to the Integrated Public Utilities Database (IKVA) completed in 2019, and its proper professional operation, data processing, evaluation and maintenance, and ultimately the provision of data underpinning the asset and cost management strategy, must be ensured.
- During the Rolling Development Planning of the infrastructure (15-year long-term planning) the following points must be taken into account
    - a significant decrease in consumption in recent decades (more than 90% at extreme values, and more than 50% on average)
    - the methodological principles for lifecycle cost and variation analysis supporting the cost-effectiveness of asset and fee management (MASZESZ, 2011) (MASZESZ, 2016)
    - a system-level (regionalization, hydraulic modelling (decreasing diameters), water supply management, digital system management) approach to the development (renewal / replacement) of system components in critical condition

    - methodological development of the RDP design with a focus on cost-effectiveness, testing on a sample project if possible
    - the provision of development funds in line with the asset portfolio of HUF 5,000 billion with a replacement ratio of approximately HUF 10,000 billion and an average obsolescence ratio of 50%,
        - average replacement funding requirement is HUF 200 billion / year
        - average value retention funding requirement HUF 100 billion / year
- in order to maintain and develop the service provider's ability to satisfy the growing consumer and environmental protection expectations and needs, taking into account changes in climate, water regime and water quality the following elements need to be provided
    - asset value-based innovation funding insurance
    - knowledge-based human resource management
    - life cycle cost-based decision making
    - horizontal solidarity maintaining small settlements
    - vertical solidarity supporting the next generation
    - strengthening the skills for social participation
        - strengthening water-value communication
        - raising awareness

List of publication

Kovács Károly (Kovács Károly vízgazdálkodás) Water Utility Integration in Hungary: impacts and future expectations SOCIETY AND ECONOMY (1588-9726 1588-970X): 41 4 pp 509-522 (2019)
Kovács Károly (Kovács Károly vízgazdálkodás) A víz értéke, megfizethető-e a tiszta víz? HIDROLÓGIAI KÖZLÖNY (0018-1323): 101. évfolyam különszám pp 67-74 Paper 25374. (2021) Nyelv: Magyar IV. Agrártudományok Osztálya A
Kovács Károly (Kovács Károly vízgazdálkodás) Water Utility Asset Management in Europe Megjelenés: (2020) Kutatásra alapozott webes konferencia összefoglaló Nyelv: Angol
Kovács Károly (Kovács Károly vízgazdálkodás) Viziközművagyon - Gazdálkodás és Fejlesztés VÍZMŰ PANORÁMA: VÍZ- ÉS CSATORNAMŰVEK ORSZÁGOS SZAKMAI SZÖVETSÉGE LAPJA (1217-7032): 2010 5. p. 17. (2010) Nyelv: Magyar

Lisf of references

American Water Works Association (2010) *BURIED NO LONGER :Confronting America's Water Infrastructure Challenge*. Available at: http://www.climateneeds.umd.edu/reports/American-Water-Works.pdf.

Kovács, K. and et al (2010) 'Többszempontú Integrált Közmű Adatbázis (TIKA)'. Budapest: BDL Kft.

MASZESZ (2020) *A vízellátás, szennyvízszolgáltatás lakossági megítélése*. Available at: http://maszesz.hu/tudastar/a-vizellatas-szennyvizszolgaltatas-lakossagi-megitelese.

MO.KORMÁNYA (2017) *NEMZETI VÍZSTRATÉGIA*. Available at: https://www.vizugy.hu/vizstrategia/documents/997966DE-9F6F-4624-91C5-3336153778D9/Nemzeti-Vizstrategia.pdf.

MTA (2018) 'A NEMZETI VÍZTUDOMÁNYI KUTATÁSI PROGRAM KIHÍVÁSAI ÉS FELADATAI', pp. 1–67. Available at: https://mta.hu/data/dokumentumok/Viztudomanyi Program/NVKP_20180331.pdf.

NFM (2013) *24/2013. (V. 29.) NFM rendelet a víziközművek vagyonértékelésének szabályairól és a víziközmű-szolgáltatók által közérdekből közzéteendő adatokról*. Available at: https://net.jogtar.hu/jogszabaly?docid=a1300024.nfm.

Szőlőssy Nagy, A. and et al (2019) *BUDAPEST WATER SUMMIT 2019 SUMMARY*. Available at: https://www.budapestwatersummit.hu/hu/Vilagtalalkozo/Letoltheto_dokumentumok.