sciendo Ovidius University Annals Series: Civil Engineering, Year 26, 2024
DOI: 10.2478/ouacsce-2024-0014

Investments, performance and economic impact in the wastewater sector: correlations and trends in the period 2012-2022

Octavia Moise[1*], George Banghiore[2], Mari-Isabella Stan[3]

1* National Institute for Economic Research "Costin C. Kirițescu" (corresponding author, e-mail: moctavia2005@yahoo.com)
2 National Institute for Economic Research "Costin C. Kirițescu" (e-mail: george.banghiore@gmail.com)
3 Ovidius University of Constanta (e-mail: stanisabella@yahoo.com)

***Abstract* – This study analyses the relationships between investments, network expansion, operational costs, tariffs and environmental compliance in sewage services in Romania, over the period 2012–2022. Using a quantitative methodology based on correlation matrix and principal component analysis (PCA), the research highlights the interdependencies between key indicators. The results show that connected population and tariffs are determinants of economic sustainability, while investments indirectly contribute to improving environmental compliance. The study highlights the need for an integrated strategy that combines financial efficiency, infrastructure modernization and environmental compliance to ensure long-term sustainability.**

Keywords – economic impact, investments, performance, wastewater.

1. INTRODUCTION

Wastewater management is a key area in the current context of sustainable development, with significant implications for environmental quality, population health and economic sustainability. The literature emphasizes that investments in infrastructure and technology in this sector are critical to address the pressures caused by urbanization, population growth and climate change [1]–[3].

The performance of operators in this sector is determined by the level of investment and the efficiency of resource use. References [4], [5] emphasize that the sustainable development of operators in Romania depends on the integration of sustainable strategies into the infrastructure. In a similar approach, several authors [6]–[8] highlight the need to use performance indicators to assess economic efficiency, demonstrating that targeted investments can increase both profitability and sustainability. Also, adopting circular economy principles in the wastewater sector offers opportunities for resource recovery and environmental impact reduction. According to [1]–[3], implementing circular economy in wastewater management brings technological and organizational challenges, but also significant economic and ecological benefits. Similarly, other authors [9], [10] explore the

ISSN 2392-6139 / ISSN-L 1584-599

financial strategies needed to support this model, emphasizing that investments in the circular economy are essential for sustainable development.

From the perspective of infrastructure investments, [11] underline the importance of detailed economic and financial assessments to ensure the profitability of wastewater projects as they affect both investors and wider communities. In this regard, [12] show the importance of using economic instruments in water resources management, while [13] highlight the need to include sustainability considerations in investment decision-making. In this regard, another determining factor is the influence of regulatory policies and institutional capacity on the performance of operators. According to [14], hybrid financing models can support the necessary investments in this sector, while [15], [16] emphasizes the role of legislation and the involvement of local institutions in promoting sustainability, and [17], [18] add that the success of absorbing European funds for infrastructure projects depends on administrative capacity.

Digitalization and the integration of advanced technologies are emerging trends that can redefine the wastewater sector. Reference [19] highlight that digital transformations bring both opportunities and challenges for operators in this sector, underlining the need to adopt resilient financial strategies. Similarly, [20], [21] argue that increasing research and development activities can accelerate the transition to more efficient and sustainable practices.

Therefore, investments in wastewater infrastructure and technologies play a key role in optimizing water reuse and maximizing economic efficiency, thus contributing to sustainable urban development [22]. At the same time, the financial stability and economic performance of water and wastewater operators depend on their ability to integrate sound financial models and assess risks to increase competitiveness and operational efficiency [23]–[25]. Detailed economic evaluations of investments in wastewater treatment plants highlight the need for well-founded strategies to support financial sustainability and reduce operational costs [11].

2. RESEARCH METHODOLOGY

The data used in this study were collected from official reports, financial statements and performance evaluations of sewage service providers. The indicators analyzed include infrastructure investments financed from European funds (Vt), population connected to sewage systems (Pr), volumes of untreated wastewater (Vau), average tariffs (Tsc), total revenues (Vte), operational and maintenance costs (Ct) and penalties for non-compliance with environmental regulations (Cp). These variables were selected for their relevance in assessing economic and environmental performance.

The dataset covers a decade-long period, 2012-2022, which allows for a detailed examination of time trends and the impact of policy changes, investment cycles and operational adjustments.

The main analysis method used was the correlation matrix, which quantifies the strength and direction of relationships between variables. This method is particularly useful for understanding how interconnected factors influence the overall performance of sewerage services. In addition, principal component analysis (PCA) was used to visualize the distribution of annual data according to the main dimensions analyzed. PCA allowed the identification of patterns and clusters in the data, highlighting years with significant improvements or stagnation [26], [27].

The results provide practical insights for policymakers and operators, highlighting areas where investments, policy adjustments or operational changes can support greater sustainability. Furthermore, the proposed methodological framework can be adapted for similar analyses in other infrastructure-intensive sectors, which gives it relevance beyond the specific scope of this study.

3. FINDINGS

This section presents the main results of the analysis, highlighting the relationships between investments from EU funds, economic and operational performance indicators, and trends associated with sustainability and compliance in the wastewater sector over the period 2012-2022 (Table 1).

Table 1 Correlation Matrix[a]

		Vt	**Pr**	**Vau**	**Tsc**	**Vte**	**Ct**	**Cp**
Correlation	Vt	1.000	0.118	-0.047	0.234	0.154	0.211	-0.315
	Pr	0.118	1.000	-0.458	0.836	0.892	0.866	-0.100
	Vau	-0.047	-0.458	1.000	-0.065	-0.306	-0.322	-0.201
	Tsc	0.234	0.836	-0.065	1.000	0.926	0.920	-0.508
	Vte	0.154	0.892	-0.306	0.926	1.000	0.993	-0.235
	Ct	0.211	0.866	-0.322	0.920	0.993	1.000	-0.277
	Cp	-0.315	-0.100	-0.201	-0.508	-0.235	-0.277	1.000
Sig. (1-tailed)	Vt		0.365	0.445	0.244	0.326	0.266	0.173
	Pr	0.365		0.078	0.001	0.000	0.000	0.385
	Vau	0.445	0.078		0.424	0.180	0.167	0.277
	Tsc	0.244	0.001	0.424		0.000	0.000	0.055
	Vte	0.326	0.000	0.180	0.000		0.000	0.243
	Ct	0.266	0.000	0.167	0.000	0.000		0.205
	Cp	0.173	0.385	0.277	0.055	0.243	0.205	

a. Determinant = 1.458E-6

Investments from European funds (Vt) show low or even negative correlations with most variables, suggesting a limited impact on operational and economic results in the short term. The weak positive correlation with the connected population (Pr, r = 0.118) shows that these investments are not necessarily directed towards network expansion, but probably towards the modernization of the existing infrastructure. In addition, the negative correlation with the volume of untreated wastewater (Vau, r = -0.047) could indicate that the financed projects did not have as their main objective the reduction of this volume.

A moderate negative correlation with penalties for non-compliance (Cp, r = -0.315) suggests, however, that investments indirectly contribute to improving compliance with environmental regulations. This can be explained by the modernization of treatment plants or the implementation of new technologies, which reduce the risks associated with non-compliance.

The connected population (Pr) is a major determinant of sustainability, with very strong and significant correlations with total revenues (Vte, r = 0.892) and total costs (Ct, r = 0.866). This indicates that a larger user base generates higher revenues, but also increased costs for operation and maintenance. The growth of the connected population directly

contributes to economic sustainability, but can amplify the pressure on the infrastructure, requiring additional investments to maintain the quality of services.

The high positive relationship between the connected population and the service tariff (Tsc, r = 0.836) suggests that operators adjust tariffs according to the network growth, possibly to cover additional costs. In contrast, the moderate negative correlation with the volume of untreated water (Vau, r = -0.458) shows that network expansion can reduce the amount of untreated water discharged, thus contributing to improving environmental performance.

The average sewerage tariff (Tsc) has a very strong relationship with revenues (Vte, r = 0.926) and total costs (Ct, r = 0.920). This correlation indicates that tariff adjustment is essential to balance revenues and costs, being an important lever for economic sustainability. At the same time, a moderate negative correlation with penalties for non-compliance (Cp, r = -0.508) suggests that additional revenues generated by higher tariffs can be used for investments that reduce exposure to sanctions.

This dynamic highlights the need to establish tariffs that cover both operational costs and those associated with infrastructure improvements, without significantly affecting the accessibility of services for consumers.

Operating revenues (Vte) and operating costs (Ct) show an extremely strong correlation (r = 0.993), suggesting that revenues are almost entirely used to cover costs. This relationship indicates a low profitability margin, which may pose a risk to long-term sustainability. Such a situation underlines the need for cost optimization and diversification of revenue sources, such as accessing additional European funds or expanding services.

Penalties for non-compliance (Cp) are negatively correlated with almost all other indicators. Thus, the moderate negative correlation with tariff (Tsc, r = -0.508) and investment (Vt, r = -0.315) suggests that these two variables play an important role in reducing penalties. Lower penalties may reflect an improvement in infrastructure and better resource management, but the lack of significant correlations indicates that they are also influenced by external factors such as the intensity of controls or legislative changes.

The analysis of the correlation matrix reveals that the economic and operational sustainability of sewerage services is influenced by a complex interaction between investments, tariffs, network expansion and regulatory compliance. The population connected to the sewerage networks proves to be a key factor, as their expansion generates considerable revenues, but also implies significant costs, which require rigorous planning. Tariffs play a central role, being closely linked to revenues and costs. They must be set in such a way as to support both investments and compliance, without becoming a burden on consumers. Investments contribute directly to environmental compliance, reducing penalties and improving environmental performance, although their economic benefits are not always immediately visible. At the same time, the analysis highlights a strong relationship between revenues and costs, suggesting limited room for profit, which emphasizes the need to optimize and streamline operations. These findings highlight that the long-term success of sewerage services depends on implementing an integrated strategy, including sustainable investments, setting fair tariffs and strict compliance with environmental regulations.

The analysis of the dynamics of these indicators can be highlighted by plotting the dynamics of the years included in the study using principal component analysis (Figure 1). The distribution of points in the four quadrants highlights significant differences between the years, depending on the combined influences of the two main factors analyzed.

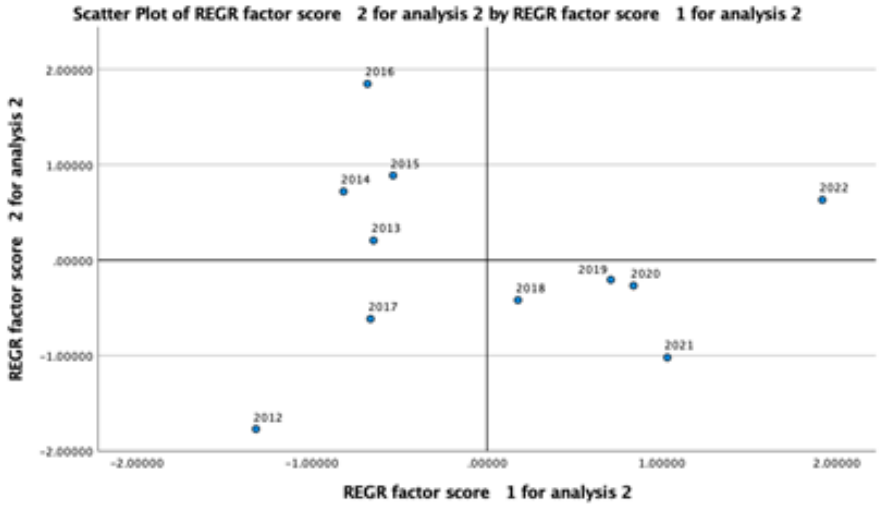

Fig. 1 Using PCA to dynamically visualize the period 2012-2022

In the top right quadrant, the years 2022, 2019 and 2020 are characterized by positive values on both factors, suggesting a combination of strong economic performance and improved environmental or operational compliance. The extreme position of 2022 reflects a peak in overall performance, likely due to recent investments, operational optimizations, or a significant increase in the degree of population connection to the sewerage network. The lower right quadrant groups the years 2018, 2019, and 2021, indicating good economic performance but with little influence from environmental or compliance factors. The low position on the Factor 2 axis suggests that while revenue and cost management was effective, issues related to environmental regulations or investments in environmental infrastructure were not a priority. In particular, the position of 2021 near the origin shows a balanced performance but without significant improvements compared to previous years. On the upper left are the years 2014, 2015, and 2016, which reflect good environmental and operational compliance but lower economic performance. This can be explained by a period of significant investment in ecological infrastructure, which did not generate immediate economic benefits. This type of profile is common in years when infrastructure projects were prioritized but had no immediate impact on revenues. The lower left quadrant, which includes 2012 and 2017, shows negative scores on both factors, indicating poor performance both economically and environmentally. The position of 2012, extremely low on both axes, suggests a difficult starting point, marked by significant infrastructure deficiencies, low revenues, and compliance issues. In contrast, 2017, although closer to the origin, reflects continued operational problems and a lack of major progress compared to previous years.

4. CONCLUSIONS

Correlation matrix analysis provides a detailed insight into the dynamics and relationships between key variables influencing the sustainability of sewerage services. The results suggest significant complexity in the interaction between investments, network expansion, tariffs, operational performance and environmental regulations.

Investments from European funds (Vt) show low correlations with most of the indicators analyzed, indicating a limited impact on economic and operational results in the short term. While the weak positive correlation with the connected population (Pr) suggests that these funds are directed towards the modernization of existing infrastructure rather than network expansion, a moderate negative correlation with penalties for non-compliance (Cp) indicates that the investments have indirectly contributed to improving environmental compliance.

The connected population (Pr) proves to be a critical factor for sustainability, having strong and significant correlations with total revenues (Vte) and operational costs (Ct). This highlights that an expanded user base can generate substantial revenues, but also imposes significant costs for maintenance and operation, emphasizing the need for rigorous planning to maintain economic balance. In addition, the positive relationship between the connected population and tariffs (Tsc) suggests tariff adjustments to cover the increased costs associated with network expansion.

Tariffs play a central role in balancing revenues and costs, and the very strong correlations with financial indicators (Vte and Ct) show that setting appropriate tariffs is essential for economic viability. However, the negative relationship with non-compliance penalties suggests that revenues generated by higher tariffs can be used for infrastructure investments, thus reducing exposure to financial sanctions.

The volume of untreated wastewater (Vau) remains a signal of critical deficiencies in the existing infrastructure. The negative correlations with the connected population and investments reflect that network expansion and infrastructure modernization can significantly contribute to reducing these volumes. However, progress in this direction requires a more consistent prioritization of investments in treatment plants and advanced technologies.

Total revenues (Vte) and operating costs (Ct) are closely correlated, suggesting a very low profitability margin in the sector. This dynamic highlights the need for interventions to optimize costs, diversify revenue sources, and improve operational efficiency.

The distribution of years according to the two main factors analyzed highlights distinct performance patterns. The year 2022 reflects a remarkable overall performance, with positive results from both an economic and environmental perspective, probably due to recent investments and operational optimizations. In contrast, the years 2012 and 2017 are characterized by poor performance across the board, indicating significant challenges in infrastructure and compliance. These differences underline the importance of an integrated strategy, which ensures efficient allocation of resources and enables long-term sustainable development.

In conclusion, the results suggest that the success of sewerage services depends on a balance between investment, cost management, affordable tariffs and compliance with environmental regulations. Such an approach could facilitate the reduction of existing deficiencies and ensure greater economic and operational sustainability in the future.

5. REFERENCES

[1] Ramm K. (2022), *Considerations Related to the Application of the EU Water Reuse Regulation to the Production of Snow from Reclaimed Water*, Circ.Econ.Sust. vol. 2, pp. 569–587. https://doi.org/10.1007/s43615-021-00075-4

[2] Guerra-Rodríguez S., Oulego P., Rodríguez E., Singh D. N., Rodríguez-Chueca J. (2020), *Towards the implementation of circular economy in the wastewater sector: Challenges and opportunities*, Water, vol. 12(5), 1431. https://doi.org/10.3390/w12051431
[3] Faragò M., Damgaard A., Madsen J. A., Andersen J. K., Thornberg D., Andersen M. H., Rygaard M. (2021), *From wastewater treatment to water resource recovery: Environmental and economic impacts of full-scale implementation*, Water Research, vol. 204, 117554. https://doi.org/10.1016/j.watres.2021.117554
[4] Fülöp K. E., Fülöp Á. Z. (2023a), *The relationship between financial results and sustainable development at water and sewage operators in Romania*, Annales Universitatis Apulensis-Series Oeconomica, vol. 25(2), pp. 95-104
[5] Fülöp K. E., Fülöp Á. Z. (2023b), *The performance measurement of water and sewerage operators in Romania through the key performance index*, Journal of Financial Studies, 8(15), pp. 106-118
[6] Bakó K. E., Fulop A. Z. (2017), *Profitability and Efficiency Analysis in Water and Sewerage Sector in Romania*, Annals-Economy Series, 4, pp. 96-102
[7] Bakó K. E., Fülöp A. Z. (2021), *The efficiency equation for water and wastewater operators in Romania*, Annals of the Constantin Brancusi University of Targu-Jiu. Economy Series, nr.1, pp. 168-175
[8] Topor D. I., Anghelache C., Ionescu C. A., Căpușneanu S., Fülöp M. T., Cioca I. C., Rakoș, I. -S., Coman, M. D., Breaz, T. O., Bakó, K. -E. (2022), *Econometric Model for the Financial Performance of Romanian Companies Operating in the Water Supply and Sewerage Field*, Water, vol. 14(12), 1929. https://doi.org/10.3390/w14121929
[9] Munteanu I., Ionescu-Feleagă L., Ionescu B. Ș. (2024), *Financial Strategies for Sustainability: Examining the Circular Economy Perspective*, Sustainability, vol. 16(20), 8942. https://doi.org/10.3390/su16208942
[10] Micu A., Aivaz K., Capatina A. (2013), *Implications of logistic service quality on the satisfaction level and retention rate of an e-commerce retailer's customers*, Economic Computation & Economic Cybernetics Studies & Research, vol. 47(2), pp. 147-155
[11] Ćetković J., Knežević M., Lakić S., Žarković M., Vujadinović R., Živković A., Cvijović J. (2022), *Financial and Economic Investment Evaluation of Wastewater Treatment Plant*, Water, vol. 14(1), 122. https://doi.org/10.3390/w14010122
[12] Platon V., Frone S., Constantinescu A., Jurist S., Banghiore G., Moise O. (2024), *Main Trends on Using Economic Instruments for Management of Water Resources in Romania*. In: Chivu, L., Ioan-Franc, V., Georgescu, G., De Los Ríos Carmenado, I., Andrei, J.V. (eds) Europe in the New World Economy: Opportunities and Challenges. ESPERA 2023. Springer Proceedings in Business and Economics. Springer, Cham. https://doi.org/10.1007/978-3-031-71329-3_41
[13] Ashley R., Blackwood D., Butler D., Jowitt P., Davies J., Smith H., Gilmour D., Oltean-Dumbrava C. (2008), *Making asset investment decisions for wastewater systems that include sustainability*, Journal of Environmental Engineering, vol. 134(3), 200-209. https://doi.org/10.1061/(ASCE)0733-9372(2008)134:3(200)
[14] Machete I., Marques R. (2021), *Financing the Water and Sanitation Sectors: A Hybrid Literature Review*, Infrastructures, vol. 6(1), 9. https://doi.org/10.3390/infrastructures6010009
[15] Brașoveanu F. (2023a), *The Impact of Regional Development on the Environment*, Ovidius University Annals, Economic Sciences Series, vol. 23(1), pp. 42-49
[16] Brașoveanu, F. (2023b), *The Role of Legislation and Legal Institutions in Promoting Sustainable Development at the Regional Level*, Ovidius University Annals, Economic Sciences Series, vol. 23(1), pp. 50-57

[17] Stan M. I., Tasențe T. (2023), *Evaluating the Implementation of Administrative Capacity Enhancement Projects in Romania: The Multidimensional Role of POCA* (2014-2020), Annals of the University Dunarea de Jos of Galati: Fascicle: I, Economics & Applied Informatics, vol. 29(2), pp. 171-180, https://doi.org/10.35219/eai15840409352.
[18] Stan M.-I., Cojocaru S.-E. (2022), *An analysis of the absorption rate of EU funded social projects at macro-regional level*, Technium Social Sciences Journal, vol. 36(1), pp. 466–479. https://doi.org/10.47577/tssj.v36i1.7551
[19] Munteanu I., Aivaz K. A., Micu A., Căpățână A., Jakubowicz F. V. (2023), *Digital transformations imprint financial challenges: accounting assessment of crypto assets and building resilience in emerging innovative businesses*, Economic Computation & Economic Cybernetics Studies & Research, 57(3), pp. 203-220
[20] Rus M. I., (2018), *Financing of Research Activity from Private vs. Governmental in Romania*, Ovidius University Annals, Economic Sciences Series, vol. 18(1), pp. 505-509.
[21] Rus M. I., (2023), *The Impact of Sustainability in Research-Development-Innovation* Activity, Ovidius University Annals, Series Economic Sciences, vol. 23(1), pp. 1053-1058
[22] Bauer S., Linke H. J., Wagner M. (2020), *Optimizing water-reuse and increasing water-saving potentials by linking treated industrial and municipal wastewater for a sustainable urban development*, Water Science and Technology, 81(9), pp. 1927-1940. https://doi.org/10.2166/wst.2020.257
[23] Bakó K. E., Fulop A. Z., Stanciu A. (2021), *Economic and financial stability for water and wastewater operators in Romania*, The Annals of the University of Oradea. Economic Sciences, vol. 30(2nd), pp. 19-25
[24] Stroie C., Duțescu A., Munteanu I. F., Aivaz K. A. (2023), *The reorganisation decision test: A risk analysis model to increase competitiveness.* Journal of Competitiveness, 15(2), pp. 70-87
[25] Aivaz K. A., Munteanu I., Rus M. I., Chiriac (Matei) A., Leta (Mihai) F. (2023), *Clarifying the Impact of Sanctions on Financial Indicators in Transports. An Empirical Comparative Analysis Using the Discriminant Model*, Transformations in Business & Economics, vol. 22, No 3A (60A), pp. *933-953*
[26] Mirea M., Aivaz K. A. (2016), Analyzing "the workforce cost" and "the net nominal earnings" in the main economic activities, by principal component analysis, In BASIQ International Conference: New Trends in Sustainable Business and Consumption, (vol. 2457, pp. 201-209)
[27] Vancea D.P.C., Aivaz K.A., Simion L., Vanghele D. (2021), *Export Expansion Policies. An Analysis of Romanian Exports Between 2005- 2020 Using the Principal Component Analysis Method and Short Recommandations for Increasing this Activity*, Transformations in Business & Economics, vol. 20, No 2A (53A), pp.614-634