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Managing water consumption per capita using performance indicators: a case study

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ABSTRACT

Water scarcity represents a significant challenge in Jordan, exacerbated by increasing domestic, industrial, and agricultural water demands amidst the backdrop of limited available water resources. The current study utilized water consumption per capita per day (PCD) as a productivity measure that aligns with the goals of water utilities to provide safe and enough water to customers. It identified and explained the critical performance indicators (PIs) affecting PCD. The study was conducted based on the time series secondary data of the applied PIs collected from Jordan Water Company (Miyahuna) between 2009 and 2018. To identify the PIs most strongly associated with the PCD variable, a correlation analysis was performed using IBM SPSS Statistics software. Indicators showing significant correlation with the PCD underwent further analysis as potential independent variables. Non-revenue water and water resources use per capita indicators showed pivotal and significant effects on PCD, exhibiting negative and positive impacts, respectively. In pursuit of improved indicators' performance, this research advocates for the implementation of Active Leakage Control methods, the adoption of innovative techniques to desalinate brackish water, the promotion of water harvesting initiatives, enhanced employee training, and the enforcement of more stringent policies to tackle water theft.

Keywords: Performance indicators (PIs); Water consumption per capita; PCD; Water management; Jordan; Water scarcity

1. Introduction

Jordan, located in one of the driest regions in the Middle East, is classified as one of the most water-scarce countries globally and faces significant challenges due to its scarcity of natural resources [1,2]. As of the end of 2019, the United Nations High Commissioner for Refugees (UNHCR) recorded a total of 744,795 registered refugees in Jordan [3]. These refugees reside in Jordan alongside the local population. The provision of clean water to the population has been a formidable challenge, exacerbated by the presence of this substantial refugee population, given the limited availability of natural water resources. Jordan relies on three major sources of water; treated wastewater constituting approximately 14% of its water resources and primarily used for agricultural and industrial purposes; surface water, accounting for approximately 27% of its water resources; and groundwater, making up the remaining 59%. It is noteworthy that Jordan shares approximately 40% of its water resources with neighboring countries, Palestine, Israel and Syria [1,2].

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Jordan is actively engaged in enhancing its water supply services, with the measurement of performance indicators (PIs) being an integral part of these efforts. In the water supply services field, water consumption per capita per day, hereinafter referred to as per capita daily (PCD), is one of the key performance indicators (KPIs). PCD quantifies the volume of water delivered (and sold) to household consumers.

According to the article "The Human Right to Water and Sanitation" published in 2010 by the United Nations (UN), the World Health Organization (WHO) has established general guidelines regarding the amount of water needed to guarantee the most basic needs are met and mitigate health concerns. The global standard identified falls within the range of 50 and 100 liters per capita per day (L/cap/d) [4]. In the case of Jordan, the PCD is approximately 73 L/cap/d and taking non-Jordanian consumers into consideration results in the value being decreased to about 59 L/cap/d [5]. Notwithstanding these values' compliance within the general WHO guidelines [6] for the daily consumption per person, this amount is certainly very low. In fact, Jordan has one of the lowest PCD levels in the entire world [7]. The average amount of water consumption has been studied by utilizing various techniques such as surveys, metering data, and others. The results have shown significant variation in the PCD values, ranging from 93 L/cap/d [8] to 430 L/cap/d [9]. It is important to note that these values are country-specific and are determined based on the lifestyle and water usage patterns within each respective country. Crouch et al. [10], on the other hand, have established 92 L/cap/d as the absolute minimum daily requirement for maintaining a healthy urban lifestyle. This value can be considered more universal, as it is based on the individual's basic requirements rather than household consumption. Notably, this minimum requirement falls within the range recommended by the WHO, which suggests a daily range of 50 to 100 L/cap/d.

This study aims to provide an overview of Jordan's water consumption per capita per day and how it has been affected by the PIs that the Ministry of Water and Irrigation (MWI) employs to gauge water companies' performance. First, Jordan Water Company (Miyahuna) PIs will be analyzed and evaluated to determine which indicators have the most significant impact on PCD. The relationship between the various PIs and the productivity measure, PCD, will then be examined, and after that, some general suggestions and resolutions will be provided to enhance Miyahuna's performance. These recommendations aim to improve the efficiency and effectiveness of water supply services in Jordan in general.

2. Literature review

The contemporary global landscape places immense pressure on the water industry, presenting a series of formidable challenges. These challenges encompass a wide range of issues, including the ability to meet the ever-increasing demands of a growing global population, enhancing the quality of service, and ensuing the sustainable management of both new and existing water services [11,12]. In addressing these challenges, Performance Measurement Systems (PMSs) assume a pivotal role. These systems provide continuous motivation to improve service quality, enhance the efficiency and effectiveness of the water supply operations, and tackle the multifaceted challenges faced by the water sector [13–15]. Alegre et al. [15], for instance, propose that assessing the performance of water supply services represents one of the most effective approaches to overcoming significant obstacles and challenges encountered in the water sector. One key advantage lies in the acquisition of comprehensive data, extending beyond mere ratio values, to inform concrete decision-making. Modern PMSs also prioritize the inclusion of all stakeholders, the consideration of areas of concern, and the evaluation of aspects with the most profound impacts within a particular environmental context [13,16].

The International Water Association (IWA) is committed to developing programs to find comprehensive solutions for both water and wastewater management. In pursuit of this mission, the IWA has created a set of PIs designed to facilitate the efficient management of water utilities. The developed system encompasses a broad range of factors, including stakeholders, users, overall company operations, environmental considerations, and every other essential aspect for efficient management [17]. KPIs are considered as an invaluable tool for top management and employees, as it assists them in understanding the significance of their work and the outcomes they strive to achieve. Corporate management can select or predefine these KPIs based on their alignment with specific utility objectives and their effectiveness in achieving them. PIs encompass a range of physical values used to measure, compare, and manage an organization's performance across diverse dimensions, encompassing quality, finance, human resources, customer satisfaction, cost efficiency, quality of service, and more [14,17–20]. Marques and Monteiro [21] categorized PIs used to evaluate water utilities' performance into structural, operational, personnel-related, quality of water and services, and economic indicators. They also integrated these indicators to a hierarchy system with three levels: basic, development and strategic. Alternatively, the Program Monitoring Unit (PMU) in the MWI adopted a three-tier structure for PIs, with KPIs exclusively featured in Level 1, while Levels 2 and 3 contain PIs. This arrangement allows for both cross-sectional and vertical analyses, with PCD being one of the KPIs in this context [22]. This structured approach to PIs and KPIs helps water utilities comprehensively evaluate and enhance their performance, ensuring effective water and wastewater management in an ever-evolving landscape.

PIs assess how efficiently and effectively services are being delivered by an organization by combining several factors. They provide information by comparing the values over time within the same organization or benchmarking them against other organizations [17].

Based on an analysis of 232 various variables that require regular monitoring and examination, a comprehensive list of 170 PIs specific to water supply has been developed and identified. These indicators are grouped into six primary categories, each covering a distinct aspect of the water supply system: economic and financial, water resources, physical, quality of service, personnel, and operational. Each of these primary categories is further divided into subcategories, and, in some cases, these subcategories can be further segmented into smaller groups for a more granular assessment.

The development of these indicators by the IWA was carried out in a multidisciplinary manner. Notably, the IWA deliberately opted for a broad and general approach, without specifically addressing particular conditions or implementation-related challenges. The primary assumption behind this approach is that these indicators were thoughtfully selected to be as versatile as possible, ensuring their suitability for application in diverse situations.

The founders of this system also elaborated that it represents general guidance, and each enterprise's responsibility is to outline the indicators' applicability and importance to them [23]. They further explained that any subgroup might be selected easily, depending on the demands and goals of the utility. Furthermore, if users find that the existing indicators lack the necessary level of detail, they have the option to introduce their own custom indicators or further subdivide the existing ones into more specific subcategories.

3. Case study

Jordan Water Company (Miyahuna) is a limited liability enterprise established in 2007 under the Company Law of Jordan. Its primary responsibility is to provide water and wastewater services to Amman, the capital, along with two other cities, Madaba and Al-Zarqa. Miyahuna delivers the water and wastewater needs to more than five million people residing in the Greater Amman, Zarqa, and Madaba governorates. This substantial service coverage represents approximately half of Jordan's total population, which stands at around 11.3 million.

Water Authority of Jordan (WAJ) completely owns Miyahuna [24], which is led by a CEO chosen by the Board of Directors. WAJ's main responsibilities are the public water supply, wastewater services, overall water resources planning and monitoring, as well as the construction, operation and maintenance [25].

The Jordanian MWI mandates that Miyahuna employs PIs, which are subsequently used by the ministry to assess and monitor the performance of water companies in Jordan.

Miyahuna applies some of the IWA PIs; 27 different PIs in total are used, which are distributed over three levels. The first and most important level consists of ten indicators measuring the enterprise's performance in attaining the strategic goals of the MWI, in addition to give indications of the enterprise's stability to the various stakeholders. The second and third levels PIs are used to evaluate the yearly performance of Jordan Water Company [5]. The employed PIs by Miyahuna are summarized in Table 1.

4. Research methodology

The current research aims to build a model that correlates the most significant PIs with the dependent factor, PCD, to facilitate a better understanding and explanation of how the PCD factor varies with those indicators. PCD is the primary dependent variable in this study, representing the daily water consumption per capita. The data for this research are secondary and have been gathered from Miyahuna company. The dataset comprises quarterly time series data for all used PIs between 2009 and the first half of 2018.

To identify the indicators most strongly associated with the PCD variable, we conducted a correlation analysis using IBM SPSS Statistics software. This analysis examined the relationships between PCD and all other PIs employed by Miyahuna. The indicators demonstrating the highest correlation with the PCD variable were selected for further analysis as potential independent variables in our model.

Finally, suggestions were made for improving the performance of the PIs that exhibit significant effects on PCD. These recommendations will be grounded in the statistical findings from our analysis. Fig. 1 provides an illustrative representation of our research methodology.

Table 1
Applied performance indicators by Miyahuna [5]

Level 1	Levels 2 & 3	
Water consumption per capita per day	Ind 10: Inefficiency of use of water resources	Ind 19: Water service connection repair rate
Ind 1: Operating cost coverage ratio	Ind 11: Water resource use per capita/system input per day	Ind 20: Speed of repair of bursts
Ind 2: Microbiological water quality compliance	Ind 12: Water quality tests performed	Ind 21: Subscriber meter replacement
Ind 3: Water loss per water service connection	Ind 13: Quality of supplied water	Ind 22: Water losses/km
Ind 4: Non-revenue water by volume	Ind 14: Physical-chemical water quality compliance	Ind 23: Energy cost ratio
Ind 5: Collection ratio	Ind 15: Water quality complaints	Ind 24: Average unit energy consumption
Ind 6: Subscribers receiving continuous supply	Ind 16: Continuity of supply (supply index)	Ind 25: Employees per water service connection
Ind 7: Non-billing (service) complaints	Ind 17: Total new connections efficiency	Ind 26: Training per employee
Ind 8: Billing complaints	Ind 18: Network repair rate	
Ind 9: Total employees per 1,000 subscribers		

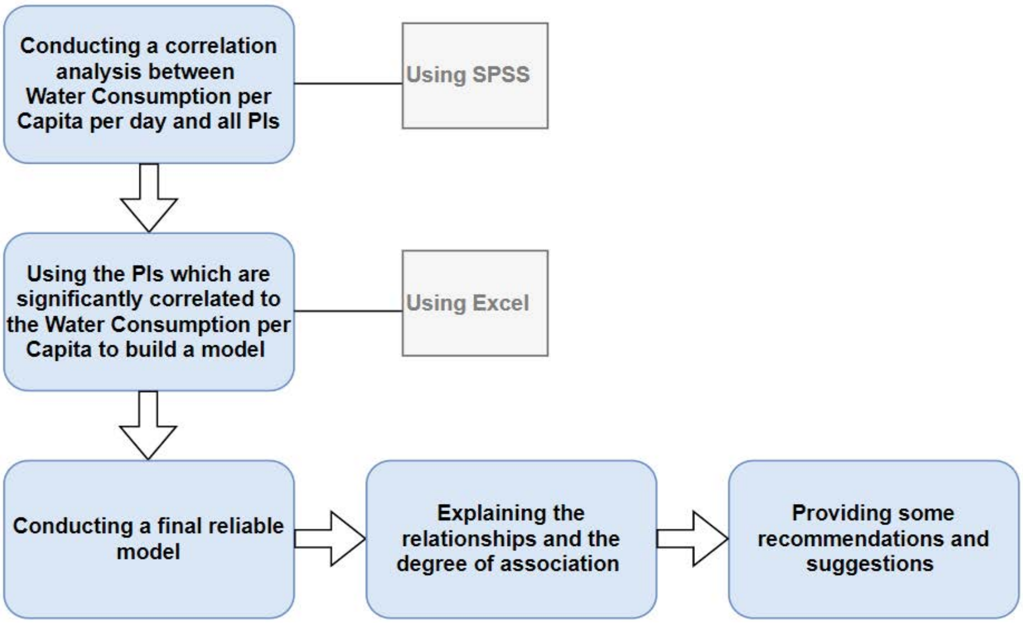

Fig. 1. Research methodology (Authors' own development, 2022).

5. Data analysis and results

The primary objective of this paper is to explore the relationship between a key productivity measure, PCD, and the PIs used by Miyahuna. It is worth noting that measuring productivity in the service sector is often more complex than in the manufacturing sector [26]. Recognizing this challenge, Hersey and Blanchard [27] suggested that, in the service sector, the effectiveness of a company might be a more suitable productivity metric than traditional productivity measures. They argued that effectiveness should be tailored to the company's specific objectives and aims, allowing each organization to define unique productivity aligned with its mission. In the case of the Jordan Water Sector, the MWI seeks to enhance both the financial sustainability and the quality of services provided. Accordingly, two productivity terms were identified to serve the MWI's aims; operating cost coverage ratio as an effectiveness measure to enhance financial sustainability ([28]), and the focus of this paper, PCD, to serve as an effectiveness measure to improve the quality of service provided.

With this context in mind, the following sections will delve into the analysis and results, examining the relationship between PCD and the various PIs employed by Miyahuna. This analysis will shed light on how specific PIs impact PCD, providing valuable insights into the effectiveness of the water supply services in Jordan.

5.1. Overview of water consumption in Jordan

To track water consumption in Jordan between 2009–2018, Box–Plot and Tukey tests were used.

Considering the low billing efficiency in 2010, the high-water consumption per capita per day in 2011 can, therefore, be attributed to the billing of water quantities consumed in 2010. Further, the billing efficiency was high in 2011, which has reflected positively on the PCD. Year 2012 witnessed a decline in water consumption per capita per day due to billing inefficiency and the increased refugee influx escaping the Syrian Civil War. In addition, the significant increase in PCD during 2013 compared to 2012 was primarily due to the integration of the Disi Project into the water resource network in the middle of that year.

Fig. 2 also shows improvement in the water consumption per capita per day from 2009–2011, mainly due to the successive reduction in the non-revenue water (NRW) in those years, which decreased from 35% to 32%. On the other hand, it shows insignificant variation in the PCD for the years 2013–2017. This could be attributed to the increased water supply to the greater Amman area after the Disi water supply project became operational rather than a decline in water losses, which on the contrary witnessed a successive increase in those years. These findings demonstrate the ineffectiveness and inadequacy of the methods employed and the efforts exerted to reduce water losses. It is clear that Miyahuna must adopt best practices and utilize advanced technologies to reduce losses, such as Active Leak Control Methods, better management of network pressures, employing GIS in network maintenance, etc.

Seasonal effects on the volume of water supplies are critical to water services provision. Typically, water demands are lower in quarters 1 and 2 of the year than in quarters 3 and 4; Q1 and Q2 exhibit cooler temperatures. The quarterly domestic consumption reveals this, with the lowest value being in Q1 followed by increases in Q2 and Q3 (the highest value), and then decreases in Q4. Conversely, the NRW is typically lower in Q3 and Q4 compared to Q1 and Q2. In this context, results showed a significant difference ($p < 0.05$) between the PCD values through different seasons of the year in the period between 2009 and 2018 (Fig. 3). For instance, significant differences were captured between Q1-Q3 ($p < 0.05$), Q1-Q4 ($p < 0.05$), Q2-Q3 ($p < 0.05$), and Q2-Q4

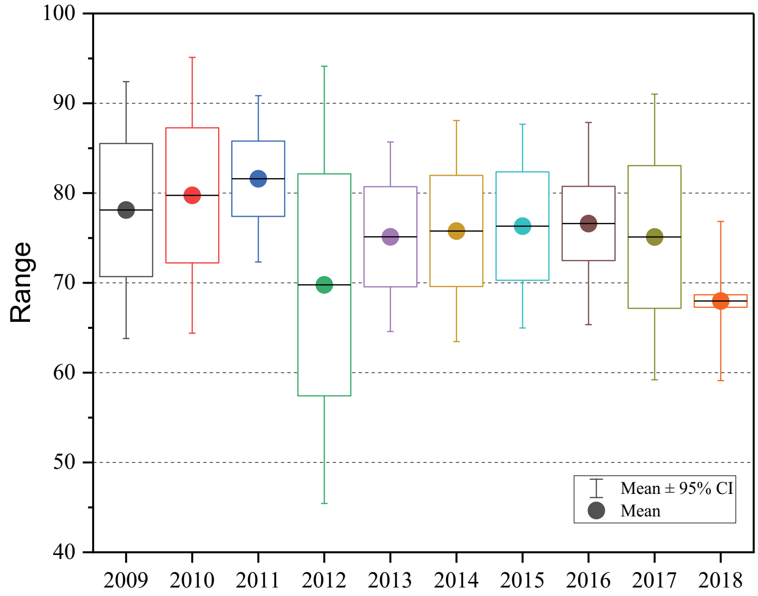

Fig. 2. Box–plot analysis for the PCD mean in the period between 2009–2018 (Authors' own development, 2023).

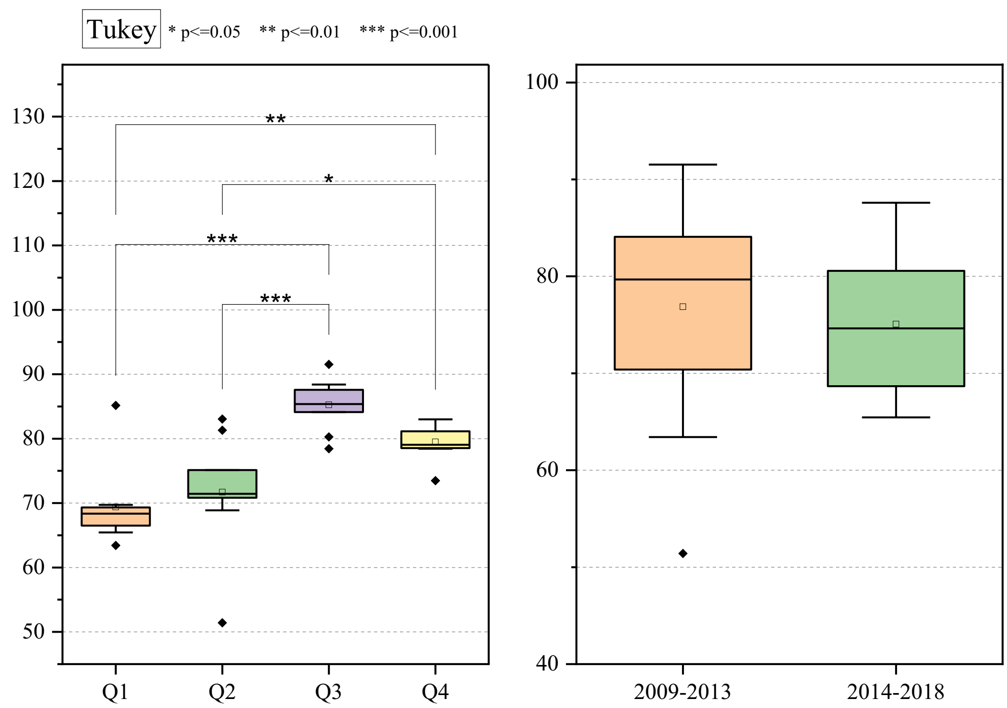

Fig. 3. Tukey analysis (Authors' own development, 2023).

($p < 0.05$). On the other hand, no significant differences were captured between Q1-Q2 and Q3-Q4, reflecting the seasonal effect of PCD in Jordan. Interestingly, the Tukey analysis did not capture any differences in PCD between (2009–2013) and (2014–2018) (Fig. 3). These insignificant differences observed at the annual levels can primarily be attributed to the consistent values of water resource utilization per capita.

Furthermore, as Miyahuna has an intermittent water supply, in Q1 and Q2, the network becomes increasingly pressurized while demand is low, which may lead to increased leaks. Fig. 3 shows how the preceding factors collectively caused the PCD variation and the daily water consumption per capita in Q1, which has decreased.

5.2. Principal component analysis

Principal component analysis (PCA) is a powerful statistical technique that is used to summarize complex data by reducing a collection of indicators into a smaller set of components that decrease data dimensionality while capturing the most important variation [29]. PCA was employed in this study to summarize this complex data set which composed of a total of 26 PIs in addition to the PCD. In our analysis, almost 77.62% of the data's total variance was maintained by using the first five principal components, which allows for a considerable reduction in dimensionality while maintaining important data. The results of the PCA are depicted in Fig. 4. In this context, the first principal component (PC1) accounted for 25.22% of the total variance. Indicators such as 3, 10, 11, and 22 have a high positive contribution on the PC1. This component could be interpreted as a measure that increases as these variables increase. On the contrary, indicators like 9 and 25 have a high negative contribution on the same PC, indicating that the measure increases, as these variables decrease. On the other hand, the second principal component (PC2), which accounted for 19.5% of the total variance, is significantly influenced by indicators 6, 19, 20, and 24. Interestingly, variables 20 and 24 have a high positive contribution on the PC2, while indicators 6 and 19 have a negative contribution. These interpretations contribute to the comprehension of the underlying patterns and relationships within the dataset by offering useful insights into how the major components are created and which variables have the greatest impact on them.

5.3. Correlation and regression analysis of PCD

Correlation analysis was conducted to examine the impact of each PI on PCD. The results of the correlation analysis reveal that PCD exhibits a significant correlation with the following indicators shown in Table 2. The results of the correlation analysis are shown in Table 3.

These seven PIs were utilized to construct a regression model aimed at elucidating the nature of the relationships between these indicators and the PCD.

From the indicators listed in Table 2, several attempts were performed to reach the following final model of the PCD presented herein. The model is presumed to be a multiple exponential one, best described by the general Eq. (1):

$$\text{Water consumption per capita per day}\left(\text{PCD}\right) = \beta_0 \cdot \beta_1^{X_1} \cdot \beta_2^{X_2} \cdot u \quad (1)$$

The developed model exhibits a remarkable adjusted *R*-squared value of 0.83, signifying that it effectively explains a substantial portion of the variance observed in PCD. Furthermore, the model boasts a notably low standard error of 0.021, indicating precise estimations. The results of the PCD regression analysis are summarized in Table 4. Notably, all indicators in the model have achieved statistical significance at 95% confidence interval, as illustrated in Table 4, affirming their importance in explaining PCD.

5.4. Results, discussion, and recommendations

Based on the analysis results, the relationship between PCD and the significant indicators is represented by Eq. (2):

$$Y = 61.32177 \times 0.980194^{X_1} \times 1.005994^{X_2} \quad (2)$$

where Y: PCD; X_1: NRW by volume (% of system input); X_2: Water resource use per capita per day (L/cap/d).

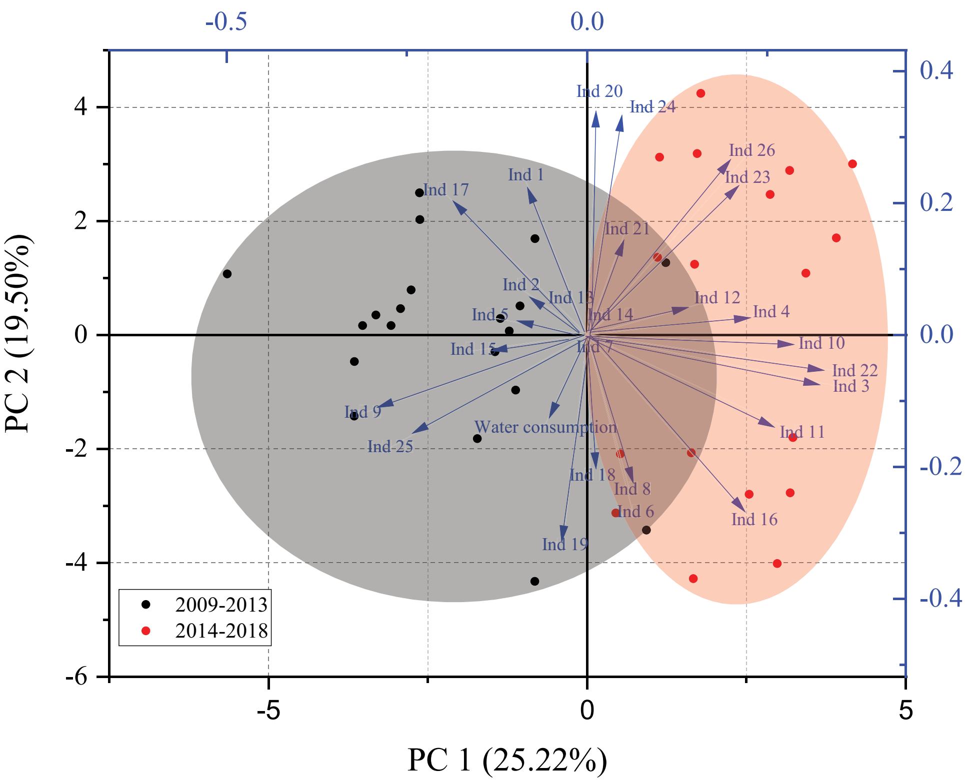

Fig. 4. Principal component analysis components plot (Authors' own development, 2023).

Table 2
Performance indicators exhibiting significant correlation with PCD variable

Ind 4	Non-revenue water: "the difference between System Input Volume and Billed Authorized Consumption" [30]. And it consists of real and apparent losses.
Ind 5	Collection ratio: a measurement of the cash flow [5].
Ind 7	Non-billing complaints: the service complaints as a percentage of the total number of registered subscribers [5].
Ind 8	Billing complaints: the percentage of the billing complaints of the total number of registered subscribers [5].
Ind 10	Inefficiency of use of water resources (100%): "the percentage of "System Input Volume" lost through leakage and other forms of real losses" [17].
Ind 11	Water resource use per capita/system input per day: the amount of water resource available per capita per day [5].
Ind 19	Water service connection repair rate: the rate at which maintenance and repairs are needed on the water connections.

Table 3
Correlation coefficients between PCD and performance indicators (Authors' own calculation, 2022)

	PCD	Ind 4	Ind 5	Ind 7	Ind 8	Ind 10	Ind 11	Ind 19
PCD	1							
Ind 4	–0.57**	1						
Ind 5	–0.442**	–0.092	1					
Ind 7	0.366*	0.235	–0.477**	1				
Ind 8	0.54**	–0.344*	–0.147	–0.14	1			
Ind 10	–0.53**	0.928**	–0.105	0.065	–0.161	1		
Ind 11	0.372*	0.446**	–0.546**	0.388*	0.314	0.574**	1	
Ind 19	0.446**	–0.057	–0.018	0.239	0.255	–0.053	0.377*	1

**Corresponding variable is significant at 1% level (2-tailed);
*Corresponding variable is significant at 5% level (2-tailed).

Table 4
Summary of PCD regression analysis (Authors' own calculation, 2022)

	Coefficients (β)	Standard error	*t* Stat	*P*-value	Lower 95%	Upper 95%
Intercept	1.787615	0.036157	49.4408	5.62E-34	1.7142	1.861
NRW	–0.00869	0.000706	–12.3067	2.85E-14	–0.0101	–0.0073
Water resource use per capita per day	0.002595	0.000254	10.21072	4.9E-12	0.0021	0.0031

Table 5
Elasticity index results and interpretation (Authors' own calculation, 2022)

Indicator	Indicator 1	Indicator 2
$\varepsilon_{xi,y}$	–0.83%	0.96%
Interpretation	A 1% increase in the latest value of NRW results in a 0.83% decrease in PCD.	A 1% increase in the latest value of daily per capita water resource use results in a 0.96% increase in PCD.

The model reveals that the PCD has a negative relationship with NRW by volume and a positive relationship with the per capita daily water resource use. In other words, as NRW by volume increases, PCD tends to decrease, while an increase in per capita daily water resource use is associated with an increase in PCD.

The magnitude of the impact of each PI on PCD can be explained using the elasticity index (ε), presented in Eq. (3):

$$\varepsilon_{xi,y} = X_{if} \ln \beta_i \quad (3)$$

where $\varepsilon_{xi,y}$: is the *i*-th variable (X_i) elasticity of the dependent variable (Y); X_{if}: the latest measured value of the independent variable (X_i); β_i: the parameter of the *i*-th independent variable.

The elasticity index indicates the percentage variation in the dependent variable when the independent variable experiences a one percent change from its given value. Table 5 summarizes the elasticity index results.

Those two indicators have a major impact on the PCD productivity term of Miyahuna. Thus, improving these indicators has a significant impact on improving the company's productivity. We recommend a couple of suggestions and preventative practices to be followed.

5.4.1. Non-revenue water

The efforts towards decreasing the NRW amounts should be intensified significantly. Furthermore, it must include limiting both losses, real and apparent. Of the most popular and common resolutions, we suggest the following: rehabilitating the water networks and improving the response time in case of any water connection failure. Furthermore, applying any of these methods/techniques:

- ***Pressure management technique***: it is a standard strategy to minimize water losses, it revolves around the concept of regulating and optimizing hydraulic pressure levels in the water distribution systems [31].
- ***Supervisory Control and Data Acquisition (SCADA)***: it is used in water distribution systems to provide real-time monitoring and control; it provides the necessary data to facilitate the immediate response need [32].
- ***Smart Water Grid***: it is considered as an advanced technique in managing water systems as it assists overcoming critical water problems. It works by integrating multiple data sources and communication technology into the water distribution system that helps optimizing the amount and quality of supplied water and reducing risks [33].
- ***Advanced Metering Infrastructure (AMI)***: it is a preferable method for a more accurate way to measure water consumption, it provides two-way communication, and it assists in leak detection and more efficient billing. Furthermore, it is an important part of smart water grids [34].
- ***Automated Meter Reading (AMR)***: similar to AMI however, less effective. It is a technological advancement that aids in solving the issues of the traditional (manual) meter reading [35].
- ***Active Leakage Control (ALC) methods***: very effective methods that are used as a proactive way to detect, locate, and control water leakage, specifically unreported leaks. Therefore, reducing water losses [36].

These methods are effective as they monitor, detect, and diagnose any problem occurring in the water distribution systems and their infrastructure continuously. Thus, reducing the NRW, as detecting any water leaks is not confined to the reporting by the public.

The second part of the NRW is the apparent losses, which occurs due to handling errors of systematic data and inaccuracies of customers' meters. Placing new digital meters that give more precise readings can control the losses. Another cause of the apparent losses is unbilled (unauthorized) consumption. These losses can be controlled by setting clear and strict policies, regulations, and penalties against violations in the water supply, such as common thefts, metering, and billing processes. Last but not least, raising the awareness of the local community plays a vital role in reducing water losses.

5.4.2. Daily per capita water resource use

Water resources availability is already a challenge in Jordan. However, there are some recommended procedures, such as increasing the harvesting of rainwater by building additional dams, brackish water desalination, as well as raising the amount of water to be desalinated. Another important procedure is the treating of wastewater, which can be used for several non-potable water needs, its main uses in Jordan are for irrigation in agriculture and for some industrial processes such as cooling. The use of treated wastewater for such purposes provides a reliable source of water that significantly assists in reducing the demand on freshwater resources. These procedures help increasing the overall water resources availability in Jordan that is readily accessible for human consumption and utilization.

6. Conclusions

Jordan has been suffering from water scarcity as a major issue and challenge for an extended period, prompting substantial efforts by Jordanian authorities to enhance water management and mitigate these challenges. Despite these ongoing efforts, unfortunately, these challenges are still present. Measuring, evaluating, and controlling some PIs have a great role in assisting this process and improving the performance of water service providers.

Productivity is a fundamental success factor for companies, but its measurement poses unique challenges in the service sector. While measuring productivity in the manufacturing field is often straightforward, the service sector grapples with complexities that make defining and quantifying productivity more elusive. These challenges persist, leaving service companies searching for effective measurement approaches. One widely accepted recommendation, as pursued in this research, is for service companies to take a tailored approach. Instead of attempting to fit into a universal definition of productivity, each company should identify and develop productivity terms that align with their specific business, goals, and long-term objectives. For service sector companies, the journey toward meaningful productivity measurement begins with a deep understanding of their core business, goals, and the challenges they face. This understanding paves the way for the development of customized productivity terms that can serve as valuable metrics for enhancing operational efficiency and achieving long-term success.

Within the framework of Miyahuna's goals, the PCD investigated in this paper is believed to be one of the most pertinent and critical productivity terms. Linking PIs and productivity is primarily aimed at driving overall performance improvement within the company. The deliberate focus on PCD is driven by the understanding that the results of this investigation hold the potential to deliver invaluable insights. These insights, in turn, will empower Miyahuna and similar companies to make informed decisions regarding where to channel their major efforts. By pinpointing areas for improvement and optimizing resources, companies can enhance their operational outcomes and, ultimately, increase their productivity. The connection between PIs and productivity is, therefore, a strategic pathway toward achieving sustained growth and success in the water service sector.

PCD stands as one of the most critical indicators when evaluating the quality of services provided by water suppliers to consumers. Our study delves into the evaluation of this indicator, scrutinizing the factors influencing it and the extent of their impact. Through this analysis, we have arrived at significant conclusions with direct implications for water service providers.

In our study, we pointed out two primary factors that exert substantial influence on daily PCD: non-revenue water (NRW) and per capita daily water resource use. Notably, NRW has a negative effect on PCD, while the effect of the per capita daily water resource use is positive. Quantitatively, NRW's adverse influence and the favorable effect of per capita daily water resource use are of considerable magnitude. NRW reduction and optimization of water resource utilization emerges as pivotal strategies for enhancing PCD.

Upon analyzing the results, we have outlined several suggestions for procedures and corrective actions for Miyahuna, which, when implemented, hold the potential to ameliorate the factors influencing PCD. By following these recommendations, Miyahuna can achieve significant improvements in PCD, thereby augmenting the daily water supply available to consumers.

Among the suggested methods used to monitor the water distribution systems continuously are SCADA, AMI, AMR, ALC methods, and Smart Water Grid. These technologies empower water service providers to monitor, manage, and optimize their systems effectively, ensuring a consistent and reliable water supply for consumers.

Level 1 indicators are KPIs used to gauge the utility's adherence to the strategic goals of MWI of improved and sustainable water services as well as those of the utility, which give the various stakeholders (e.g., the public, the decision-makers in MWI/WAJ, the board of directors and the top management of the company, etc) an overview of the standing of the utility. Meanwhile, levels 2 and 3 indicators measure the performance of the utility's departments and their adherence to the set targets. The above is the classification of performance indicators adopted by the PMU and based on the IWA indicators list.

Based on Miyahuna's three levels of PIs, we suggest categorizing the aforementioned methods into two categories, namely, data collection and monitoring systems and advanced control and management systems. For the first level, which is the most important one, we would include SCADA, AMI, and AMR approaches. These methods can be extremely significant in attaining MWI's strategic goals and stakeholders' stability. On the other hand, for the second category, providing valuable tools to monitor and improve Jordan water companies' efficiency, we would suggest the adoption of ALC methods, pressure management technique, and Smart Water Grid systems to support the yearly performance evaluation at levels 2 and 3.

These categorized methods not only align with Miyahuna's performance measurement framework but also work synergistically to create a comprehensive and efficient approach to water service management. By strategically implementing these methods, Miyahuna can enhance its operational performance, meet MWI's objectives and ensure reliable water supply for its stakeholders.

References

[1] The Water Authority of Jordan, Jordan Water Sector Facts and Figures, 2017 (Retrieved 2 Feb. 2022). Available at: http://www.waj.gov.jo/sites/en-us/default.aspx

[2] UNICEF Jordan, Water, Sanitation and Hygiene: Access to Safe Water and Sanitation for Every Child (Retrieved 25 May 2022). Available at: https://www.unicef.org/jordan/water-sanitation-and-hygiene

[3] UNHCR Jordan: The UN Refuge Agency, UNHCR Continues to Support Refugees in Jordan Throughout 2019 (Retrieved 25 May 2022). https://www.unhcr.org/jo/12449-unhcr-continues-to-support-refugees-in-jordan-throughout2019.html#:~:text=As%202019%20comes%20to%20close,total%20of%2052%20other%20nationalities

[4] B. Ki-moon, U.S. General, The Human Right to Water and Sanitation, Media Brief at the United Nations General Assembly, 2010.

[5] Jordan Water Company, Miyahuna Annual Monitoring Report, 2018.

[6] World Health Organization, How Much Water is Needed in Emergencies: Technical Notes on Drinking-Water, Sanitation and Hygiene in Emergencies, 2013, pp. 1–4.

[7] T. Lachaut, J. Yoon, C. Klassert, A. Tilmant, Aggregation in bottom-up vulnerability assessments and equity implications: the case of Jordanian households' water supply, Adv. Water Resour., 169 (2022) 104311, doi: 10.1016/j.advwatres.2022.104311.

[8] A. Athuraliya, P. Roberts, A. Brown, Residential Water Use Study Volume 2-Summer 2012, Yarra Valley Water, Melbourne, 2012.

[9] E.R. Hay, K. Riemann, G. van Zyl, I. Thompson, Ensuring water supply for all towns and villages in the Eastern Cape and Western Cape Provinces of South Africa, Water SA, 38 (2012) 437–444.

[10] M.L. Crouch, H.E. Jacobs, V.L. Speight, Defining domestic water consumption based on personal water use activities, AQUA Water Infrastruct. Ecosyst. Soc., 70 (2021) 1002–1011.

[11] M. Falkenmark, Growing water scarcity in agriculture: future challenge to global water security, Philos. Trans. R. Soc. London, Ser. A, 371 (2002) 2012.0410, doi: 10.1098/rsta.2012.0410.

[12] V. Yildiz, M.A. Hatipoglu, S. Yurdagül Kumcu, Water and Wastewater Management: Global Problems and Measures, M. Bahadir, A. Haarstrick, Eds., Climate Change Impacts on Water Resources, Springer International Publishing, Cham, 2022, pp. 17–25.

[13] WAREG European Water Regulators, An Analysis of Water Efficiency KPIs in WAREG Member Countries, 2017 (Retrieved 10 March 2023). Available at: https://www.wareg.org/documents/an-analysis-of-water-efficiency-kpis-in-wareg-member-countries/

[14] D. Saal, D. Parker, Assessing the Performance of Water Operations in the English and Welsh Water Industry: A Panel Input Distance Function Approach, Aston Business School, 2005. Available at: https://www.researchgate.net/publication/265002974

[15] H. Alegre, J.M. Baptista, E. Cabrera Jr., F. Cubillo, P. Duarte, W. Hirner, W. Merkel, R. Parena, Performance Indicators for Water Supply Services, IWA Publishing, London, 2006.

[16] M. Sattarov, T. Volkova, A performance management framework for water utilities in developing countries, J. Bus. Manage., 6 (2020) 91–109.

[17] H. Alegre, J.M. Baptista, E. Cabrera Jr., F. Cubillo, P. Duarte, W. Hirner, W. Merkel, R. Parena, Performance Indicators for Water Supply Services, IWA Publishing, London, 2016.

[18] S.V. Berg, Performance assessment using key performance indicators (KPIs) for water utilities: a primer, Water Econ. Policy, 6 (2020) 1–25.

[19] EuroEau, How Benchmarking is Used in the Water Sector, 2015 (Retrieved 10 March 2023). Available at: https://www.eureau.org/resources/position-papers

[20] C. Berg, A. Danilenko, The IBNET Water Supply and Sanitation Performance Blue Book: The International Benchmarking Network for Water and Sanitation Utilities Databook, World Bank Publications, Washington, D.C., 2011.

[21] R.C. Marques, A.J. Monteiro, Application of performance indicators in water utilities management - a case-study in Portugal, Water Sci. Technol., 44 (2001) 95–102.

[22] PMU, Performance Indicators for Water and Wastewater Services, Version 07, Amman, 2009.

[23] H. Alegre, W. Hirner, J.M. Baptista, R. Parena, In: Beitrag zum Workshop Views and Experience Gained Through Implementing IWA Performance Indicators Project, im Rahmen des 3rd World Water Congress in Melbourne, Highlights of the IWA System of Performance Indicators for Water Supply Services, Vol. 7, 2002.

[24] Miyahuna, Who we Are? Miyahuna Official Website (Retrieved 25 May 2022). Available at: https://miyahuna.com.jo/en/page/Who-We-Are-2

[25] Jordanian e-Government, Water Authority (Retrieved 25 May 2022). Available at: https://portal.jordan.gov.jo/wps/portal/Home/GovernmentEntities/Ministries/Ministry/Ministry%20of%20Water%20and%20Irrigation/Water%20Authority?current=true&nameEntity=Water%20Authority&entityType=sub

[26] J. Rutkauskas, E. Paulavičienė, Concept of productivity in service sector, Eng. Econ., 43 (2005) 29–34.

[27] P. Hersey, K.H. Blanchard, The management of change, Train. Dev. J, 34 (1980) 80.

[28] L. Owais, T.K. Judit, Developing a financial sustainability model of the performance indicators applied by Jordan water company (Miyahuna), Int. J. Eng. Manage. Sci., 5 (2020) 75–87.

[29] M. Ringnér, What is principal component analysis?, Nat. Biotechnol., 26 (2008) 303–304.

[30] M. Farley, G. Wyeth, Z.B.M. Ghazali, A. Istandar, S. Singh, N. Dijk, E. Kirkwood, The Manager's Non-Revenue Water Handbook: A Guide to Understanding Water Losses, Ranhill Utilities Berhad and the United States Agency for International Development, Bangkok, 2008.

[31] E. Price, G.R. Abhijith, A. Ostfeld, Pressure management in water distribution systems through PRVs optimal placement and settings, Water Res., 226 (2022) 119236, doi: 10.1016/j.watres.2022.119236.

[32] S.L. Andhare, P.J. Palkar, SCADA a tool to increase efficiency of water treatment plant, Asian J. Eng. Technol. Innovation, 2 (2014) 7–14.

[33] S.W. Lee, S. Sarp, D.J. Jeon, J.H. Kim, Smart water grid: the future water management platform, Desal. Water Treat., 55 (2015) 339–346.

[34] D. Bian, M. Kuzlu, M. Pipattanasomporn, S. Rahman, 2014 IEEE PES General Meeting | Conference & Exposition, Analysis of Communication Schemes for Advanced Metering Infrastructure (AMI), 2014, pp. 1–5.

[35] S. Palaniappan, R. Asokan, S. Bharathwaj, N. Sujaudeen, Automated meter reading system - a study, Int. J. Comput. Appl., 116 (2015) 39–46.

[36] A.O. Lambert, M. Fantozzi, Recent advances in calculating economic intervention frequency for active leakage control, and implications for calculation of economic leakage levels, Water Sci. Technol.: Water Supply, 5 (2005) 263–271.