TaKaDu

Are you properly tracking your Technical Efficiency score and Infrastructure Leakage Index?

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Among all the key performance indicators (KPIs) that water utilities can and should track, there are two whose value is often overlooked – **Technical Efficiency** and **Infrastructure Leakage Index**. Utilities that want to develop effective strategies for proper non-revenue water (NRW) management can utilize these two handy indicators to help them track the evolution of their DMAs (District Metered Areas) and prioritize activities.

This article explains how each of these KPIs are calculated and what each can reveal about the status and trends in your water network.

The value of KPIs

KPIs are used in almost every industry to measure the efficiency and effectiveness of a service. The main information provided by a KPI is the result of a comparison with a goal. Tracking individual KPIs across time provides insights into trends and can provide visibility into improvement (or the opposite). In water networks, there are many KPIs that focus on DMA performance. They compare the current value with previous values of the same DMA or with the values of other DMAs.

As water utilities invest in more telemetry devices and wider telemetry coverage, they gain instantaneous visibility that answers the question "Where are we now?". This allows utilities to implement good reactive plans for immediate activities.

However, there is more that can be gained from all that telemetry. Combining historical data and real-time data provides visibility over time, enabling answers to more questions: "Where were we?", "Where are we right now?" and "Where are we going to be in X period of time?". By keeping track of combined indicators, utilities can plan immediate proactive activities and formulate effective mid- and long-term plans for proactive maintenance schedules and strategies for ongoing improvement.

Two handy KPIs that help with non-revenue water management

Differentiating apparent losses from physical ones is a great challenge for organizations, often turning this task into a seemingly insurmountable obstacle. At TaKaDu, we propose a simplified approach: the use of two indicators that, while they are not 100% precise, are close enough to be very acceptable for the prioritization of areas to search for leaks.

The two KPIs we recommend are:

- Technical Efficiency
- Infrastructure Leakage Index

The first one is relatively simple, and the second one is more complex, but both are well within the capabilities of any utility. As well-proven, internationally recognized indicators, their use can provide utilities with peace of mind that they are compliant with industry best practices.

Technical Efficiency

Technical Efficiency represents a gross estimation of the percentage of the total water supplied to a sector over a specific period of time that is not wasted as losses (apparent + physical).

The formula

Technical Efficiency is the relation between Minimum Nightline and Total Supply for the previous calendar month.

$$TE = \left(1 - \frac{MonthlyMinimumAchievedNightFlow * (1 - NightConsumptionFactor) * DaysInMonth}{TotalMonthlyFlow}\right) * 100$$

The Minimum Nightline is comprised of Commercial Losses (apparent) + Physical Losses (real) + Night Consumption. As a result, the Estimated Night Loss is equal to Minimum Nightline – Night Consumption.

Night Consumption is dependent on the type of consumers of each DMA. In the case of public and business consumers such as factories, hospitals, harbors, pubs, etc., you may expect higher levels of consumption during the night than in a residential area. In most cases (residential areas), it is assumed that Night Consumption is less than 10% of the Minimum Nightline.

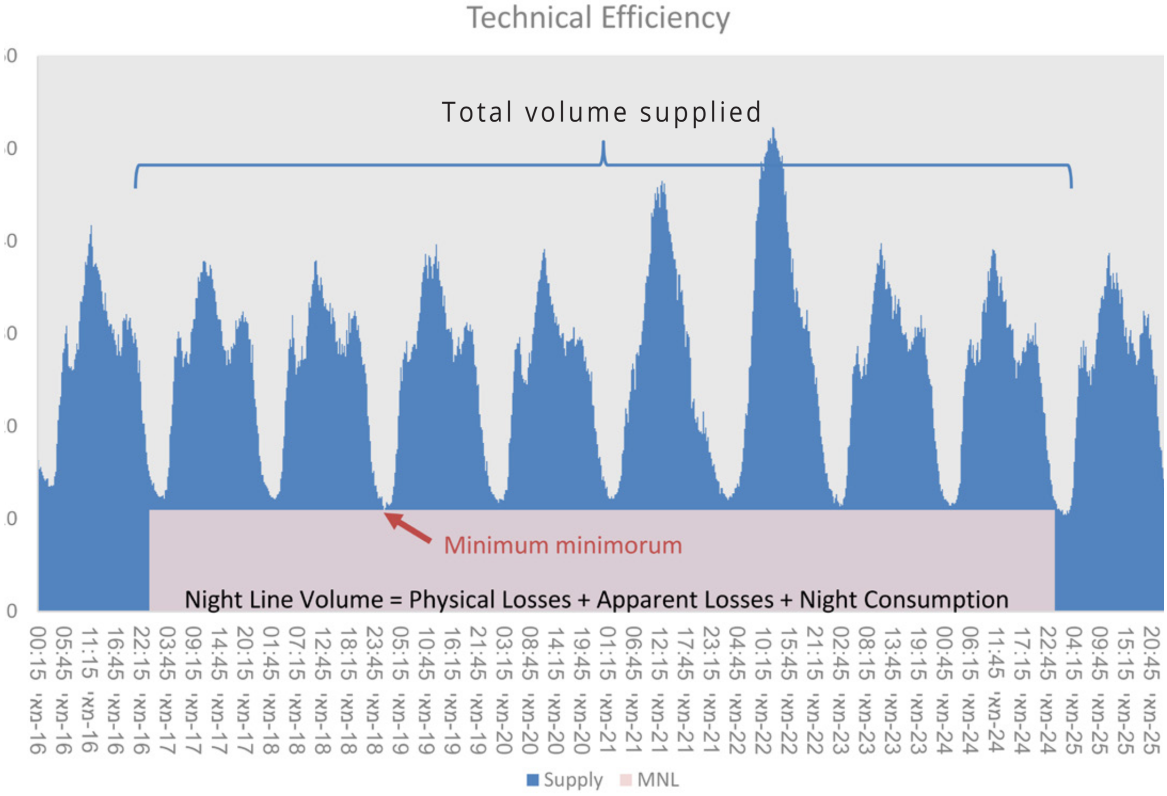

Figure. 1: Technical Efficiency: main variables

As an example, below is a calculation of Technical Efficiency across one week.

As a first step, we should find the Minimum Achieved Night Flow (MANF). To do this, we use the Minimum Minimorum flow rate achieved during the time window. As the specific moment at which the night consumption is the least significant, it is the best scenario we are able to measure.

In the graph above, the MANF point occurred on the night of May 19, 2022.

In order to get the Minimum Night Volume (MNV), we multiply the MANF by the period. In this case 7 days. NCF is the Night Consumption Factor (we can apply it if we have it. If not, use 0.1 or 0.0).

$$MNV\ l = MANF \frac{l}{s} * 7\ d * 24 \frac{h}{d} * 3600 \frac{s}{h} * (1 - NCF)$$

Total Supplied Volume (TSV) is the total amount of water supplied into the DMA in the time window, which appears as all the area under the Flow (Q) curve in the time window.

$$TSV\ l = \int_{t0}^{t1} Q(t)\ dt$$

If we divide the MNV by the TSV, we get the Inefficiency of the DMA. This tells us the minimum percentage of the total supplied water into the DMA that is Technical Losses + Apparent Losses.

$$Technical\ Inefficiency\ \% = \frac{MNV\ l}{TSV\ l} * 100$$

Rather than viewing this indicator as *Inefficiency*, as above, it is easier to see it from the opposite perspective, as *Efficiency* – i.e., the maximum percentage of the total supplied water into the DMA that is being consumed by customers.

$$Technical\ Efficiency\ \% = (1 - \frac{MNV\ l}{TSV\ l}) * 100$$

Benefits of the Technical Efficiency indicator

- Technical Efficiency is very easy to calculate. It does not require many parameters. It works well even without having an estimation of Night Consumption Factor.
- It provides a quite accurate idea of the status of all the DMAs at a specific moment.
- It can be calculated on a daily basis if needed.
- As Technical Efficiency is a percentage, it can be used to compare different DMAs of different sizes and monthly supplied volumes.
- It allows the utility to quickly and easily prioritize which DMAs to search for leaks. The lower the Technical Efficiency of a DMA, the higher the probability that leaks will be found in the DMA.
- The utility can track the performance of the DMAs in relation to the water supplied to the DMA, and not only based on the MNL or the total Supply. This is very useful in areas with high variability in seasonal consumption.
- Technical Efficiency is a better indicator than looking only to the MNL, as it considers the *relation* between the total amount of water supplied and the MNL. If the relation is equal to or lower than the previous period for a DMA then we can assume that the DMA did not deteriorate.
- Technical Efficiency is a better indicator than looking only at Supply, as that is affected by consumption patterns.

Limitations of the Technical Efficiency indicator

- The Technical Efficiency indicator is based on assumptions regarding the Nightline and Night Consumption Factor. Looking at Technical Efficiency side by side with the Commercial Efficiency indicator results in a more accurate set of information. However, this would require the utility to monitor real consumption on an hourly basis (requiring

Advanced Metering Infrastructure) or to wait for the meter readings of the commercial department, forcing the utility to tolerate longer and less-automated periods for the calculation.

- As Technical Efficiency is based on the MNL, it inherits the high level of sensitivity of the nighttime activity. This is problematic in areas with high levels of consumption during the night if, as is commonly the case, the utility cannot calculate a consistent Night Consumption Factor.
- Technical Efficiency does not provide accurate values for networks with intermittent supply as it is based on the Nightline pattern.
- The same indicator value may have different meanings depending on the consumption and apparent losses in the area.
- Using Technical Efficiency as an indicator of management efficiency is not recommended.

Infrastructure Leakage Index

The Infrastructure Leakage Index (ILI), proposed by the International Water Association, is a unit-less performance indicator of real (physical) water loss from the supply network.

In a perfect world, a network would not leak, not even a drop. However, the reality is very different, forcing us to accept the best scenario as one in which the minimum possible leaks are achieved considering the type of materials, lengths of pipes and number of connections in an area of the network subjected to specific pressure.

The ILI indicator will tell us how many times an area of our network is above that desired objective. Reading between the lines, the ILI is a measurement of how well the network is being maintained, repaired and rehabilitated.

The formula

The *Infrastructure Leakage Index* is the relation between Current Annual Real Losses (CARL), also called Current Real Losses (CRL), and Unavoidable Annual Real Losses (UARL), which is also referred to as Unavoidable Background Real Losses (UBRL). The ILI represents a performance measure of active leakage control and assets management under a certain average operating pressure.

$$ILI = \frac{CRL\ \frac{l}{d}}{URL\ \frac{l}{d}}$$

Below is how we calculate the CRL:

The goal is to get a figure as close as possible to the Current Real (Physical) Losses. This is not an easy task as Water Losses are a mix of Real + Apparent Losses, and therefore some assumptions are needed.

For example, in emerging countries, as a general rule, water theft is much higher than in first world countries. High water theft is also relatively common in countries with high water prices and many rural areas, which are harder to monitor. Consequently, in these scenarios, the Water Loss Curve will have a greater component of Apparent Losses.

To improve our ILI calculation, whenever possible, we should define two factors based on this formula (all factors are defined as values between 0 to 1):

*TotalFlow = Flow * (Physical Losses Factor + Apparent Losses Factor + Consumption Factor)*

1 = (Physical losses Factor + Apparent losses Factor + Consumption Factor)

If the correction factors per area are known then it is always beneficial to apply them, as the result will be more accurate. If they are not known then we can assume *no* Apparent Losses and *no* Consumption during the night, and therefore set each of these values to 0.

The following three methods cover scenarios from lower to higher availability of consumption and apparent losses data, and each method increases the accuracy accordingly. The first two methods below are a poor man's calculation of the formal ILI calculation that is explained in Method 3.

Method 1: When Water Loss is based on a rough estimate of Night Flow, the calculation is:

$$CRL\ \frac{l}{d} = MANF\frac{l}{s} * 24\frac{h}{d} * 3600\frac{s}{h} * (1 - \ NCF - NALF)$$

MANF: Minimal Achieved Night Flow (l/s)

NCF: Night Consumption Factor (between 0.0 and 1.0)

NALF: Night Apparent Losses Factor (between 0.0 and 1.0)

If the necessary information and resources are available to the utility, one of the following alternative calculations are preferred.

Method 2: Loss Curve = Supply Curve – Consumption Curve.

$$CRL\ \frac{l}{d} = 1\ day\ volume\ based\ on\ Loss\ Curve$$

This calculation requires AMI technology in the field.

Method 3: Real Losses based on Number of Connections or Pipe Length* 24 hours of service pressure.

$$CRL\ \frac{l}{d} = Real\ Losses\ \frac{\frac{m^3}{d}}{conn} * NrConnections\ conn * 1000\ \frac{l}{m^3}$$

$$CRL\ \frac{l}{d} = Real\ Losses\ \frac{\frac{m^3}{d}}{km} * NetworkLength\ km * 1000\ \frac{l}{m^3}$$

**NOTE: TaKaDu is able to calculate ILI based on the top 2 methods described above. Method 3 can be calculated if the utility provides the data for Real Losses per connection or per km pipe.*

This is the calculation for UBRL:

$$UBRL\frac{l}{d} = P\ mH2O * \left(18\ \frac{\frac{\frac{l}{km}}{d}}{mH2O} * L_m\ km + 0.8\frac{\frac{\frac{l}{conn}}{d}}{mH2O} * N_c\ conn + 25\frac{\frac{\frac{l}{km}}{d}}{mH2O} * L_p\ km\right)$$

P: Average pressure in the sector (mH2O).

L_p: Length of service pipes, distance from property line to meter (km).

N_c: Number of service connections (No).

L_m: Length of distribution pipes (km).

The UBRL indicator is very interesting as it allows us to roughly estimate the lowest technically achievable real losses for a time window for a specific length of pipes and connections under a certain pressure regime.

TIP – Reverse calculation of the Night Flow Target: In TaKaDu CEM we can set a Night Flow Target for each DMA.

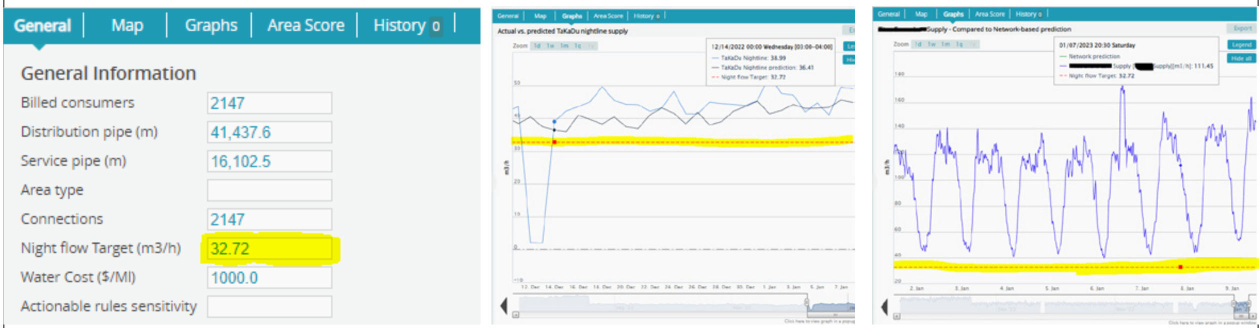

Figure 2: In TAKADU CEM, Night Flow Target appears in the graphs as a red dashed line, facilitating the comparison with the current nightline or supply pattern. This example is from the same utility as Figure 1.

Having calculated the CRL and URL, it is now possible to calculate the ILI:

$$ILI = \frac{CRL\ \frac{l}{d}}{URL\ \frac{l}{d}}$$

The closer this indicator is to 1 the better, as it means the lowest possible physical losses are being achieved for the set of assets under the defined pressure.

Utilities can apply their own criteria and goals to define the Night Flow Target. However, one useful option is to take advantage of the calculated UARL per DMA and convert that into the proper units to set the Night Flow Target (don't forget to apply the Apparent Losses Factor and Consumption Factor in so doing). When the actual Night Flow overlaps with this Night Flow Target then the area will calculate as ILI = 1, which is ideal.

How to interpret Infrastructure Leakage Index results

Target ILI Range	Financial Considerations	Operational Considerations	Water Resources Considerations
1.0 - 3.0	Water resources are costly to develop or purchase; ability to increase revenues via water rates is greatly limited because of regulation or low ratepayer affordability.	Operating with system leakage above this level would require expansion of existing infrastructure and/or additional water resources to meet the demand.	Available resources are greatly limited and are very difficult and/or environmentally unsound to develop.
>3.0 - 5.0	Water resources can be developed or purchased at reasonable expense; periodic water rate increases can be feasibly imposed and are tolerated by the customer population.	Existing water supply infrastructure capability is sufficient to meet long-term demand as long as reasonable leakage management controls are in place.	Water resources are believed to be sufficient to meet long-term needs, but demand management interventions (leakage management and water conservation) are included in the long-term plan.
>5.0 - 8.0	Cost to purchase or obtain/treat water is low, as are rates charged to customers.	Superior reliability, capacity and integrity of the water supply infrastructure make it relatively immune to supply shortages.	Water resources are plentiful, reliable and easily extracted.
> 8.0	Although operational and financial considerations may allow for a long-term ILI greater than 8.0, such a level of leakage is not an effective use of water as a resource. Setting a target level greater than 8.0, other than as an incremental goal to a smaller long-term target, is discouraged.		
< 1.0	If the value of the ILI for your system is 1.0 or less, two possibilities exist: 1) You are maintaining your leakage at low levels in a class with the top worldwide performers in leakage control; or 2) A portion of your data may be flawed, causing your losses to be greatly understated. This is likely if you calculate a low value but do not employ extensive leakage control practices in your operations. In such cases, it is beneficial to validate the data by performing field measurements to confirm the accuracy of production and customer meters, or to identify any other potential sources of error in the data.		

Figure 3: Table created by the Water Loss Control Committee of the American Water Works Association to help utilities determine an approximate ILI that is appropriate for their water system and conditions.
Source: https://www.twdb.texas.gov/conservation/municipal/waterloss/doc/InfrastructureLeakageIndex.pdf

Benefits of the ILI indicator

- As a unit-less indicator, the ILI makes it easy to compare between countries that use different measurement units.
- If the CRL is calculated consistently, the ILI allows good comparisons between different DMAs in the same utility and between different utilities.
- By focusing on the processes related to the operations department, the ILI indicator mostly excludes the non-physical variables that affect total water loss volume.
- The ILI is good for field activities prioritization because it relates to physical issues in the network.
- The ILI takes into account multiple parameters, including the density of connections, intermittent water supply situations, low and high-pressure systems and differences in consumption levels.
- This indicator provides value for top-level management, helping them to track the current physical status of the network and its evolution, and it also provides sufficient specific detail for the operations department, enabling better prioritization in assigning resources to the DMAs.

Limitations of the ILI indicator

- The ILI is less-effective for small DMAs or areas with very high pressure (less than 5000 connections, less than 20 connection per km mains, and pressure beyond the 25-100 mH2O range). However, a recently proposed version of the KPI calculation with additional correction factors works well in small areas with water pressure outside the noted limits. Contact TaKaDu to learn more about this new version.
- Calculating the ILI requires manual input of many parameters, although just one time!
- The indicator's origin is based on empiric expression.
- To improve accuracy for external comparison, periods longer than a year should be considered.
- If the information is provided by the TaKaDu system, the CRL calculation may include the apparent losses and consumption if they are not properly identified. Depending on the specific situation at the utility, this can negatively impact the ILI indicator. That said, the indicator is good for relative comparison over time.

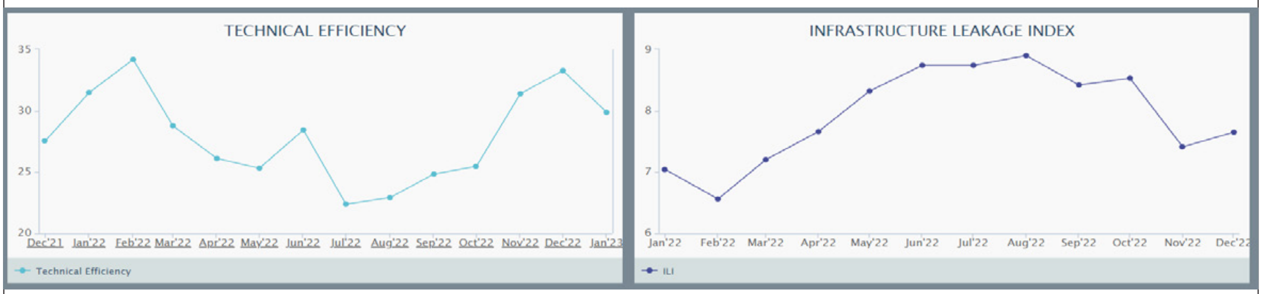

Figure 4: TaKaDu graphs showing the trends for the Technical Efficiency and ILI indicators. This example is from the same utility as in Figures 1 and 2.

Using Technical Efficiency and ILI in conjunction with TaKaDu CEM

The Technical Efficiency and ILI indicators can both be calculated for any area in the utility, from large zones to small DMAs. The Technical Efficiency is not affected by the size of the DMA, however it cannot be calculated if water supply is intermittent. The ILI has some limitations as the results may be less accurate in DMAs with a small number of connections and/or low water pressure. Nevertheless, tracking these indicators across time has value. TaKaDu can calculate and keep track of both indicators on a daily basis, providing information that can be used for historical comparisons, as all the samples across time are affected more or less in the same manner.

As already noted, Technical Efficiency is a very basic and easy-to-calculate indicator. It is included as standard in TaKaDu and calculated by the TaKaDu system based solely on the supply pattern of the DMA, without any special extra information from the utility.

The ILI is a more complex indicator that requires some additional effort by the utility to provide specific information about each zone or DMA. Depending on the available information and the ILI accuracy level required by the utility, TaKaDu may propose one method over another. Compariing between utilities requires calculation Method 3. For internal tracking and prioritization of field activities, either Method 1 or Method 2 would provide good-enough reference data.

Examples

The following scenarios are just two examples of how considering the Technical Efficiency and ILI indicators along with other insights from TaKaDu CEM can enhance utilities' decision making.

Example A: A utility deploys field teams each day to fix leaks based on reactive activities and also conducts scheduled proactive leak detection campaigns. For these campaigns a predefined order of scanning the DMAs should be established. By reviewing Technical Efficiency, ILI, DMA data quality, water cost per DMA and total water supply side by side in the TaKaDu dashboard and considering them all together, the utility can set good prioritization criteria, and thus optimize the efficacy of its proactive leak detection campaigns.

Example B: A utility cycles through all DMAs in order to detect hidden leaks – a process that typically takes this utility more than a year. After completing the cycle, the process starts over again in the same order. Even when it covers the entire network, this approach is not ideal, as a recently inspected DMA could soon develop hidden leaks that might not be noticed until the next cycle, up to a year or more later. In such a case, the amount of water wasted in between the two inspections could be substantial. This raises a fundamental question: why assign a search team to a DMA that is in good shape when we could instead assign the resources to a DMA that requires attention? TaKaDu can provide many indicators to help the utility's NRW team to improve this "sweep the network" process and provide daily information to update the order of the DMAs in the inspection list. This creates a dynamic and more-efficient list that will improve water recovery and reduce consumption of resources.

Conclusion

While both the Technical Efficiency KPI and the Infrastructure Leakage Index KPI provide value, each of them has advantages and disadvantages that should be kept in mind. It is very important to measure properly and set a consistent procedure for calculating each of these indicators.

By doing so, a utility can build a framework of reference for activity in the field and for planned campaigns. Even when a utility is not able to fine-tune these indicators, they still provide value for prioritization of activities in the field and for keeping track of evolution over time.

The TaKaDu system is able to calculate both the Technical Efficiency indicator and the Infrastructure Leakage Index indicator on a regular basis for the entire network, providing operators and managers with comprehensive, real-time information for effective NRW management.

Sources:

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