WHITE PAPER

Enhancing availability and safety in public transport networks with a connected maintenance approach

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EXECUTIVE SUMMARY

With public transport networks under increasing pressure to handle larger volumes of people and extend their operating hours, “connected maintenance” approaches are gaining in popularity as a way to help operators enhance both equipment availability and safety by significantly improving the efficiency and effectiveness of their maintenance processes.

Connected maintenance leverages the latest data gathering and analytics technologies, such as AI and cloud computing, and combines them with an existing maintenance knowledge base and equipment reference data. Connectivity devices are installed on vertical and horizontal transportation solutions (VHTS) such as escalators, elevators, and moving walkways gather data, which is then transferred to a cloud-based platform for analysis, which involves comparing the collected data to a reference base of installed equipment in order to more easily identify anomalous behavior and generate recommendations for action.
Incorporating a “learning loop” that feeds back on the outcome of maintenance actions enables continuous improvement in terms of maintenance quality and enables more efficient use of human technical support resources. A connected maintenance approach also provides the opportunity to enhance maintenance planning. With equipment-specific usage profile data available, the maintenance provider can accurately identify the optimal time window to perform the work to minimize disruption to passenger flows.

Connectivity can also be an effective way to minimize disruption by enabling accurate remote identification of the nature of a stoppage or other issue: Is the fault electrical or mechanical? Can the equipment be safely restarted by staff on site without presenting any risk to passenger safety?

By improving the quality, speed, and effectiveness of VHTS maintenance, a connected maintenance approach supports public transport operators’ goals of ensuring safe, efficient people flow across increasingly busy networks.

About the author

Werner Ettrich is a highly experienced professional in the field of escalator and elevator maintenance strategy and service delivery. His career has encompassed a wide variety of roles relating to the development and implementation of new maintenance concepts and solutions focused on improving delivery quality and field productivity on both a local and global scale.

URBANIZATION AND THE RISE OF THE 24-HOUR CITY

We are living in the urban age. As a percentage of the total global population, more people live in cities than ever before in history. By 2050, it is estimated that more than two thirds of the world's population will live in urban areas. Every day, about 200,000 people move into cities across the globe. To put this into perspective, every hour, over 40 people move to Mumbai, about 70 to Lagos, and over 60 to Dhaka. These megacities, like many others, are projecting an urbanization rate of between one and six percent a year.

The paradox is that the more attractive cities become, the more challenges they have in terms of travel congestion and environmental quality. Smart development strategies are essential, and they range from comprehensive, well-coordinated planning to the integration of digital technologies that minimize transport congestion and improve the ground-up responsiveness of city administration and public transport operators.

Public transportation under pressure

In Europe and the US for example, the urbanization wave is typically being driven by an aging population and the changing preferences of younger generations. As people get older they are moving away from suburbs into cities to be closer to the services they need, including public transport. Younger generations are increasingly opting for public transportation over private cars.

As a result of these changing trends preferences, public transport networks – and rail and metro systems in particular – are under increasing pressure. Not only are they required to handle larger volumes of people than ever before, but they are increasingly being required to extend their operating hours in order to serve the needs of growing populations.

According to the UITP (Union Internationale des Transports Publics) World Metro Figures 2018 statistics brief, at the end of 2017 there were established metro networks in 178 cities in 56 countries, carrying an average total of 168 million passengers per day.

Seeking sustainable solutions for cities that never sleep

In recent years we have seen a huge rise in the popularity of electric vehicles as individuals and industry seek ways to address the growing threat of climate change. But replacing petrol or diesel-powered cars with electrically powered vehicles is not the silver bullet it first appears to be. Electric cars still need roads and parking spaces, and if they are powered by fossil fuel-generated instead of carbon-free electricity they simply shift the pollution problem away from city centers to out-of-town power plants. They also still generate particle pollution – from road wear, tyres, and brake components.

Efficient mass transport systems therefore hold the key to developing livable, sustainable urban environments with their ability to provide safe and more environmentally friendly transportation for burgeoning urban populations. Over the last 20 years many megacities, typically defined as those with populations of over 10 million, have shifted towards 24/7 availability for their public transport networks, both on weekends and weekdays.

BRINGING THE OLD AND THE NEW PARADIGMS TOGETHER

The trend towards 24/7 availability has significant implications for public transport network operators, not least in terms of people-flow and maintenance planning. With stations and other transport hubs operating for longer hours, there is an increasingly narrow window of downtime for performing preventive maintenance on their vertical and horizontal transportation solutions (VHTS) – such as escalators, elevators, and moving walkways.

Furthermore, should a breakdown or other issue occur that requires more immediate corrective maintenance, technicians will need to be on call to address the problem quickly to mitigate the risk of having to restrict passenger flows, or in the worst case close a station completely. Naturally, longer operating hours and the need to serve increasingly large volumes of people also has an impact on the life cycle of wear components in VHTS solutions.

The traditional approach to VHTS maintenance is based on an old paradigm where networks operated for far less hours and with lower passenger volumes. There are fixed maintenance schedules for equipment based on annual running hours, with corrective and preventive repairs performed as required, and operators rely on fixed labor models and established competence and skill paths for maintenance technicians.

Leveraging the power of digitalization in the new paradigm

Beyond increasing urbanization, there is another trend that is shaping the way we live, work, and travel – and providing us with a host of opportunities to innovate new services and solutions. In the digital age, rapid advances in the capabilities of sensors, connectivity, analytics, and mobile technologies are redefining many industry sectors, including public transport.

In the public transport realm specifically, digitalization is enabling the introduction of innovative new digitally enabled monitoring and maintenance approaches for VHTS, referred to as “connected maintenance” approaches. These bring together real-time equipment data and expert knowledge to generate valuable insights and translate them into clear actions.

By taking AI and cloud computing technologies from the new paradigm and combining them with existing maintenance knowledge base and equipment reference data from the old paradigm, connected maintenance can enhance both equipment availability and safety by significantly improving the efficiency and effectiveness of maintenance processes.

Human and machine in perfect harmony

Gathering VHTS equipment data using the latest techniques and technologies is a great first step, but the real value lies in what we do with that data.

Based on the gathered data the service provider knows what equipment is installed in a given location and its projected design lifetime based on load-profile assumptions.

Controller data provides a real-time picture of the situation on site and can include parameters such as whether the equipment is running or not, its direction of travel, the current operation mode, and, if the equipment is stopped, the reason for that stoppage, such as a broken handrail in the case of an escalator.

Sensor data provides a picture of trends for specific component groups, e.g. gearbox vibration and temperature, as well as noise level. A sudden change in one of these parameters indicates an event but may not indicate that action needs to be taken; a change in several parameters compared to a normal run setup indicates a service requirement. The system can provide an indication of the level or urgency and clear instructions to the service engineer on what the problem is and how to resolve it.

The real value comes with the addition of back-reporting data from preventive and corrective actions. This data, gathered over a long period from a service-provider's wide installed base, provides insights that – with the help of AI, machine learning, and human expertise – can be used to trigger actions. It is therefore vitally important that human and machine are working together in perfect harmony.

Digitalization in the context of VHTS

For the purposes of this paper we define digitalization as comprising the following:

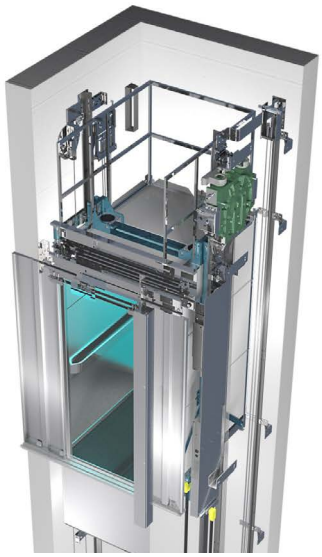
- **Using sensors** to gather data from equipment
- **Connectivity** to enabling remote monitoring and diagnostics via the cloud
- **Data storage** through cloud computing, with its ability to quickly and easily scale up capacity
- **Analytics** to turn data into valuable insights using AI and machine learning
- **Data mobilization**, which means combining the four elements above into a solution that helps us understand equipment condition and make better decisions
- **A learning loop**, whereby the gathered data is used to 'train' the system, helping it to make better decisions as time goes on

Gathering equipment data using sensors

By sensors we refer to devices installed on VHTS equipment that gather information on key operating parameters, usage statistics, and faults. For example, for escalators sensors can monitor systems like the handrail, step-band, and drive. In elevators, sensors might monitor door behavior, stopping accuracy, and brake and push-button functioning. The sensors gather data on parameters such as noise, temperature, vibration, and power consumption.

Examples of key parameters monitored

- Movement
- Mileage and drive time
- Usage statistics
- Stopping accuracy and stopping behavior
- Emergency stops



- Doors opening and closing behavior
- Push button functioning
- Stopping accuracy and stopping behavior
- Position and movement in shaft
- Mileage and drive time
- Usage statistics

Connecting the equipment

A data transmission device provides real-time communication between the equipment and the maintenance service provider's cloud platform, where the analytics engine is located.

Cloud-based data storage

The gathered equipment data is stored in the service-provider's cloud platform together with reference data gathered from other connected equipment. This reference data can include information such as equipment type, operational environment, and usage data.

Big-data analytics and AI machine learning

The analytics engine applies intelligent algorithms to the equipment data and makes comparisons with reference data collected from other equipment. If the system identifies a potential fault or other issue that requires some form of maintenance, it either alerts a technician immediately with the right information in real-time, or contacts technical support or customer service, according to how critical the problem is. For non-critical issues, action can be taken during the next scheduled maintenance visit. This predictive approach minimizes the risk of breakdowns and therefore helps to extend the lifetime of VHT assets.

Data mobilization

Performing intelligent analyses on the data received from equipment gives a clear picture of the equipment's current condition. Here we move into the realm of predictive maintenance. This is the brains of the whole operation, where we transform data into valuable pieces of information. For example, we can determine whether or not a unit is in operation and provide technicians with diagnostic guidelines for fault-finding and resolution, or whether the issue poses a safety risk to passengers and requires more immediate action.

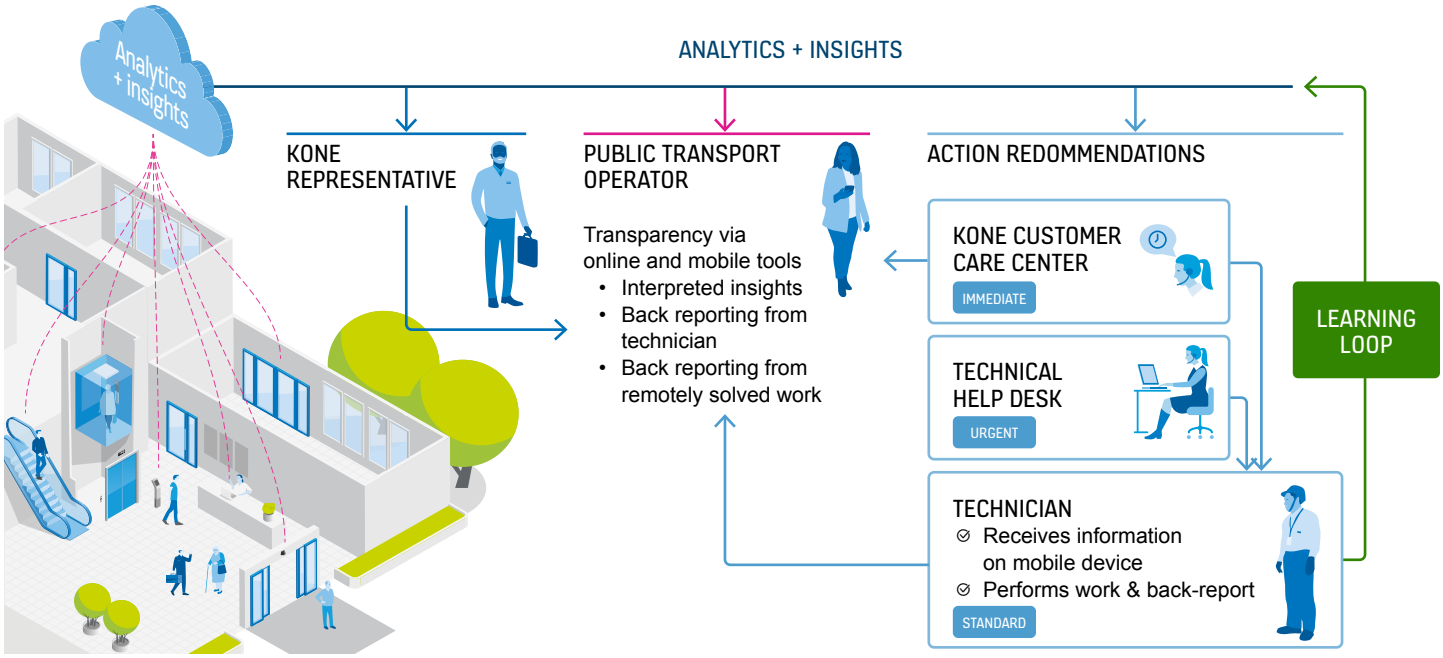
The learning loop

When employing AI and machine learning, the models are trained to identify future events by teaching them to recognize past events with similar patterns as identified in the gathered data. Gathering feedback in a systematic way is therefore essential to ensure that the service recommendations the system provides are properly validated. Just like a human being, the system learns and improves its identification abilities as time goes on, identifying new types of events and gradually weeding out the erroneous or inaccurate recommendations that are more common when this type of approach is first implemented.

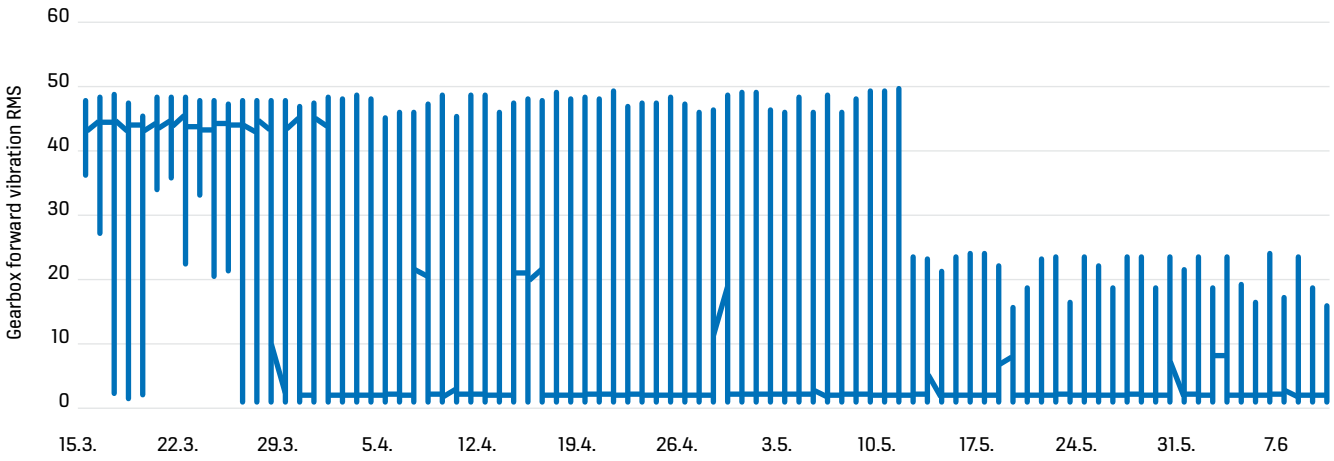
Translating valuable insights into actions

The goal of connected maintenance is to combine the new paradigm of real-time equipment data with expert knowledge from the old paradigm in order to generate valuable insights and translate them into clear actions together with the public transport operator. By improving the quality, speed, and effectiveness of VHTS maintenance, this kind of approach supports public transport operators' goals of ensuring safe, efficient people flow across increasingly busy mass-transport networks.

In the future the goal is to leverage digital technologies in order to both speed up and improve diagnostic work to provide as much information as possible about a problem before any decisions are made about next steps. Nonetheless, when it comes to preventive actions such as adjustments, parts replacement, and cleaning of equipment there is still a very human element needed. Qualified technicians and service experts are still a key part of the equation – AI is merely present in a supporting role.



CASE EXAMPLE:
GEARBOX VIBRATION MONITORING ENABLES EARLY DETECTION OF ESCALATOR MOTOR REPLACEMENT NEED



Let's look at a real case example from an airport customer with 15 escalators connected to KONE 24/7 Connected Services with a full sensor-based solution.

In this case, the gearbox vibration sensors installed in escalator A clearly indicated that the motor was vibrating at levels much higher than the motors in the comparison group of 14 escalators, all of which were installed at the same time, and operating in the same environment with a similar traffic load.

A technician was dispatched to investigate, and they determined that a single broken motor bearing was the cause of the abnormally high levels of vibration. With this information at hand, KONE was able to proactively plan the motor replacement process well in advance, including sourcing the parts, and labor, and ensuring that the necessary lifting equipment would be available.

The work, which took just four hours, was performed outside of the airport's standard operating hours in order to minimize disruption to passenger flows. Had the problem not been detected early and the motor left to run to failure point, resulting in a breakdown, the process would have required four days instead of four hours. And had the escalator been an older piece of equipment, or the correct spare parts not available immediately on site, sourcing the parts could have potentially extended the repair timetable by weeks.

Indirect benefits of motor replacement

After the motor replacement, **the friction level of the handrail decreased by 50–60%**, clearly improving its lifespan. The friction level decrease was detected with sensors installed on the handrail.

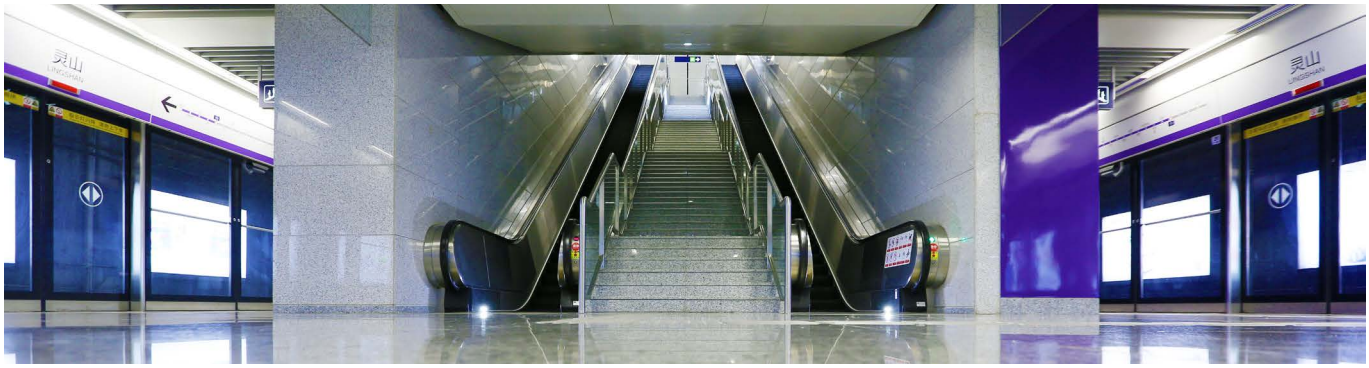
We also saw a **7% reduction in no-load power consumption**. Taking into account the total power consumption for the months before and after the replacement, this equates to an annual power consumption reduction of 2800 kWh, or €560 in power costs –about the same amount of electricity needed to power an apartment for a year.

Lastly, there was a **17% reduction in noise levels**, increasing ride comfort for passengers.

Typical early indicators of escalator faults

A connected maintenance solution provides the opportunity to automatically detect early indicators of faults or safety risks that escalator users rarely report. These can include:

- Problems with core running components
  - Handrail bearing failed or over-tensioned, causing increased handrail temperature
  - Step band misalignment or rusty chain, generating increasing noise
- Immediate indications of safety risks
  - Braking distance increases
  - Speed difference between handrail and step band
- Stopped equipment
  - Stopped due to electrical system protection
  - Stopped due to foreign objected entrapped in step band or comb plates
- Problems with key components
  - Drive station unstable: excessive vibration detected in gearbox
  - Oli degradation: temperature increase detected in gearbox

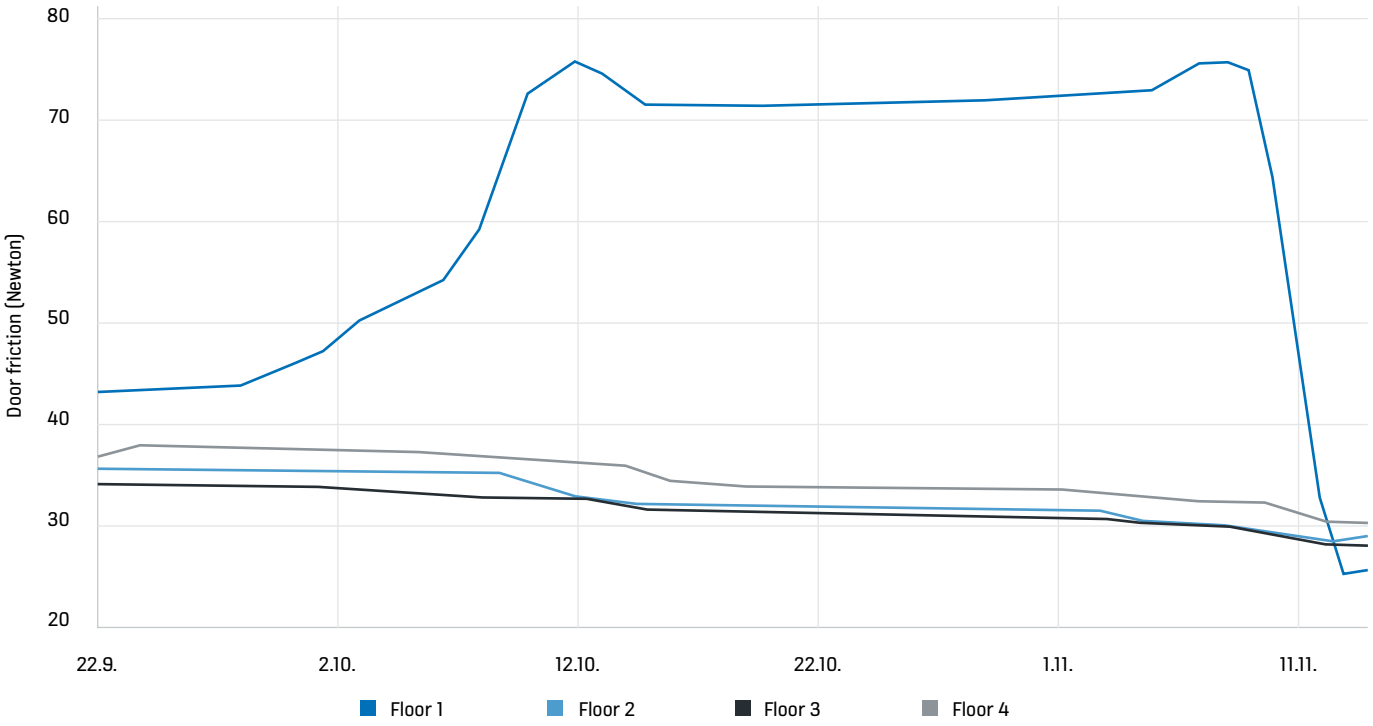


CASE EXAMPLE:
EARLY DETECTION OF ELEVATOR DOOR FRICTION ISSUES

To illustrate how connected maintenance adds value for elevator operations, we can focus on one of the most failure-prone elements: the automatic doors. Elevator doors are subject to heavy usage, opening and closing several hundred times a day in busy buildings. When we analyze the technical causes of elevator failures, a significant proportion are door related.

To a certain extent these issues can be mitigated with a robust preventive maintenance plan, but with traditional approaches field technicians can often find it difficult to pinpoint where to focus their efforts in terms of the landing doors. With a solution such as KONE 24/7 Connected Services, because information is continuously gathered from several data points on each individual floor. This information is fed to the technicians visiting the site, helping them to focus on the landing doors that require most attention.

The graph below shows an example of a door friction data series gathered for an elevator over a period of months. It can clearly be seen that the door friction is increasing on floor 0 compared to other floors over time. KONE 24/7 Connected Services detected this abnormality and guided the technician to perform preventive maintenance actions during the next scheduled maintenance visit, thereby preventing potentially more serious problems from occurring in the future that would have resulted in an extended period of downtime.



CONCLUSION

Connected maintenance approaches, which bring together old and new maintenance paradigms and leverage the power of digitalization, offer operators a tremendous opportunity to significantly improving the efficiency and effectiveness of their maintenance processes.

Combining data gathering and analytics technologies such as AI and cloud computing with an existing maintenance knowledge base and equipment reference data makes it possible to more easily identify anomalous behavior and generate valid recommendations for action. In terms of maintenance planning, by providing full visibility over equipment-specific usage profile data a connected maintenance approach makes it easier to schedule maintenance so that it results in minimal or even zero disruption to passenger flows.

KONE's 24/7 Connected Services solution, first launched in 2017, is a successful example of how a connected maintenance approach has been applied in the field to improve the quality, speed, and effectiveness of VHTS maintenance. The solution is already supporting several public transport operators in achieving their goals of ensuring safe, efficient people flow across increasingly busy networks.

ABOUT KONE

KONE is an innovative leader in the elevator and escalator industry. The purpose of public transportation is to provide safe, reliable, and eco-efficient ways for people to move within and between cities – and this aligns perfectly with KONE's long-standing mission: to improve the flow of urban life.

In public transportation, reliability, accessibility, maintainability, and safety are the key priorities. By identifying the right blend of equipment and services we help cities and transport-system operators to meet citizens' expectations and enable a better quality of life for all.

Working closely with partners and customers around the world, we deliver value for all the stakeholders involved, including the owners, developers, and operators of public transport systems. Metro and railroad stations and mixed transport hubs all have unique people flow requirements, so it our job to help customers to fulfill the vertical and horizontal transportation needs of these demanding environments.

Keeping everything running on time is all about optimizing the design, equipment, and services according to the project in question. With our planning and consulting services we can add value right from the early stages of the project life cycle by optimizing vertical and horizontal flows to ensure smooth, safe movement of people around the clock. During construction and commissioning our world-class project management capabilities and dedicated team of experts help to keep everything running smoothly, on schedule, and on budget.

In order to contribute to a better quality of life in urban environments, public transportation systems need innovative, eco-efficient, and durable solutions that are tailored to their precise needs. Our solutions include elevators, escalators, and automatic building doors – all of which can be kept running smoothly around the clock and help to enhance asset management with smart services that enable predictive, proactive maintenance.

Our solutions can be seen in use in some of the world's busiest and most complex public transport systems – such as Washington, London, Singapore, and Shanghai – helping to deliver safe, reliable people flow that keeps people and cities moving around the clock.

KONE Corporation

Corporate offices

Keilasatama 3
P.O. Box 7
FI-02151 Espoo
Finland
Tel. +358 (0)204 751

www.kone.com