Algorithm-based data analytics for lifts

How data analytics can elevate your lift operations to the next level of efficiency

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1. From pain to gain: challenges of the lift industry and the benefits of digitalization

A lack of transparency and growing technological complexity are increasingly challenging the business of lift operators, original equipment manufacturers (OEMs), and service providers. Why is this happening? With every new innovation cycle, it is getting harder to maintain lift safety and availability with the current practice of conventional failure diagnosis and predominantly reactive maintenance regimes.

1.1 The lift operator’s perspective

In the event of a lift failure, it is still uncommon for operators to automatically receive the relevant information directly from the lift or its control system. Instead, the process of issue reporting is often left unmanaged and relies on the informal flow of information between building occupants and facility managers. When the information is finally received and maintenance activities are proposed to the building owners, they face the challenge of validating these activities in terms of necessity, scope, cost appropriateness, technical effectiveness, and economic efficiency. Generally speaking, operators often lack a more solid basis for decision-making in order to determine optimal maintenance activities required to avoid lift failures and downtime.

Safety is another essential concern for operators. Issues can arise when even sufficiently trained and experienced technical professionals work under time pressure.

Is there a better way to maintain lifts? There certainly should be, especially given the rapidly increasing number of high-rise buildings being constructed to address growing urbanization needs. While in smaller buildings lifts may be a matter of extra comfort, in high-rise buildings they are a crucial asset fundamental for the proper functioning of these multistory structures. Operators can greatly benefit if lift availability and safety issues resulting from unexpected incidents are prevented and if a consistent quality of maintenance is ensured. For this to happen, lift operation parameters must be monitored, analysed, and interpreted objectively and reliably.

1.2 The challenges of OEMs and maintenance service providers

On their part, OEMs and service providers face challenges such as high prime costs of maintenance services and a shortage of qualified personnel. In the service contracts they offer, OEMs guarantee customers high lift operation availability. Therefore, they have to find ways to fulfil their contract obligations while also keeping their business profitable. For that purpose, OEMs and service providers turn to digital solutions that could bring a return on investment (ROI) by reducing the
number of on-site maintenance visits and streamlining operational processes and workflow.

1.3 Operators and OEMs – complementary parties with common pain points

To sum it up, operators and OEMs/service providers have the following pain points in common:

- Lack of maintenance transparency and difficulty assuring its consistent quality
- Deficit of objective and reliable data for decision-making and lack of valid indicators for operational planning
- Unpredictable occurrence, frequency, and duration of lift malfunctions and downtimes
- Unavailability of consistent, real-time information on the operational status and utilization of lifts
- Predominantly reactive maintenance regimes or expensive preventive maintenance based on long checklists instead of proactive and need-oriented maintenance planning
- Heavy reliance of maintenance activities on random sampling and visual inspection
- Shortage of skilled and experienced lift maintenance professionals
- High costs of physical, on-site maintenance service in light of growing technological complexity and narrowing time frames
- Need for objective and reliable interpretation of the lift’s key performance indicators.
1.4 TÜV SÜD and Bosch.IO: joint expertise turns pains into gains

How can we resolve these pain points? This can be achieved through a combination of the following competencies:

- **The Internet of Things (IoT) know-how**: expertise in connecting physical objects through sensors; collecting data on their status, condition and utilization; processing the data and presenting it in a ready-to-use graphical form.

- **Data analytics and data science know-how**: expertise in generating insights from the collected data using scientific methods and approaches such as probabilistic networks, algorithms, and artificial intelligence (AI).

- **Lift domain know-how**: expertise in industry normative requirements, lift technology, technical design and functions, and operational processes.

Due to the diverse nature of these competencies, it is highly unlikely that a single company can reliably cover them all. The core competencies of companies developing lift digitalization solutions usually include only one or two of the above fields.

As a result, there are presently two observable market trends in integrated lift monitoring solutions: Some solution providers invest in developing a missing competency from scratch, which is a costly and time-consuming exercise. Others enter into strategic partnerships that pool expertise to bundle different core competencies and create a solution. The latter is precisely the approach TÜV SÜD and Bosch.IO chose to develop the integrated Lift Manager solution.

![Figure 1: Interdisciplinary approach](image)
2. Overview of the Lift Manager solution

2.1 A universal solution for operators, OEMs, and service providers

The Lift Manager solution is the result of a systematic synergy of expertise in the Internet of Things by Bosch.IO with lift domain knowledge and associated data analytics/data science expertise by TÜV SÜD. This comprehensive solution provides three key capabilities that lift operators and OEMs can benefit from:

- ✓ Remote monitoring of lift operations
- ✓ Anomaly detection and alerts
- ✓ Predictive analytics for better targeted maintenance planning.

Thanks to non-invasive retrofits of a sensor node on top of the lift car, the solution can be applied to new or existing lifts regardless of their brand or model.

In addition, the Lift Manager’s edge computing capabilities and its configurable standard APIs ensure easy integration with other solutions and provide a high level of flexibility to the customer.

With all these capabilities, the Lift Manager offers lift operators, OEMs, and service providers a remarkable advantage of bringing an entire lift portfolio under the umbrella of a single IoT solution for the optimization of both lift operations and maintenance activities.
2.2 From individual expertise to a comprehensive knowledge base

Up until now, many lifts are still maintained through physical checks and visual inspections. Quality and efficiency of such maintenance services are often inconsistent as they are determined by the skills and experience of lift technicians and the amount of time at their disposal. The Lift Manager is designed to resolve this issue through the digitalization of this implicit expertise and its conversion into a virtual knowledge base.

Consequently, all lift industry stakeholders can benefit from improved efficiency and productivity while increasing safety and availability of every single lift in their lift portfolio. The use of customized sensors, data-crunching edge computing, highly available cloud services, and sophisticated, AI-backed data analytics are fundamental differentiators of the Lift Manager.

2.3 Capabilities of the solution

Let us take a closer look at the main functions and capabilities of the Lift Manager solution and the benefits they provide.

Operation monitoring

Centralized, remote, around-the-clock monitoring of lift condition, utilization, and ride comfort

The Lift Manager system continuously monitors key performance indicators of the lift and collects data on its utilization. The operation monitoring function provides a sweeping view of all major operating parameters and physical characteristics of the lift and its components. Among other important parameters, it includes trips, door movements, mileage, vibrations, and environmental conditions. Criteria related to the passenger’s comfort, such as jerk and acceleration/deceleration, are also monitored. Operators can see current data and historical trends on the dashboard. This information is later used as a basis for predictive maintenance.

Anomaly detection

Real-time anomaly detection and immediate alerts to notify appropriate personnel of critical events

The Lift Manager promptly detects lift parameters that fall outside the predefined range for normal lift operations. Typical examples are mantrap, incorrect leveling of the cabin floor, door opening and closing issues, and abnormal vibration or noise. The system immediately alerts appropriate personnel when a major problem occurs, thus significantly improving critical incident response time.
Predictive maintenance

The predictive maintenance module provides a breakdown forecast and identifies its likely root cause

The predictive maintenance module of the Lift Manager identifies and evaluates abnormal behavior or a change in operating parameters before the anomaly detection threshold is reached. It uses data interpretation to predict and detect initial and ongoing degradation processes before an actual failure occurs. This complex and advanced function of the Lift Manager offers customers a major advantage as it allows them to proactively schedule service interventions for lifts.

2.4 Providing added value

The Lift Manager goes beyond the usual problem-solving capacity of other solutions currently available in the market. Here are the additional benefits it provides:

Enhanced passenger safety and equipment availability:

- Continuous monitoring of lifts for operational anomalies and real-time emergency detection ensures higher safety standards
- Equipment degradation and failure prediction based on operational, environmental, and secondary data secures passenger safety and lift availability by prompting action before a breakdown happens

Cost savings:

- Minimization of wear and tear of lifts and components with real-time monitoring and predictive maintenance functionality
- Reduction of equipment life cycle costs by ensuring high-quality maintenance with the help of AI algorithms and by avoiding premature refurbishment or unnecessary part replacement works

Process optimization:

- Ability to do more with existing workforce thanks to better workload planning, with advance information on necessary repairs and reduced time spent on site
- Overall optimization of maintenance planning, scheduling, and regime
An independent interface for connecting lifts of all types:

✓ Universal fit regardless of lift type – the Lift Manager can be installed on any lift brand or model as a retrofit solution; lifts of different manufacturers can be monitored centrally through a single dashboard

✓ Single point of access for authorized personnel as lifts across different properties are connected through a single interface and are accessible at all times from any location

A step toward autonomous buildings

✓ A shift from the current practice of on-site maintenance checks towards remote, real-time monitoring and breakdown prediction with an accuracy of more than 80 percent.

3. How the solution works

Implemented in an advanced IoT environment, sensors on top of the lift car record key operational parameters in real time. Examples for sensor-tracked parameters are three-dimensional acceleration and environmental conditions such as air pressure or magnetic field alternations. These parameters are later processed, interrelated via the sensor fusion process, and fitted into threshold-based patterns and conditional networks. This upfront process enables lean and efficient data processing for complex analysis. Another major benefit of edge processing is a significant reduction in data transmission volume and thus a reduction of related costs.

In addition, sophisticated middleware and the backend IoT device management system facilitate reliable data communication without data loss and enable remote management of the hardware installed on lifts including firmware over-the-air updates (FOTA), device monitoring and troubleshooting.

Data is transferred over the air to the corresponding cloud service via an IoT gateway. There, it is processed accordingly by means of rule-based algorithms, advanced probabilistic models, and AI applications. Finally,
the results are made available to the user via an interactive dashboard interface. The role-specific user interface is designed to conform to system-ergonomic and software-ergonomic principles that make the user’s work more efficient and comfortable.

4. The brain of the Lift Manager

This chapter illustrates the approach TÜV SÜD followed when developing the Lift Manager’s “brain” – the analytics engine – and covers its functionality and features.

The analytics engine of the Lift Manager is a highly modular and configurable software system that delivers universal condition monitoring and predictive maintenance capabilities for lifts connected through the IoT.

4.1 A two-tiered approach to analytics

The Lift Manager refrains from a solely inductive approach that relies exclusively on data-driven probabilistic interpretations. For the Lift Manager, TÜV SÜD developed a two-tiered analytics approach that integrates a common inductive approach with a deductively derived logic structure system. This is done through systematically combining the domain expertise on what has happened and what will happen in lift operation with collected empirical data and data analytics procedures.

This is a completely new way of evaluating and pre-interpreting data that provides highly reliable, valid, and accurate results and predictions after only a short system “learning” time.

This special deductive logic structure is labelled Lift Scenario Library (LSL) as it uses probabilistic approaches of the Fault Tree Analysis (FTA), following EN 61025\(^1\) and Event Tree Analysis (ETA), and NUREG CR-2815\(^2\) requirements. The LSL contains systematically related and elaborated data on lift failures, defects, and deficiencies that TÜV SÜD has been gathering for over 80 years as part of their testing, inspection, and certification business. This logic structure system serves to perform pre-channelling for interpretation of observed lift events and data processes in terms of relevance and significance.

Moreover, it also provides concrete maintenance recommendations prioritized according to the analysis performed by the predictive maintenance module.

This is a clear differentiator of the Lift Manager as compared to other IoT solutions for digitalization of lift operations.

\(^1\) BS EN 61025. Fault Tree Analysis (FTA)
4.2 The Remaining Time to Downtime indicator

When a potentially abnormal process is detected, the Lift Manager’s predictive maintenance module sends an alert to the dashboard. The alert indicates when a related lift component or subsystem is expected to fail. This information is displayed in a dedicated area of the dashboard as the Remaining Time to Downtime (RTD).

The RTD indicator has three priority categories to specify the urgency of a required intervention:

- **Green status**: low urgency; the recommended maintenance actions should be taken in one of the subsequent monthly maintenance checks
- **Orange status**: normal urgency; the recommended actions should be taken in the next scheduled maintenance check
- **Red status**: high urgency; the recommended actions should be taken immediately to prevent a lift breakdown

![Figure 3: The Remaining Time to Downtime (RTD) alerts](image)

**Case study**
Scan to learn how a business park in Singapore is managing its diverse lift portfolio
4.3 Precise recommendations on how to avoid an upcoming breakdown

Further to this, the Lift Scenario Library (LSL) provides specific actionable insights derived from observed or predicted events:

- **LSL root causes**
  For each observed or predicted lift anomaly a link is established to its root cause or root cause scenarios. A component identified as faulty can then be repaired or replaced before a failure occurs, thus avoiding an impact on passenger safety and lift availability.

- **LSL recommended actions**
  Each abnormal event, together with its set of root causes/root cause scenarios, is linked to the priority list of recommended maintenance actions. This allows operators to effectively plan ahead for a required maintenance intervention.

![Figure 4: The two-tiered analytics process of the predictive maintenance module](image)

4.4 The system that keeps learning

In addition to the vast common knowledge base available, the Lift Manager is capable of learning from and adapting to the particular customer’s environment.

As soon as the system is installed, its algorithms start learning from the sensor readings and prediction validations collected by the specific system installation. This allows for even higher prediction and recommendation accuracy over the course of time. The Lift Manager’s observations and predictions are verified through on-site validations and evaluation of the actual maintenance data conducted by lift inspectors and experts. Methods such as pattern recognition and machine learning continuously improve prediction accuracy and extend the horizon, so the longer the system is in use, the finer it is tuned for the specific customer’s environment. Altogether, these methods help establish a highly reliable monitoring and prediction system within just a few months.
5. Conclusion

The Lift Manager solution is a comprehensive combination of the IoT know-how of Bosch.IO with the independent and integrative approach of TÜV SÜD that fuses data analytics and lift domain expertise. With its elaborate data analytics methodology and domain-specific analytics engine, the Lift Manager offers lift operators, OEMs, and maintenance service providers:

- a powerful and high-performing integrated system for remote lift condition monitoring and predictive maintenance
- an independent, third-party solution by a globally acknowledged lift testing and inspection organization that is universally applicable to any lift portfolio
- the technical expertise of Bosch.IO as a recognized global player in the IoT field, integrating software, sensors, and cloud services
- more than 80 years of TÜV SÜD experience in lift inspections crystallized in the state-of-the-art Lift Scenario Library.

Disclaimer: The Lift Manager cannot and must not be used to replace any safety or emergency functions of the lift. As it is completely independent from the lift and its constituting components, it does not in any way replace nor modify any functions of the lift. The information provided in this white paper is for general informational purposes only. TÜV SÜD and Bosch.IO reserve the right to modify the solution specifications without prior notice. For the latest information on the solution please get in touch with us via the email addresses provided below.
About TÜV SÜD

Add value. Inspire trust. TÜV SÜD is a trusted partner of choice for safety, security and sustainability solutions. It specialises in testing, certification, auditing and advisory services. Since 1866, the company has remained committed to its purpose of enabling progress by protecting people, the environment and assets from technology-related risks. Through more than 24,500 employees across over 1,000 locations, it adds value to customers and partners by enabling market access and managing risks. By anticipating technological developments and facilitating change, TÜV SÜD inspires trust in a physical and digital world to create a safer and more sustainable future.

As a classic domain expertise provider in the field of TIC services, TÜV SÜD has always been closely linked to its customers and partners. We rely on the knowledge of >100 years and a worldwide pool of >550 experts in the field of elevators. Typical in this business are the independent inspection, acceptances and evaluation of elevator components as well as complete elevator systems. We conduct ~300,000 inspections annually.

Contact us for more information:
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About Bosch.IO

Bosch.IO GmbH combines the full set of consulting and implementation skills to deliver IoT and digital projects, focusing on the retail, energy, building, industry, consumer goods, agriculture, and mobility sectors. Bosch.IO has 900 experts on board, including consultants, coaches, cloud software developers, digital marketers, UX and business model designers, solution architects, and project managers. The interdisciplinary team works together at locations in Germany, Bulgaria, Spain, Japan, China, Singapore and the U.S. to serve customers around the world. Drawing on a broad base of industry knowledge and a deep well of software expertise, this Bosch company has proven its merits in more than 250 IoT projects.

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