ELEVATOR DIGITAL TWIN FOR HIGH RISE BUILDING AND SPECIAL HOIST WAY ATMOSPHERES

Jegan. M, Vinoth Rajendran and Mohammed Rizwan. M

KEYWORDS: Digital Twin, Design, Testing and Qualification

ABSTRACT:

The integration of digital twin technology in elevator systems offers a groundbreaking approach to enhancing the design, testing and qualification of elevators in high-rise buildings and special atmospheric conditions. Digital twin technology creates a virtual replica of physical elevator systems, enabling realistic testing and optimization of performance. This paper explores the application of digital twins in the context of high-rise buildings, where elevators face unique challenges such as increased mechanical stress, greater energy consumption, and the need for enhanced safety measures.

In the design phase, digital twin models allow engineers to simulate various operational scenarios, providing insights into potential issues and allowing for design refinements before elevator construction. This proactive approach enhances safety and reliability by ensuring that the design is robust and optimized for the building's specific requirements.

For testing and qualification, digital twins provide a virtual environment to simulate and evaluate elevator performance under various conditions. This capability enables thorough testing without physical prototypes, saving time and resources while ensuring compliance with safety and performance standards.

In special atmospheres, such as those with extreme temperatures or corrosive environments, digital twins provide a crucial advantage by enabling continuous monitoring and adaptation to the changing conditions.

The paper concludes by highlighting the potential of digital twin technology to revolutionize the elevator industry, offering significant benefits in design, testing and qualification. By leveraging digital twins, our proposition is that customers can achieve a more sustainable and resilient elevator infrastructure, well-suited to the demands of modern high-rise buildings and special atmospheric environments.

1. INTRODUCTION

The rapid advancement of digital technologies has significantly transformed the engineering and manufacturing industries. Among these innovations, digital twin (DT) technology has emerged as a powerful tool to bridge the physical and virtual worlds, enabling real-time monitoring, simulation, and optimization of complex systems. Originally applied in aerospace and automotive sectors, DT is now gaining traction in vertical transportation, especially in the context of elevator systems.

Elevators in high-rise buildings face unique engineering challenges, including increased **mechanical stress**, **traffic patterns**, **energy consumption concerns**, and **stringent safety** requirements. These challenges are further compounded in special hoist-way atmospheres, such as coastal environments prone to corrosion, underground shafts with high humidity, or regions with extreme temperatures.

To address these challenges, the integration of digital twins into elevator systems offers a groundbreaking approach. By creating a virtual replica of the elevator, including its mechanical components, control systems, and environmental interactions, engineers can simulate real-world conditions, test various scenarios, and refine designs before physical implementation. This proactive strategy enhances the quality and robustness of elevator solutions while reducing the need for costly physical prototyping and testing.

This paper explores the application of digital twin technology in the elevator industry, with a focus on high-rise buildings and special hoist-way conditions. It highlights how digital twins can improve the design, testing, and qualification processes, and ultimately, enhance system performance and user safety. The insights presented here aim to contribute to the ongoing digital transformation of vertical transportation systems.

2. Digital Twin Technology in Elevator Systems

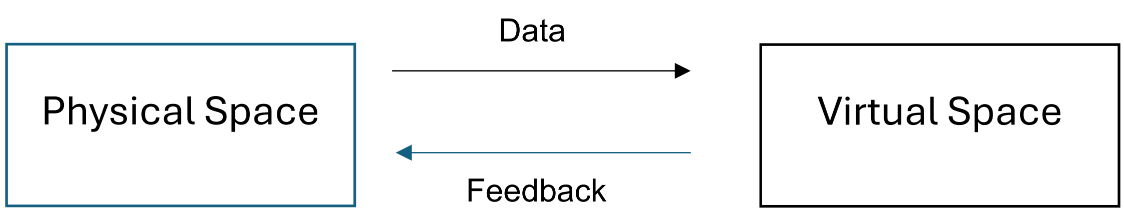

Figure 1. The Schematic Block Diagram

As shown in schematic block diagram, virtual space uses data from the physical space as input. The physical space uses information from the virtual space. Thus, there is a bidirectional connection between physical space and virtual space. Figure & Figure shows an overview of how digital twin technology can be integrated or implemented in our elevator systems.

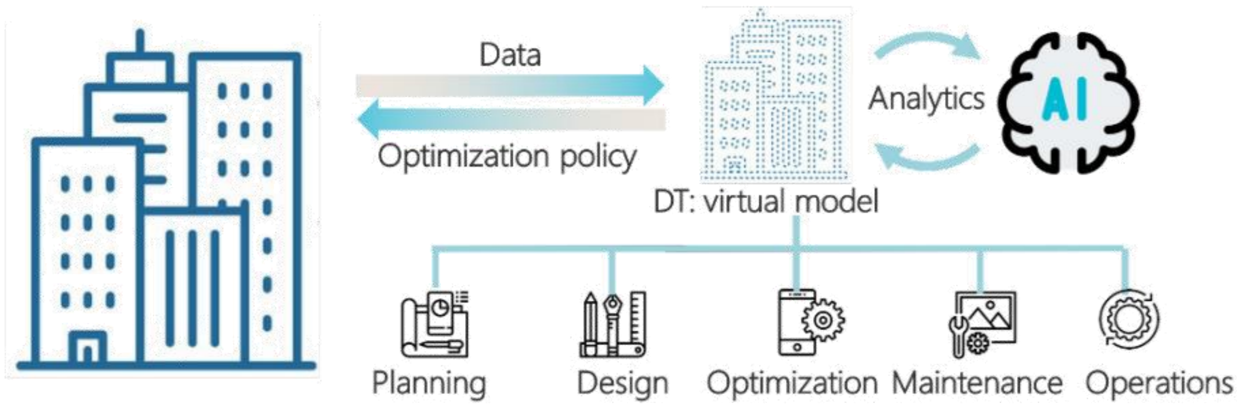

Figure 2

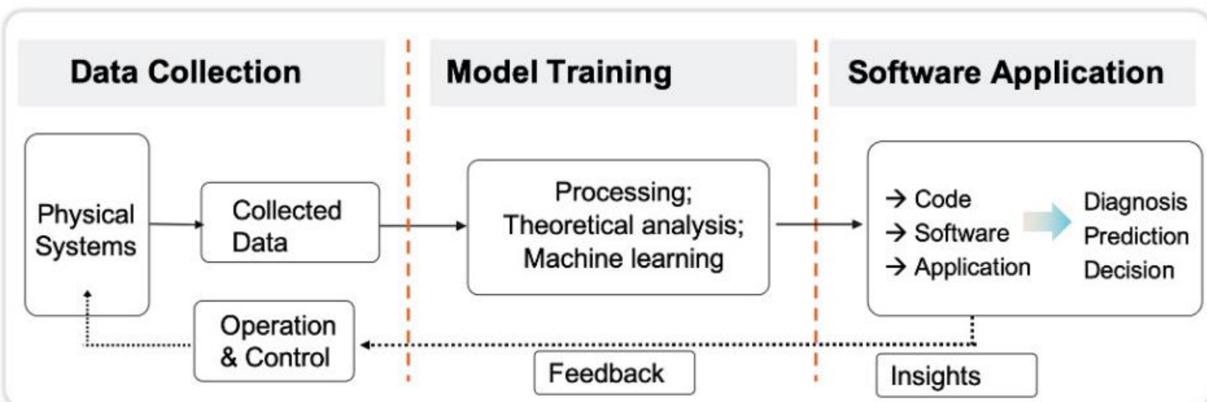

Figure 3

3. The Gap or the Challenges with the Traditional Method

Testing elevators in very tall buildings is challenging because:

- Buildings are reaching new heights, but test towers worldwide are still catching up to the tallest structures.
- Real-world validation involves substantial investment in terms of time and money.
- It can be challenging to recreate real conditions like wind, earthquakes, or temperature changes.

[1]

Traditional Method **Digital Twin technology**

Figure 4

With digital twins, engineers can assess all this virtually. They could find and fix problems early, improve safety, and make sure the elevator works optimally before it is even installed. This saves time, reduces costs, and ensures better performance, especially in skyscrapers.

4. Testing and Qualification with Digital Twin Technology

The testing and qualification phase is critical in ensuring that elevator systems meet safety, reliability, and performance standards before they can be deployed in

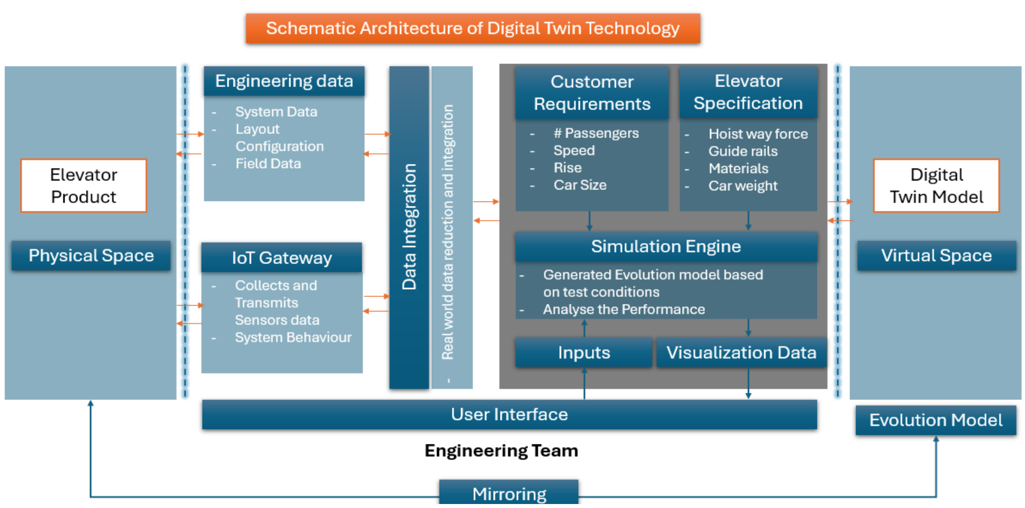

Figure 5

---

[1] Disclaimer: All AI-generated images used in this publication are for conceptual illustration only and were created using publicly available generative tools (Copilot). No real-world entities, individuals, or proprietary data are represented.

real-world settings. Traditional testing methods often rely on **physical prototypes and on-site commissioning, which can be time-consuming and costly.** Digital twins offer a transformative approach by enabling virtual testing environments that accurately simulate real-world conditions and scenarios.

4.1 Data Is Needed to Create a Digital Twin of an Elevator

To replicate a physical elevator system virtually, we need three main categories of input.

a. Design Data

- **CAD files**: 3D models of elevator components (car, shaft, counterweight, motor, etc.)
- **Mechanical specifications**: Dimensions, weight, material properties
- **Electrical schematics**: Motor ratings, brake systems, control panels

b. Operational Data

- **Sensor data**: Real-time or historical data from installed sensors
    - Speed, acceleration, jerk
    - Load weight
    - Temperature (motor, shaft)
    - Vibration and noise
    - Door cycle timing
- **Control logic**: Dispatch algorithms, emergency protocols, door operations

c. Environmental Context

- **Building layout**: Number of floors, shaft geometry
- **Ambient conditions**: Temperature, humidity, wind pressure (for external shafts)
- **Usage patterns**: Passenger flow, peak hours

4.2 Required Software for a Digital Twin

<u>Utilization of Existing Platforms:</u>

Below is a non-exhaustive list of popular platforms which support digital twin development:

- **Siemens NX / Teamcenter**
- **PTC Thing Worx**
- **Dassault Systems 3DEXPERIENCE**
- **Azure Digital Twins (Microsoft)**
- **Ansys Twin Builder**

These platforms allow us to:

- Import CAD models
- Connect sensor data streams
- Run simulations
- Visualize and analyse performance

4.3 Custom Development

<u>If the system is unique or needs full control:</u>

- Develop a custom application using tools like:
  - Unity or Unreal Engine (for visualization)
  - Python or MATLAB (for simulation and analysis)
  - OPC UA or MQTT (for real-time data integration)
- Need to build:
  - A simulation engine
  - A data ingestion pipeline
  - A user interface

4.4 How is Data Transferred to the Digital Twin?

1. **Sensors on the elevator** collect real-time data.
2. **IoT gateway** aggregates and transmits data.
3. **Cloud or edge computing platform** receives and stores data.
4. **Digital twin engine** uses this data to update the virtual model.
5. **Simulation and analytics tools** process the data for insights.

<u>Protocols used:</u>

- **MQTT / OPC UA / REST APIs** for data transfer
- **CSV / JSON / XML** formats for structured data

4.5 Case Study: Emergency Stop Simulation Using Digital Twin Technology

High-rise elevator systems are critical for vertical transportation in modern urban infrastructure. Ensuring their safety during emergency scenarios, such as sudden power failures, is essential. Traditional physical testing methods are often constrained by high cost of failure, limited access to full-height test towers, and high operational costs. This case study explores the use of digital twin technology to simulate and validate emergency stop performance in a high-rise elevator system.

Objective: Evaluate the dynamic response and safety compliance of a high-rise elevator system during an emergency stop triggered at the 60th floor under an 80% passenger load, using a digital twin simulation framework.

a) System Configuration

- **Elevator Speed**: 3 m/s
- **Passenger Load**: 80% of rated capacity
- **Trigger Event**: Simulated power failure at the 60th floor

b) Digital Twin Model

The digital twin incorporates:

- **Mechanical Components**: Elevator car, counterweight, traction system
- **Electrical Subsystems**: Motor, brake system, control logic
- **Environmental Factors**: Shaft geometry, ambient temperature

c) Simulation Engine

- Brake engagement and deceleration profile modelled using dynamics models
- Real-world sensor data used for calibration:
  - Brake response time
  - Cabin sway dynamics

- Passenger load distribution

d) Results & Analysis

- All performance metrics met or exceeded safety and comfort standards.
- Minor cabin sway was observed post-stop.
- Root cause analysis identified delayed counterweight damping as the source of oscillation.
- Additional details on the case study analysis may be provided upon request. Contact jegan.m@otis.com

f) Feedback:

- Integrate passive sway dampers into the cabin suspension system.
- Update control logic to pre-activate counterweight brakes during emergency deceleration.

d) Conclusion

This case study demonstrates the effectiveness of digital twin simulations in evaluating elevator safety under emergency conditions. The approach provides a reliable, scalable, and cost-effective alternative to physical testing, enabling rapid design iteration and predictive maintenance strategies

5. Benefits of Digital Twin Adoption

The adoption of digital twin technology in elevator systems marks a significant evolution in the way elevators are designed, tested, operated, and maintained. It moves the industry from a physical-prototype-driven approach to a proactive, simulation-based paradigm that emphasizes efficiency, safety, and long-term reliability.

5.1 Futuristic Opportunities

The role of digital twins in elevators is only beginning to evolve. Key future developments include:

- Integration with Building Digital Twins
- AI-Driven Optimization

- Edge Computing and 5G
- Sustainability Analytics
- Digital Twin Marketplaces

6. Conclusion

The integration of digital twin technology into elevator systems, particularly for high-rise buildings and special hoist-way atmospheres, represents a transformative shift in the elevator industry's approach to engineering and operations. By creating a dynamic, virtual replica of the physical system, digital twins empower designers, engineers, and maintenance teams to simulate, analyze, and optimize elevator performance throughout its lifecycle.

From enhanced design flexibility and virtual testing to predictive maintenance and adaptive control in harsh environments, digital twins could offer measurable benefits in safety, efficiency, cost reduction, and user experience.

As technology matures, digital twins will play an increasingly central role in the future of smart buildings, enabling elevators to become systems more intelligent, responsive, and data-driven assets that adapt to evolving demands.

In conclusion, embracing digital twin technology is not just a technological upgrade, but it is a strategic imperative that can redefine the standards of performance, reliability, and innovation in vertical transportation systems.

7. References

1. EN 81-20:2020 – Safety rules for the construction and installation of lifts – Lifts for the transport of persons and goods. European Committee for Standardization (CEN).
2. Glaessgen, E. H., & Stargel, D. S. (2012). *The Digital Twin Paradigm for Future NASA and U.S. Air Force Vehicles*. AIAA.
3. Zhuang, Y., et al. (2020). *Digital Twin-based Smart Elevator System for Predictive Maintenance*. IEEE Access, 8, 193895–193905.
4. ISO 18738-1:2012 – *Measurement of ride quality – Part 1: Lifts (elevators)*.

5. Zhang, Y., & Wang, L. (2021). *Multi-physics Simulation of Elevator Systems Using Real-Time Sensor Data*. Journal of Building Engineering, 44, 103313
6. Boschert and R. Rosen, “Digital Twin—The Simulation Aspect,” in Mechatronic Futures, Springer, 2016, pp. 59–74.

BIOGRAPHICAL DETAILS

M. Jegan is an experienced Engineering Manager currently working in OTIS India at Bangalore. With a strong background in elevator systems and technology integration, he plays a key role in driving innovation and operational excellence. His work focuses on leveraging emerging technologies such as enhance elevator design, Layout and contract management.

Vinoth Rajendran is a seasoned engineering professional with expertise in elevator design and mechanical systems. As Assistant Manager at OTIS India Limited, he leads global module harmonization, innovative design strategies, and product portfolio optimization, while pursuing a B.Tech at Birla Institute of Science and Technology.

Mohammed Rizwan M is a seasoned engineering professional currently serving at OTIS Elevator India, based in Bangalore. With deep expertise in elevator systems and technology integration, he plays a pivotal role in fostering innovation and ensuring operational excellence. His work primarily focuses on benchmarking various elevator products and modules, contributing to the enhancement of elevator design and performance.