Enabling Innovation Through an Internet of Things (IoT) Platform that Operates Alongside the Lift Controller Without Modifying the Safety Chain

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Abstract. The vertical transportation industry is dominated by a small number of global players who have introduced many significant innovations. However, these have typically been deployed as proprietary systems, limiting wider adoption and preventing others in the industry from building upon them.

Various efforts have been made to increase accessibility and interoperability across manufacturers, particularly for self-contained subsystems where innovation is permitted within the bounds of applicable codes. More intelligent applications, however, often require interaction with the lift controller.

To improve interoperability, multiple initiatives have sought to standardise communication protocols between lift controllers and subsystem devices. Despite some of these efforts dating back decades, widespread adoption remains limited. In the absence of regulatory requirements, uptake depends on individual manufacturer strategy—many of whom favour fully integrated systems for reasons including product standardisation, subsystem coordination, and legacy compatibility.

This paper explores an alternative approach: enabling innovation through an Internet of Things (IoT) platform that operates alongside the lift controller without modifying the safety chain. The system architecture uses retrofittable edge devices that are compatible across different lift manufacturers and models to monitor door activity and passenger movement.

Designed for compatibility across manufacturers, models, and equipment generations, this approach creates new opportunities for integrating functions such as intelligent dispatching and people-flow analytics without relying on proprietary system access. By decoupling innovation from the core controller, it offers a scalable path towards greater openness and faster adoption of new technologies across the industry.

1 INTRODUCTION

Innovation can be open or closed depending on the extent to which an organisation needs or chooses to interact with a wider ecosystem. Historically, innovations were mainly closed, involving little communication or collaboration outside the organisation. In today's highly connected, networked, knowledge-based economy, open innovation is increasingly becoming a necessity to remain competitive as innovation cycles become increasingly shorter. Open innovation, by its very nature, requires knowledge exchange outside the organisation and in particular across the organisation's supply chain [1]. Essentially, open innovation leverages external relationships and collaboration to enhance systemic knowledge-sharing and drive innovation outcomes. Table 1 on the next page outlines the high-level differences between closed versus open innovation according to Chesbrough [1].

Table 1 Closed vs. Open innovation

Innovation Type	Intra-Organisation	Supply Chain	Wider Ecosystem
Closed	In-house research and development.	Joint research and development activities between two supply chain partners	Not Applicable
Open	Not Applicable	Co-development, IP-licensing, joint venture activities	Strategic partnerships, informal network, wider knowledge sharing

The global lift industry is traditionally characterised by its closed innovation, for which various reasons exist. Section 2 explores the current innovation dynamics in the lift industry. Nevertheless, the introduction of IoT-based technologies has and continues to have a profound impact on the innovation dynamics of the lift industry. Section 3 explores how the adoption of IoT is nudging the lift industry towards more open innovation. Subsequently, given the long lifespans and modernisation intervals of lifts, retrofit solutions are needed to make innovation accessible to the wider lift installed base. Section 4 explores how new innovations could be retrofitted on existing equipment if the safety chain is not impacted. Section 5 builds on the previous section by exploring possible practical applications from a technology viewpoint. Section 6 concludes this paper, summarising the key points.

2 CURRENT INNOVATION DYNAMICS IN THE LIFT INDUSTRY

The global lift industry is traditionally characterised by its closed innovation, for which there are various causes. This section will explore some of the common characteristics that drive the lift industry's tendency towards closed forms of innovations.

2.1 Limited need for innovation

Although records on the practical application of lifts can be traced back to the ancient Greek mathematician Archimedes of Syracuse in 236BCE [2] (recent studies trace it even further back to the construction of the Saqqara pyramid approximately 2500BCE [3]), lifts were not considered safe for use by people and therefore restricted in use for lifting materials. It was not until the invention of the lift safety brakes, which prevent lifts from falling down the shaft if the suspension cables fail, by Elisha Graves Otis in 1853 [4], that lifts became safe for use by humans. With the successive inclusion of electric motors since 1880 by Werner von Siemens [4] and automatically operated lift doors since 1887 by Alexander Miles [5], the public's confidence in the safe and convenient use of lifts increased, and the lift industry took off.

Lift design consolidated early on into a well-defined set of common elements: the cabin, counterweight, suspension cables connecting the two, rails to guide the cabin and counterweight, a motor hoist for the actual lifting, and, of course, the safety brake to prevent a free-fall from happening. Respectively, hydraulically powered lifts use a mechanism whereby a pump motor pumps hydraulic fluid into or out of a piston-cylinder, pushing a cabin up or facilitating a controlled descent from below, eliminating the need for suspension cables and a counterweight.

The consistency of the base design over time meant that there was little necessity for major innovations. Mostly, development was focused on gradually improving existing lift and subsystem designs. Wider cross-industry technology trends such as automation through electrification and later computerisation typically follow a gradual adoption curve in the lift industry. Although publicly available statistics are lacking, the development time for a new model lift is generally accepted to be between 5-7 years by industry professionals. Within this context, there was no need for the complexities typically associated with open innovation [6].

2.2 Few market leaders with a globally dominant position

A significant share of the global lift industry is dominated by a small number of players [7]. These dominant players are each characterised by a high degree of vertical integration, a business strategy where a company takes ownership of various stages of its production process to streamline operations and reduce reliance on external suppliers. This business strategy fostered the creation of highly integrated and manufacturer-specific systems and models.

Subsequently, innovation in the lift industry has been characterised by its closed nature. Research and development are mostly intra-organisational. Collaboration within the supply chain is typically limited towards how innovations from supply chain partners can be integrated into the lift manufacturer's next-generation lift model and certified accordingly. As a consequence, innovations by individual lift part manufacturers are not always compatible as a standalone innovation that is interchangeable between different lift manufacturers. Figure 2 below illustrates a simplified view of the lift industry value chain.

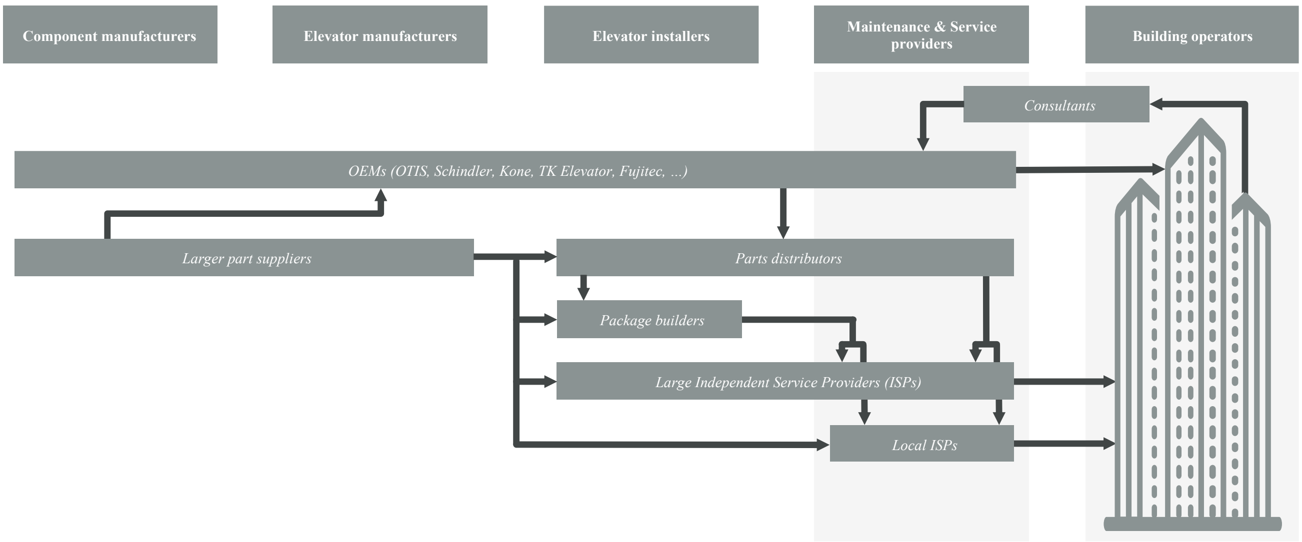

Figure 1 Simplified view of the lift industry value chain (illustration by the author)

2.3 Exclusivity and uniqueness as competitive advantages

Closed innovation of highly integrated certified systems arguably leads towards proprietary solutions by default (unless intervened by regulators or industry associations). As fewer companies became increasingly global dominant players within the lift industry, it is widely accepted that the make-up of the lift installed base evolved accordingly. Subsequently, it can be argued that the dominance of market leaders has now extended into the in-life phase of lift equipment; spare parts as well as more advanced troubleshooting capabilities are perceived as being dominated by the leading lift manufacturers. Therefore, no matter how minimised the effect, there will always exist a degree of dependency by independent players on the market leaders. Arguably, this dependency causes innovation barriers outside the control of independent players. Instead, incremental improvements of existing products catering to lift manufacturers is the typical path for smaller players across the supply chain.

Notwithstanding these dynamics, attempts are being made to mitigate the proprietary nature of the majority of lift systems. The conventional approach is to focus on the communication protocol. The lift control system is typically regarded as the proverbial “brain” of the overall system, meaning that for the lift to operate as an automated system, all subsystems need to be compatible with the respective lift control’s communication protocol. To date, there is not a globally harmonised lift communication protocol, though various cross-industry communication protocols have found wider adoption in the lift industry (e.g. RS232, RS485, CAN, Ethernet, …). To improve this situation, the non-profit CAN in Automation (CiA) association (established in 1992 and based in Nuremberg, Germany) developed the CiA 417 profile – more commonly referred to as “CANopen Lift” communication protocol – for lift control systems and released it in 2002. The goal was to agree on a common specification which enables suppliers to design interoperable CAN-connected devices for lifts [8].

2.4 Notable exceptions exist where science is applied through technology

Science refers to the systematic study of the natural world, while technology refers to the application of scientific knowledge for practical purposes. The relationship between science and technology can be seen as a two-way street; scientific discoveries lead to technological advancements, and vice versa, technological innovations drive scientific research.

The science behind lift dispatching is widely regarded as a field of study supportive of open innovation. The global lift community, as well as academia, has already collaborated closely for decades to further advance this field of study as well as its practical application through technology. However, in coherence with the lift industry’s characteristic closed innovation, solutions remained proprietary.

Fortunately, the introduction of IoT has opened up the lift industry to modes of cooperation more supportive of open innovation. Essentially, access to digital technologies was needed by the lift industry; however, these were not core to its typical area of domain expertise. Also, innovation cycles were much shorter, meaning that gradual incorporation of these technologies over time – as was the approach until then – was not a viable option. Cross-industry collaboration was therefore inevitable.

The next chapter will explore how the adoption of IoT is nudging the lift industry towards more open innovation. Subsequently, section 4 explores how IoT is crossing over into the domain of lift dispatching, enabling retrofit-based solutions for the existing lift installed base.

3 HOW THE ADOPTION OF IOT IS NUDGING THE LIFT INDUSTRY TOWARDS MORE OPEN INNOVATION

The introduction of Internet-of-Things (IoT) based technologies provided an opening towards more open innovation within the lift industry. IoT is a technology domain characterised by collaborative efforts and fast innovation cycles. The practical application of IoT continues to have a profound impact on our everyday lives and has subsequently found widespread adoption across industries. Like other internet-based technologies, its development is in a constant state of flux with limited standardisation and regulation. Due to these characteristics, the introduction of IoT technologies into the lift industry necessitated the market leaders to extensively collaborate outside their organisation.

Initially, the introduction of IoT into the lift industry was mostly regarded as an evolutionary step in remote lift monitoring – a technology that was well established since the early 1990s [9]. However, the open innovation ecosystem soon presented opportunities for IoT technology to be leveraged further. One such use case is the robot-lift interaction for autonomous robotic multi-floor operation [10]. Another use case is touchless lift access through a voice command using a cloud-based virtual assistant (e.g. Amazon Alexa) [11]. As the number of use cases keeps expanding, multiple market leaders have meanwhile introduced new, digitally native lift models such as EOX (TKE), DX-class (KONE), and the Gen3 (OTIS). With IoT first introduced at scale since 2015 [12], the lift industry has advanced significantly over the past 10 years.

As open innovation provided accelerated access to new technologies, scaling these necessitated another key enabler: finding a solution to retrofit the existing lift installed base. Although coherent statistics on the global lift installed base do not exist, Statista puts the number at 20 million lifts globally as of 2023 [13]. According to a related statistic by Statista, 1 million new lifts were added to the global installed base in 2023 [14]. At first glance, it could be argued that with an installation rate of new equipment being 1 in 20 against the existing installed base, the need for retrofittable solutions is less urgent. However, when taking a deeper look, this would be an incorrect assumption.

Firstly, installed base developments differ significantly on a regional level. According to the National Elevator Industry, Inc. (NEII), the US had an installed base of 1.03 million lifts as of 2020, and 40,000 new installations in 2016 [15]. According to the European Lift Association (ELA), Europe had an installed base of 6.22 million lifts and 145,397 new installations as of 2022 [16]. According to the China Elevator Association, China had an installed base of 10.63 million lifts and 1.03 million new installations as of 2023 [17]. Notwithstanding the coherency concerns of these statistics, what is clear is that China's emerging market accounts for the overwhelming majority of newly installed lifts globally.

Secondly, the lifecycle of existing lift equipment is generally tied to the lifecycle of the building it is installed in. Total replacements occur predominantly when a building is emptied and renovated in its entirety, as dependency on the lifts by the building's tenants does not allow prolonged unavailability of the lifts due to capacity handling concerns. A lift, like any electromechanical equipment, is susceptible to wear and tear over time; modernisation intervals of existing lifts are typically between 20-25 years [8]. For example, the ELA states that over half of Europe's lift installed base is currently over 25 years of age [18].

It is therefore clear that to scale digital technologies fast in developed economies such as the US and Europe, the new installation channel is not a feasible main option. Hence, market leaders in the lift industry first focused on retrofittable IoT solutions before developing completely integrated systems. What remains, however, is that both solution types – despite the open innovation models that enabled their creation– are still largely proprietary, causing compatibility and interoperability issues between different manufacturers, models, and ages of lift equipment.

The next section explores opportunities that enable retrofitting of new technologies across the wider lift installed base, provided that the safety chain is not impacted. Earlier references regarding lift dispatching will be further elaborated upon as a practical example of how this could work.

4 RETROFITTING NEW TECHNOLOGY ON EXISTING EQUIPMENT MEANS RESPECTING THE SAFETY CHAIN

As elaborated in section 2.1 "Limited need for innovation", the invention of the safety brake by Elisha Graves Otis in 1853 made lifts safe for use by people for the first time in history. However, in modern lifts, the safety brake is part of a larger system of safety measures whereby the safety gear contact is part of the safety chain. Essentially, one break in the chain and the lift stops until the issue is resolved. For instance, if a sensor detects that a door lock has not engaged, the lift control system prevents motion of the lift, as riding with open doors is extremely dangerous with potentially lethal consequences.

Modern lifts have two basic sets of safety components: electrical and mechanical. The electrical components include the lift control system, sensors, and automation software. As elaborated in section 2.3 “Exclusivity and uniqueness as competitive advantages”, the lift’s control system serves as the proverbial brain of the lift. Subsequently, the sensors monitor the operation and safety-related functions and send such data back to the lift control system. The automation software provides an independent assessment to validate redundant sensor systems and operate the lift in a safe manner. The mechanical components include the lift’s motor, hoist and its brake, overspeed governor, safety brakes, suspension cables, and the buffers at the bottom of the hoistway [19].

The overall system of safety measures is certified by independent authorities or notified bodies and may not be modified without recertification. To avoid potential scalability complications, the design of retrofit-based solutions for existing lifts should be preconditioned to not impact the overall safety system. This can be achieved through operating a separate intelligent platform alongside the lift control system, such as an IoT-gateway device.

Before IoT was introduced as the next generation technology for Remote Monitoring Systems (RMS) for lifts, RMS based on analogue technologies had been around since the late 1980s and had become mainstream in the 1990s [9]. Similarly, these earlier RMS were not part of the overall system of safeties – though in certain cases were designed to interface with them through means of a read-only mode – and essentially operated alongside the lift control system through a wired interface between the two systems. To function as a parallel platform, computer hardware and a communication modem were needed. These devices are typically referred to as “gateways”. As IoT-based use cases advanced, so did the IoT gateways needed to enable them.

Around the turn of the current decade, the first IoT solutions using data directly from the sensor edge (typically referred to as sensor fusion) started to emerge in the lift industry. Unlike previous generations, which take pre-processed diagnostic data from the lift’s control system, sensor fusion takes its data directly at the source from multiple different sensors working in parallel. This richer, more versatile data enabled a more physics-based data science approach towards analysing the health state of the lift. This not only changes the nature of lift monitoring – i.e. by removing the dependency on the lift’s control system, sensor-fusion based IoT platforms are compatible and interoperable across different lift manufacturers, models, and ages – but also the possibilities of what additional insights can be derived from the sensors. For example, the optical sensors of the lift’s light curtains lend themselves to object recognition, i.e. the counting of people and goods going in and out of the lift at every floor. This is where IoT crosses over with lift dispatching.

A modern lift traffic control system – often known as a dispatcher – can collect passenger calls in several ways. Conventional dispatching uses up-and-down buttons on the landing with additional buttons for each floor in the car. Destination control dispatching uses destination input devices on the landings so that passengers can select their required floor when the lift is first called. Hybrid dispatching systems use a combination of landing call buttons, car call buttons and destination input devices [20]. However, all of these methods are limited by inadequate access to information on the actual traffic of lift passengers entering and exiting the lift on each floor.

As the use of buildings evolves, the lifts are expected to accommodate this. In buildings with comparatively low lift utilisation, this is typically also the case. However, those buildings that operate with increased dependency on the lifts can be negatively impacted by evolving needs. For reference, IBM in 2010 surveyed 6,486 office workers in 16 U.S. cities for its Smarter Buildings study and asked them about 10 building-related issues, including waiting times for lifts. IBM tallied the cumulative time that office workers spent waiting for lifts during the past 12 months. Table 3 below shows the complete results [21].

Table 2 Time spent stuck in or waiting for lifts

City	Labour Force -1/10 bls.gov	Adj Elevator Pop	Years Stuck in Lifts	Years Waiting for Lifts
Atlanta, GA	2.664.311	683.800	1,9	4,3
Boston, MA	2.529.949	693.000	1,8	5,4
Chicago, IL	4.832.372	1.213.400	3,2	9,0
Dallas–Fort Worth, TX	3.211.548	743.220	2,4	5,5
Denver, CO	1.347.934	348.300	1,0	2,3
Detroit, MI	2.076.045	387.140	1,1	2,7
Houston, TX	2.881.612	878.460	2,9	6,8
Los Angeles, CA	6.412.821	1.230.240	4,3	8,7
Minneapolis–St. Paul, MN	1.842.087	539.768	0,5	3,1
New York, NY	9.436.392	2.053.548	5,9	16,6
Philadelphia, PN	2.990.914	663.625	1,7	6,0
Phoenix–Prescott, AZ	3.137.804	666.000	0,8	4,1
San Francisco–Oakland–San Jose, CA	2.229.581	691.730	1,4	4,5
Seattle–Tacoma, WA	1.889.840	506.400	1,0	3,2
Tampa–St. Petersburg, FL	1.309.090	263.800	0,6	1,6
Washington. DC–Hagerstown, MD	3.133.022	1.137.570	2,2	7,7
		Totals	**32,7**	**91,5**

Without insights into how the building operates, the typical approach would be to upgrade the equipment such that round-trip times are optimised within the given limitations of the existing building. However, lift modernisations are both invasive to the lift system, disruptive to the riding public while in progress, and costly for the building owner (and ultimately the tenants). The next section will explore the possible practical application of dynamic dispatching on the basis of IoT infrastructure.

5 EXPLORING PRACTICAL APPLICATIONS FROM A TECHNOLOGY VIEWPOINT

An alternative approach to comprehensive lift modernisations that would arguably be less invasive, disruptive, and costly would be to leverage passenger traffic and lift health status data from sensor-fusion-based IoT solutions within the dispatcher, making it more dynamic.

The concept of Sensor Fusion essentially leverages sensory inputs from multiple sensors, which are then processed simultaneously and interpreted wholistically. When properly synthesised, Sensor Fusion helps to reduce uncertainty in machine perception as each sensor comes with its unique pros and cons. Using just one sensor to identify the surrounding environment is not sufficiently reliable, which translates to errors in the produced outcome. Conversely, Sensor Fusion algorithms process all inputs and subsequently produce outcomes with higher accuracy and reliability, even when individual measurements are not always sufficiently reliable [22].

Given the advancements of IoT gateway devices, such dispatching software is no longer dependent on compatibility with the lift's control system hardware. Rather, the dispatching software could run on a platform operating alongside the lift's control system either [A] locally on the IoT-gateway device or [B] centrally on the cloud:

[A] Dispatcher running locally on the IoT-gateway device: this setup envisages both the IoT signal processing and analytics software as well as the dispatcher software to be running on the same IoT-gateway device. By integrating or synchronising both software on the same device, IoT analytics are fed directly into the dispatcher algorithms without external processing layers in between. This way, there is minimal latency and no data transmission costs. Subsequently, the IoT-gateway device should interface directly with the lift's control system as an input device, giving the lift's control system dispatching instructions. However, to run both software on a single IoT-gateway device, hardware with increased performance specifications may be required, which could increase the initial investment in hardware.

[B] Dispatcher running centrally in the cloud: this setup envisages the dispatching interface to run inside a central cloud. For this setup to work, a data feed from the sensors through the IoT-gateway device needs to be transmitted to the dispatcher running in the cloud. Post processing of the data in the cloud, the dispatcher then sends back dispatching instructions to the lift's control system via the IoT-gateway device. In the author's view, there are several downsides to this approach. Firstly, the lift can no longer operate as a self-contained system, as the dispatching logic sits physically removed from the lift system. Second, there are latency considerations concerning the time it takes to communicate between the lift and the cloud. Thirdly, the recurring operational costs of the lift could arguably increase, considering the data transmission and cloud software licence fees.

The following applies to both cases [A] and [B]:

- Based on the solution being retrofittable to existing lift installations, the physical input signal to the lift's control system must be provided by the IoT-gateway device using a common/compatible communication protocol. A wide variety of such protocols is being used across the global lift portfolio; hence, possible cases of incompatibility cannot be ruled out at this point.

- The sensor data gathered can be transmitted to the cloud for data science purposes. For option [A], this capability is not mutually exclusive. For statistical relevance purposes, having access to a larger pool of traffic and dispatching data helps the continued data science development efforts.

- Future improvements to the respective software and algorithms can be installed remotely on the IoT-gateway devices through Over-The-Air (OTA) updates using the IoT backbone infrastructure.

6 CONCLUSION

Innovation can be open or closed depending on the extent to which an organisation needs or chooses to interact with a wider ecosystem. The lift industry is typically characterised by its closed innovation. With every aspect of innovation being conducted in-house, from research and development to implementation, only limited resources and perspectives are available for innovation. Although this hinders an organisation's ability to pursue major innovations and shorten innovation cycles, the base design for lifts remained stable over time; hence, there was no perceived need.

The introduction and comparatively fast-paced development and adoption of IoT started to change this paradigm. The domain of IoT has, since its inception, been thriving on open innovation. Collaboration across wider ecosystems and fast innovation cycles are hallmark characteristics. Subsequently, this necessitated market leaders in the lift industry to accept open innovation in pursuit of their digitalisation strategies.

To open up the lift to retrofitting new technologies, the safety chain must not be compromised. This is achieved by running a platform in parallel alongside the lift's control system, typically an IoT-gateway. As use cases expanded, IoT-gateway technologies needed to advance in tandem to accommodate. With the introduction of sensor fusion, IoT gateways needed to support extensive signal processing. This gave rise to new opportunities with existing sensor data, as these were no longer pre-processed by the lift control system. For instance, the optical sensors of the lift's light curtains enabled object recognition of what passes through the doors.

By incorporating passenger traffic data, the dispatcher becomes dynamic and arguably much more precise, as this data is not available through prior conventional means. By leveraging the IoT-gateway device, the dynamic dispatcher becomes accessible to a wider lift installed base with minimal invasive impact to the system, disruption to the riding public, and cost for tenants.

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