Exploring IoT Applications for Vertical Transportation (VT) to Tackle Challenges in a Modern World

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Keywords: IoT, Lift Maintenance, Covid-19, Air Quality, Net-Zero, Energy Consumption, Lift Monitoring.

Abstract. This paper investigates and proposes applications for emerging, off-the-shelf technologies for vertical transportation (VT) equipment, with a view to tackling some of the changes in social, economic, and environmental requirements of key stakeholders for buildings.

Covid-19 has presented opportunities for IoT technologies to be used within VT systems, to measure air quality and maintain the peace of mind of tenants returning to the office. Sensors have been used to measure a range of in-car, air quality metrics, the analysis of which will be used to recognise how devices can provide stakeholders with accessible, transparent information of the environment in their lifts.

With a drive for energy efficiency, and clients striving to meet their net-zero targets, IoT devices can also be used to monitor energy usage of VT equipment and make strategic decisions to save energy and reduce carbon emissions. This paper also looks to understand if, and how we can measure power used by VT systems with these devices. This, coupled with understanding the changing habits of the average office worker, can be used to think out of the box regarding efficient operation of buildings.

The author's previous research investigated the use of IoT technology to monitor the condition of lifts. Analysis of breakdown data and interviews with key stakeholders were used to demonstrate how this technology could be used for earlier fault diagnosis.

Since the original study, the industry has moved forwards with off-the-shelf and third party IoT systems being trialled by clients and independent suppliers, to support maintenance and repair strategies. Previously, this was only possible with major lift maintenance companies.

1. INTRODUCTION

The expression 'Internet of Things' or 'IoT' is by no means a new concept with the first known 'Smart Device' being created in 1982, where students of Carnegie Mellon University, Pittsburgh, Pennsylvania installed micro switches on a Coca-Cola machine to check the stock levels and temperature of the refrigerated drinks [1]. However, the use of devices to connect VT systems to the internet and collect vast amounts of data is still relatively new, with devices being rolled out by the major lift companies over the past 5-7 years.

In 2019, the author of this paper conducted extensive research into the emergence of this technology. It was found that the introduction of Transmission Control Protocol/Internet Protocol (TCP/IP) v6 [2], along with the advancement of smaller, cheaper, and more powerful chipsets has assisted with the integration of IoT into households and various industries [3]. Heating, ventilation, and air conditioning systems are also using radio frequency identification (RFID) and TCP/IP to connect wirelessly to a network and provide vast amounts of data without human intervention [4].

Kone, Otis, WeMaintain, Thyssen and Schindler have established 'self-developed' systems in the UK and across the world with the aim of producing targeted maintenance regimes to improve reliability, callout response times, transparency, and overall service. The roll out of these systems in the UK has encouraged Clients to push for new, data driven methods of maintenance [5,6,7,8,9].

In 2022 we have seen the emergence of independent, third-party systems being introduced into the market. This equipment is supporting the adoption of IoT technology by the independent lift maintenance providers, with the goal to utilise key data points and provide options for data driven maintenance regimes. It is understood that the key suppliers providing these systems in the UK are Safeline, Thames Valley Controllers, and Kollmorgen with start-up companies in Europe such as Uptime entering the market also.

IoT technology is becoming widely adopted for assisting with maintenance related items, however, the author of this paper has explored different ways in which technology can be used to assist with specific issues relating to:

- Post Covid 19 requirements dictated by tenants' behaviour.
- Ambitious targets for reducing energy usage, carbon emissions and embodied carbon in design.

and,

- Environmental issues seen through prior callout

2. DEVICES

There are various companies that provide off-the-shelf IoT gateway and sensor devices which can be used in a range of applications.

When applying these devices to monitor lift equipment, it is common to encounter the following issues: signal between gateway devices and sensors within lift shafts, signal in motor rooms to allow the gateway devices to connect to the internet and the output of data into user friendly dashboards.

The systems that have been used for the experiments relating to this study are summarised below:

2.1 My Wireless Tag

An American company offering various sensors. This system was used throughout the author's previous study which assisted in understanding what low-cost options were available on the market.

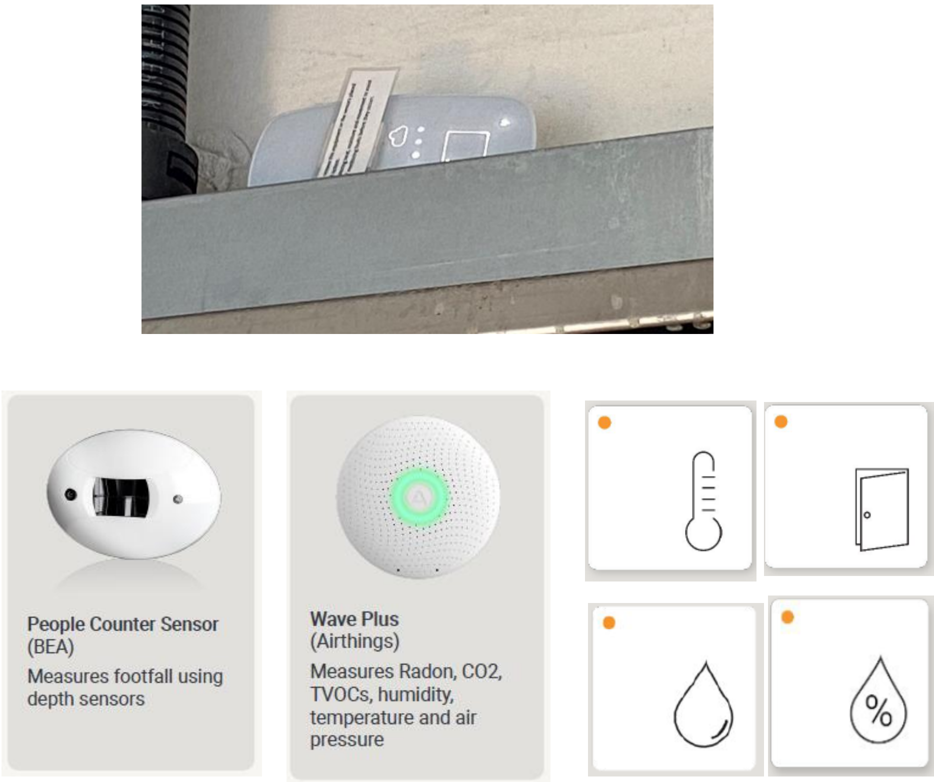
Figures 1a-e My Wireless Tag sensors and gateway device

Whilst this low-cost option proved that off-the-shelf systems are available and can be utilised to assist with earlier diagnosis of callouts, there are various limitations with regards to signal strength, connectivity, dashboard user interface and sensor functionality [10] that have been considered throughout this study.

2.2 InfoGrid

InfoGrid are a venture capitalist funded company who were founded in 2018 and provide various sensors and their own dashboard to present the data in a user-friendly interface.

The devices connect to a sealed gateway unit that has a pre-paid roaming sim card that connects to the strongest data signal available. This removes the issue relating to the complexities of connecting devices to the internet.



Figures 2a-g InfoGrid sensors and gateway device

The available sensors can monitor the following:

- People Counting
- Air Quality
- Temperature
- Door Open/Close
- Moisture/Humidity

These devices are automatically set up to connect direct to the InfoGrid gateway devices which can be located nearby. The devices are simple to set up and provide pre-set graphics to display the data.

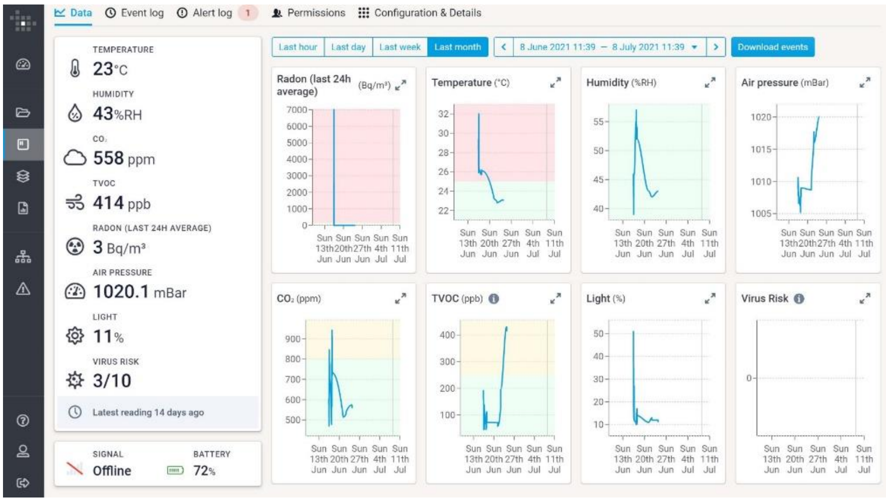


Figure 3 InfoGrid air quality dashboard example

The dashboard provided had some limitations with the functionality, however, the graphics displayed allow the user to customise the view in a way that suits them. A separate gateway device was also required when using the air quality monitoring which increases costs, power, and space requirements.

The people counting device required a 230v power supply and would be located at each landing entrance. Power supplies are not typically provided within close range to lift entrances which made this solution not suitable for lift applications.

There were also constraints with regards to the connectivity of the gateway device when adapting this for a lift shaft. It was estimated that one gateway device would be required at every other floor which would make the system very costly.

The InfoGrid solution was trialled and presented issues that could not be resolved without further significant investment both from the building owner and the author.

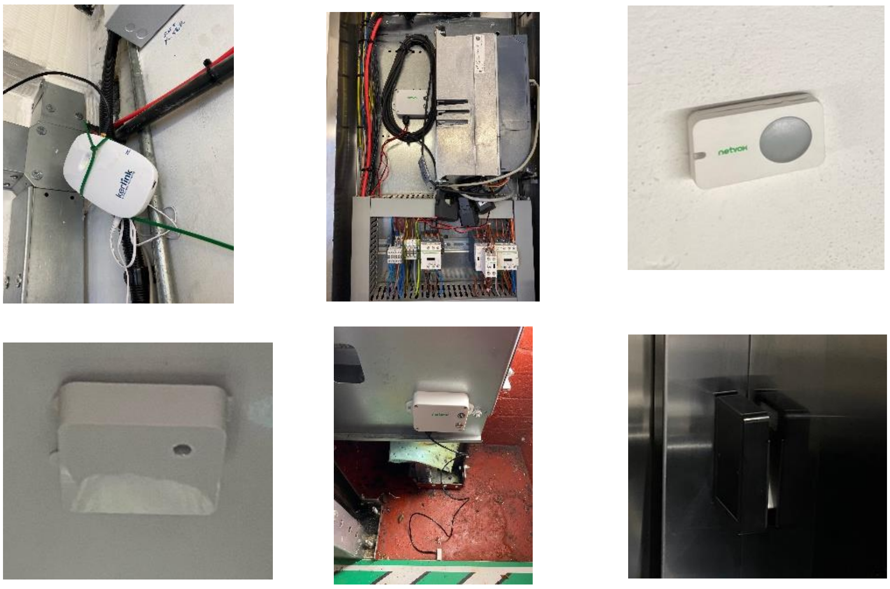
2.3 ALLIoT

Further research into alternative devices that can all be connected via the same gateway led the author to ALLIoT, a company that specialises in providing systems that use low power, long range, wide area network protocols (LoRaWAN technology).

ALLIoT provide a range of different systems and offer consultations to select devices that are most suitable to the application you require. Their services include the gateway devices, sensors, user interfaces (Dashboards) and the data storage all in one package.

Sensors that were available and suitable include:

- Air Quality (Temperature, Humidity & Carbon Dioxide)
- Movement in and out
- Light (measured in LUX)
- 3-Phase energy monitoring
- Water sensor



Figures 4a-f ALLIoT sensors and gateway device

The consultation when designing the system allows for devices to be chosen dependent on the application, it also allowed selection of devices from different manufacturers that all operate on the LoRaWAN network which can connect through the same gateway device.

There were options to use a battery-operated passive infrared (PIR) sensor to measure people movement in and out. This system was suitable as it did not require any infrastructure to use, however, limitations with battery life were a concern.

For the above reasons, the LoRaWAN system was utilised for experiments in this study.

3 OUTCOME

Experiments were undertaken on an 8-Person passenger lift within a commercial building in London.

There are 3 types of dashboards that were available to visualise the data gathered:

- Opensource - Creating dashboard with our own in-house software engineers.
- Pre-Built Public Dashboards - This is recommended for trials due to pricing and functionality.
- Bespoke Platform – Fully tailored to the users' requirements.

The devices were strategically placed around the lift and visualisations of the data were available on the Kheiron dashboard system, a pre-built public dashboard.

If required, the dashboards are interchangeable with all LoRaWAN sensors, so if a dashboard is not the right fit and we swap all data can be transferred.

Figure 5 ALLIoT air quality dashboard example

3.1 Signal

To remove the connectivity issues that had been experienced before, the system purchased included an antenna extension and a field test device which ensured signal was available when placing the sensors in discreet areas of the lift system.

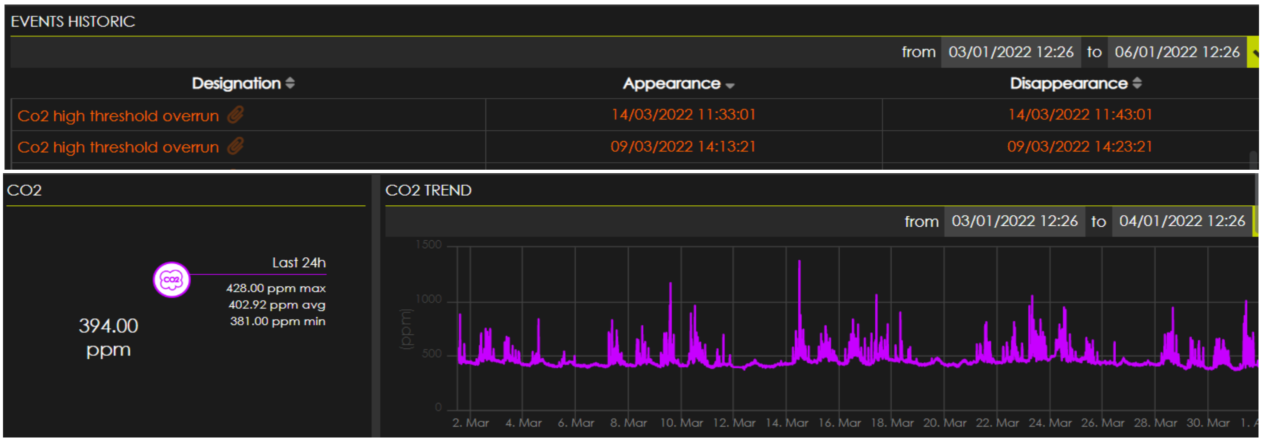
Figures 6a&b ALLIoT field test device and antenna extension

3.2 Air Quality

This device was located within the lift car and shows live data and can assist clients by providing information to tenants regarding the air quality within a lift car following the Covid-19 pandemic.

It was found that there is no standardised measurement for indoor CO2 levels that could be attributed as a ‘safe environment’, however, many indoor air quality (IAQ) professionals have adopted a value of 1000 parts per million (ppm) CO2 as a guideline for acceptable indoor air quality [11]. With this in mind, a high threshold of 1000ppm was set using the Kheiron dashboard settings.

The results show that, on average the lift had C02 measurements between 400-450ppm within the lift car. Over the three-month period between 1st March and 1st June 2022, there were six instances where the C02 levels were measured above the threshold, these were sporadic with regards to the time of day and did not follow any pattern. The values all returned to normal levels when the device took the next measurement (10 minutes later). If the CO2 levels had been persistently above the threshold, a manual or even automatic process could be implemented where the lift doors are opened, or a call placed in to force an air change and reduce any risks of virus spread.



Figures 7a&b Carbon dioxide measurements and above threshold notifications

This information is valuable to the building management companies and business owners, who can show the live data to their tenants and employees to reassure them that using the lift is safe, assisting with workers returning to offices.

This supports the statistic that 58% of employees reported feeling more comfortable if their employers used data to improve the healthiness of their buildings [12].

Measurements for temperature and humidity can also be taken from the same sensor and thresholds set to mitigate risks involved with virus spread along with improving overall passenger comfort.

3.3 PIR Sensor

In the UK, lift systems in commercial buildings are typically designed to guidance set out by the British Council of Offices (BCO) with the most recent guidance published in 2019 [13].

Table 1 BCO Guidance for lift performance in commercial buildings

Scenario	Handling Capacity (% of Population/5 Minutes)	Average Waiting Times (s)	Average Time to Destination (s)
Up-Peak	12%	≤25	≤90
		≤30	≤80
		<25	<110
Two-Way	13%	≤40	~

This sets the standard for lift performance; however, the Covid-19 Pandemic has changed the way in which the average office workers comes to work and employers are becoming increasingly flexible with working from home, staggering start times in the typical office and even trialling a national 4-day week pilot.

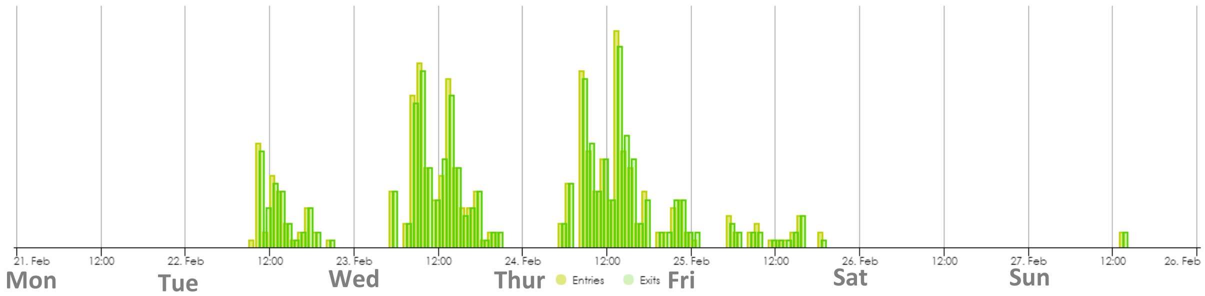


Figure 8 PIR sensor graphs showing people movement over a 1-week period

Table 2 Raw data provided by PIR sensor

Date Time	Entries	Exits
24/02/2022 07:00	0.00	0.00
24/02/2022 08:00	22.00	21.00
24/02/2022 09:00	12.00	13.00
24/02/2022 10:00	7.00	7.00
24/02/2022 11:00	11.00	11.00
24/02/2022 12:00	6.00	6.00
24/02/2022 13:00	27.00	25.00
24/02/2022 14:00	12.00	14.00
24/02/2022 15:00	10.00	11.00
24/02/2022 16:00	3.00	3.00
24/02/2022 17:00	7.00	6.00
24/02/2022 18:00	0.00	0.00

The PIR sensor device is set up to collect data and send back to the server a summary of the number of people entering and exiting the lift over a period of 1 hour. As the BCO recommendations are based on a peak 5-minute period, we can configure the device to take measurements in 5-minute intervals by adjusting the frequency of measurements. Devices can be put on each landing entrance which will help with creating an accurate passenger movement template in a specific building and also produce average waiting times and times to destinations.

This information coupled with surveys of the perception of lift performance from tenants can help understand if office users are willing to accept higher waiting times than the average of 25-30s. In turn, this could have a significant impact on how buildings are developed in the future. With potentially fewer lifts being required, developers and design teams will benefit from lower embodied and operational carbon from the VT system.

Existing buildings can also benefit from lower operational carbon if the data is used to pinpoint downtimes in lift usage and then isolate an appropriate number of lifts. This could also be used in tall buildings to produce energy by making use of Lift Energy Storage Technology (LEST) achievable by automatic transport of bags of sand throughout the building. [14].

3.4 Energy Monitoring

The requirement for measuring and reducing operational carbon is becoming prevalent in an era where the world is setting stringent Net Zero targets. In order to assist in achieving these targets, IoT sensors can be applied to measure the real time energy usage of lift systems.

Figure 9 ALLIoT Energy Meter Dashboard Example

The sensor used was originally measuring power consumption every 15 minutes which was not providing a truly accurate picture of the lift energy usage. The software was updated on the device to measure every 1 minute to improve the accuracy of the measurements. This provided more accuracy but has a significant impact on the battery life of the sensor and also relies on the lift using energy when the measurement takes place.

Other methods of measuring real time energy usage were investigated and established that Eastron meters could be used to provide a constant energy reading rather than a sample taken at certain intervals. Eastron meters can connect to the LoRaWAN network and are also powered by the supply itself, removing the need for batteries.

Figure 10 LoRaWAN Eastron meter

Overall, these sensors will provide accurate measurements that can be used to strategically isolate lifts where necessary.

3.5 Light Sensor

This sensor was applied to the lift system to identify when the shaft lights have been left on. The dashboard provides an indication when the shaft lights are on or off.

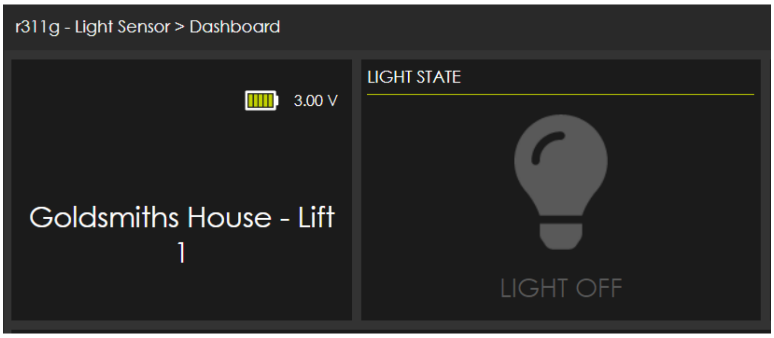


Figure 11 ALLIoT Light sensor dashboard example

With many maintenance regimes being monthly, shaft lighting left on could go unnoticed for some time. This system could notify when this has been left which can prompt someone to attend and turn them off, saving a considerable amount of energy as many lifts do not use energy efficient bulbs/LEDs in the shaft.

3.6 Water Sensor

The water sensor used within this study was placed in the lift pit and aimed to tackle environmental issues relating to flooded lift pits. Flooded lift pits were highlighted as number 12 in the top reasons for callouts in a study undertaken over a 13-month period that analysed 829 total calls across 114 lifts. This issue accounted for 2% of all calls (18 callouts) [10].

Figure 12 ALLIoT water sensor dashboard example

The UK has an average callout rate of over 4 calls per anum due to equipment failure [15]. With this in mind, ingress of fluid in lift shafts can be seen as a significant environmental issue. Various tests are typically required to identify the type of liquid found and to identify the source. An IoT system can be used to assist and highlight where the issues lie to remedy and proactively pump/clean the pits before it requires isolation.

Further development can interface devices with a sump pump to automatically remove the liquid [16].

4 FURTHER WORKS

Further works that the author would like to investigate to enhance the findings of this study are detailed below:

- Trial the LoRaWAN devices on other lift types.

- Update the PIR sensor software to improve the information and compare data with current recommendations for lift performance.
- Test Eastron meters to receive accurate energy readings of VT Systems and pair with other devices to produce strategies where lifts can be isolated to save energy or utilised for energy production in periods of downtime.
- Investigate automatic pit pumping devices that provide notifications to allow visibility of reoccurring problems.

5 CONCLUSION

Lift suppliers are providing IoT systems to assist with maintenance-related items and decrease the number of visits required, reduce the number of callouts, and provide transparency of the service provided to Clients.

Independent suppliers are just starting their IoT journeys with trials on third-party devices. This is being led by Client requirements for targeted maintenance regimes.

There is a gap in the market for the use of these devices to assist with: the design of VT systems, the comfort of passengers in a post covid world, the reduction of embodied and operational carbon emissions to meet global net zero targets and environmental issues regarding pit flooding.

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BIOGRAPHICAL DETAILS

Paul started his career in D2E as a Graduate Engineer. He has been with D2E for 8 years' and has experience largely in commercial and leisure sector, working on multiple portfolios across the UK and providing project assurance for lift replacement and modernisation projects.

In 2020, Paul moved from the Portfolio Team into the Design Team and has since worked on various key developments within D2E, predominantly in London.

Paul has achieved Masters in Lift Engineering at the University of Northampton and works towards his Chartered Engineer status (CEng) with Chartered Institution of Building Services Engineers (CIBSE).