Smarter Buildings: IoT-enhanced Traffic Analysis Embedded in Lift Sensors

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Abstract. From manual people counters to 3D camera imaging, traffic analysis technology has come a long way in the last few decades. There are various technologies and commercial solutions available in the market today for people counting. Smart devices designed for other purposes, such as light curtains and time-of-flight camera sensors for lift door safeguarding, can have the people counting function embedded in them as well. Thanks to IoT, this sensor data can be computed and visualized for numerous applications, including lift usage optimization and predictive maintenance based on wear and tear. However, the potential of traffic data collected by lift sensors goes beyond the lift itself. It provides valuable insights on people flow in the building as a basis for informed maintenance and business decisions, energy saving, and building usage optimization. As a result, the lift is becoming an important part of the smart building ecosystem.

1 INTRODUCTION

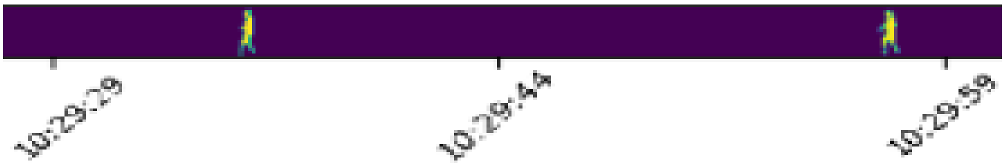
There are several modern technologies that can be applied for people counting, including Wi-Fi tracking, ultrasonic sensors, infrared beams, thermal or time-of-flight cameras, and enhanced CCTV systems. Each technology has certain advantages and disadvantages. The latter include low accuracy (like ultrasonic or thermal sensors) or privacy issues (in case of Wi-Fi tracking and CCTV). This paper focuses on two people counting methods that can be successfully applied in lifts as well as entrance automation systems - light curtain infrared beams and 3D ToF (time-of-flight) camera sensors. First, the data acquisition process is discussed, followed by possible visualizations of processed information. In the last part, the value of this data for end users in the lift business as well as in the wider context of a smart building ecosystem is explored.

2 DATA ACQUISITION AND OUTPUT

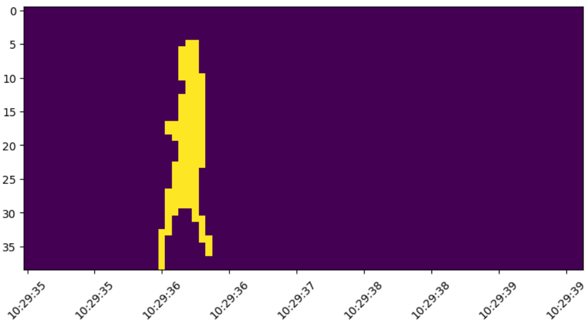
2.1 Light curtain

Figure 1 Image of a light curtain during an automatic door closing sequence

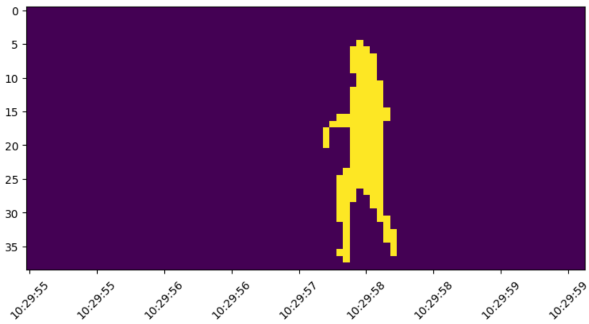
When a person passes through the beams of the light curtain, an image is captured. Below, we will analyse examples of one person and two people using a lift.



(a) Scanned image of one person entering and exiting a lift over time



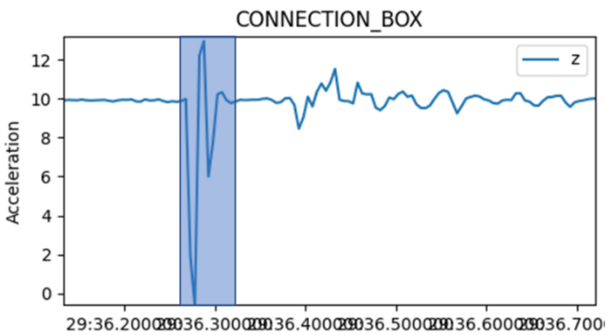
(b) Scanned image of entering



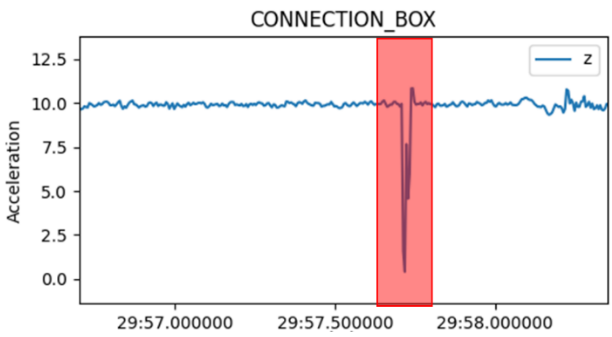
(c) Scanned image of exiting

Figure 2 Light curtain scanned image

As shown in Figure 2, the scanned image from the light curtain can describe the shape of a person but cannot indicate the walking direction, which makes it difficult to count people in the lift. Additional information (shown in Figure 3) is provided by an accelerometer, which is installed in the cabin. It indicates the cabin movement when people are entering and exiting the lift.



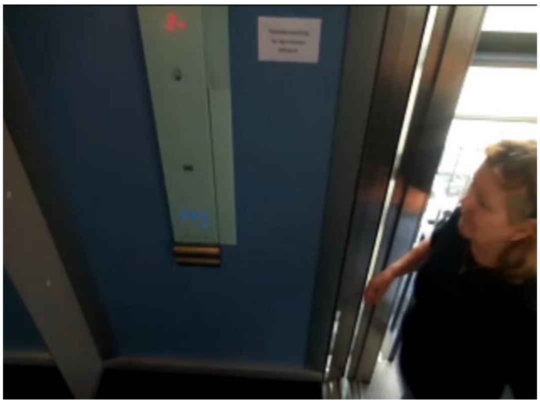
(a) Accelerometer during entering



(b) Accelerometer during exiting

Figure 3 Accelerometer data of the event showed in Figure 2

As shown in Figure 3, the cabin is quite stable before and during the ride. A significant movement is captured during entering and exiting the lift. Moreover, the behaviour of entering and exiting are different, which makes it possible to count people traffic with this solution.



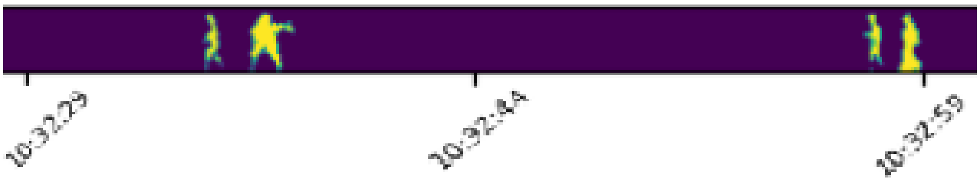
(a) Video frame during entering

(b) Video frame during exiting

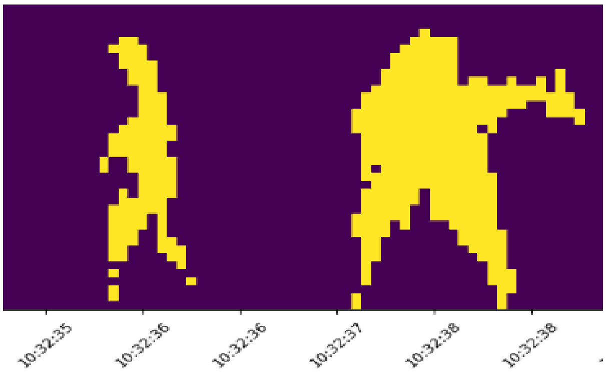
Figure 4 RGB video camera view of the event shown in Figure 2

Figure 4 shows an example frame of the mentioned entering and exiting event in Figures 2 and 3 from another RGB video camera, which is not included in this system.

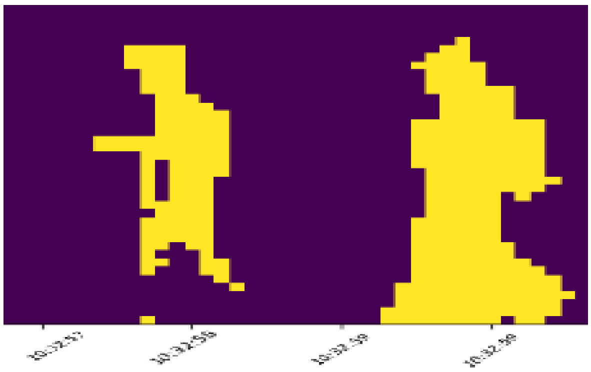
In the second example, two people are using a lift.



(a) Scanned image of two persons entering & exiting a lift over time



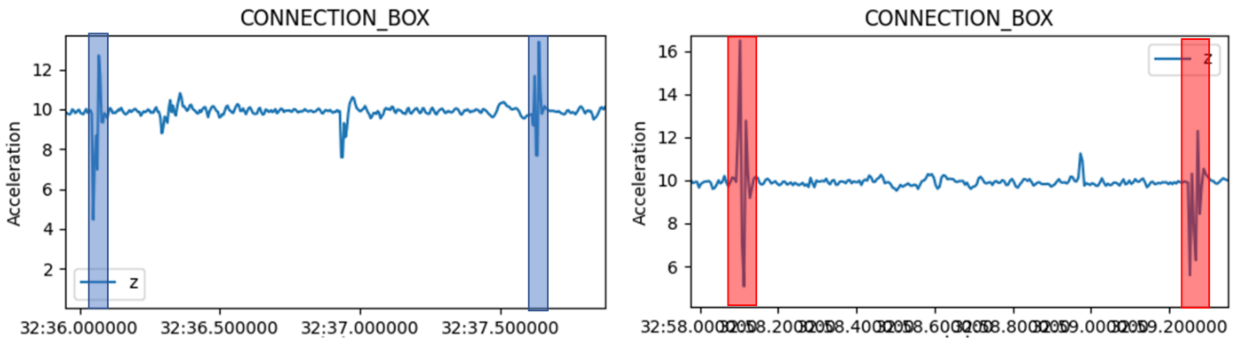
(b) Scanned image of entering



(c) Scanned image of exiting

Figure 5 Light curtain scanned image

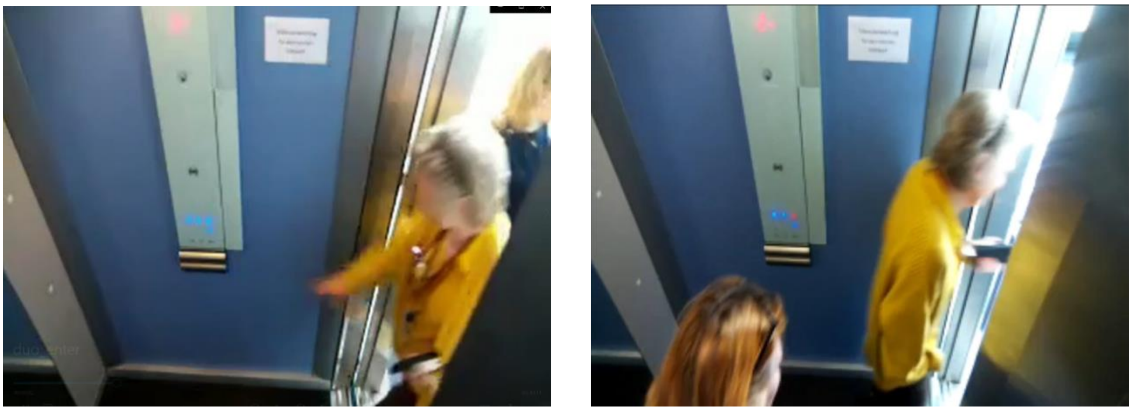
Figure 5 shows the scanned image from the light curtain of two persons entering and exiting the lift. Same as shown in Figure 2, the human shapes are clear, but the walking direction is difficult to tell.



(a) Accelerometer during entering **(b) Accelerometer during exiting**

Figure 6 Accelerometer data of the event showed in Figure 5

As shown in Figure 6, the cabin is quite stable before and during the ride. A significant movement was captured during the entering and exiting of the lift for each person separately.



(a) Video frame during entering **(b) Video frame during exiting**

Figure 7 RGB video camera view of the event shown in Figure 5

Figure 7 shows an example frame of mentioned entering and exiting events in Figures 5 and 6 from another RGB video camera.

2.2 3D image in front of the cabin

The 2019 North American Elevator Safety Code (ANSI A17.1-2019 / CSA B44-19) defines new requirements for the means of detecting persons or objects between the doors (2D) or approaching the lift (3D). A 2D light curtain combined with a 3D ToF (time-of-flight) sensor and a controller can fulfil all these code requirements (Fig. 4 and 5).

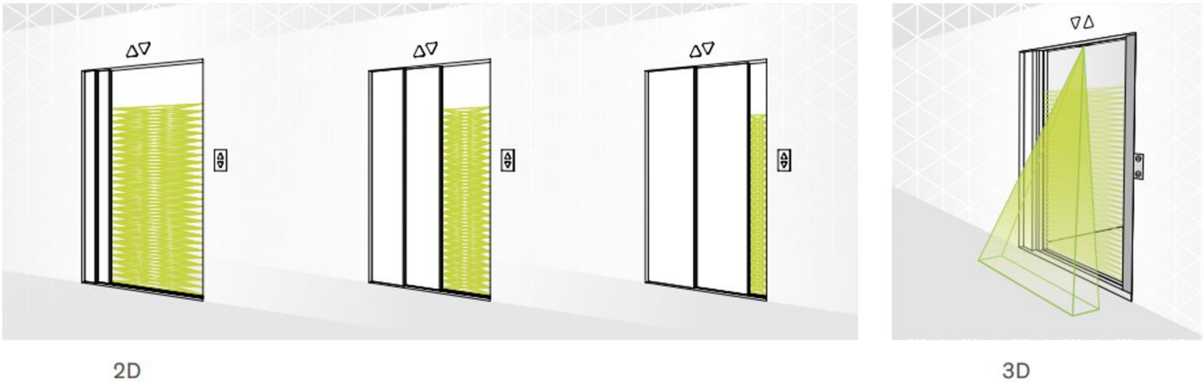


Figure 8 2D light curtain combined with a 3D time-of-flight sensor

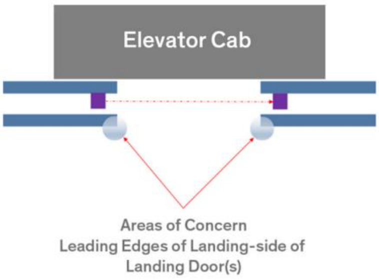


Figure 9 The detection areas of the system elements represented by red lines

When a person passes through the areas of concern, an intensity image is captured. Here is an example (shown in Figure 10) of a captured intensity image and its corresponding people detection results.

(a) No object detection

(b) One person is detected during entering the lift

(c) One person is detected during exiting the lift

Figure 10 Intensity image through a 3D ToF sensor and its object detection results

In Figure 10, the left side is an intensity map captured by a 3D ToF sensor, while the right side is an indicator of the object detection results. Blue indicates no detection of the object, and green indicates detection of the object. Compared to a light curtain solution, a 3D sensor can provide a clearer image. The walking directions are possible to calculate from its intensity images.

2.3 3D image in the lift cabin

There are also 3D ToF sensors that offer full door protection, without the need for an additional light curtain (Fig. 11). The figures below show an example with two people using the lift.

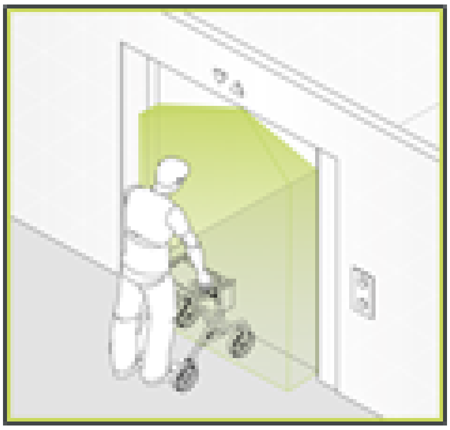


Figure 11 Full door area safeguarding with a 3D ToF sensor

Below, an example with two people using the lift is analysed.

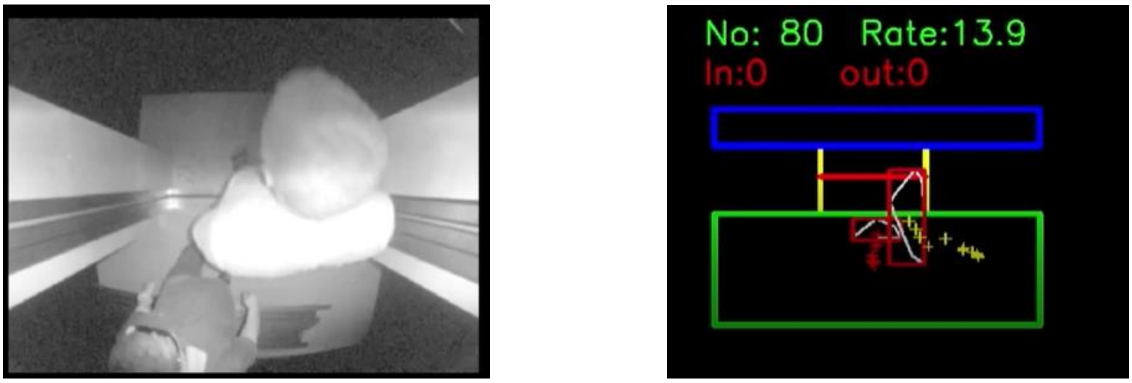


Figure 12 Two persons entering the lift

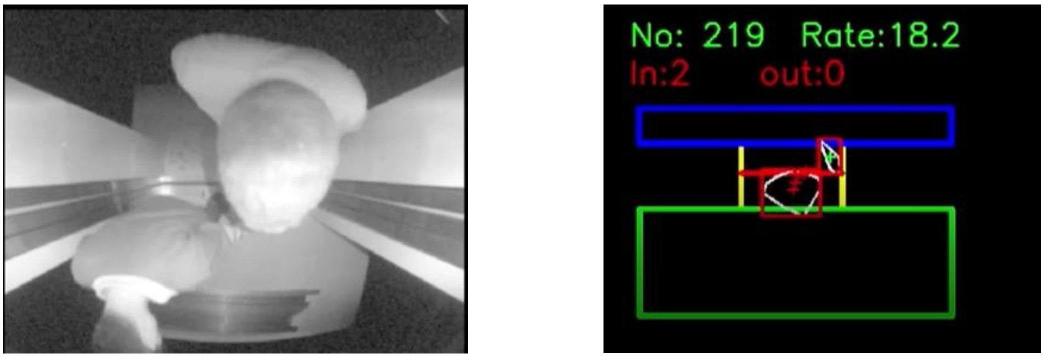


Figure 13 Two persons exiting the lift

Figure 12 shows an intensity image from a high-resolution 3D ToF sensor mounted in the transom on the left, and its related calculated results from input video frames on the right. The blue rectangle indicates the inside region of the lift, the yellow rectangle indicates the door region, and the green rectangle indicates the outside region of the lift. Additionally, red rectangles indicate detected objects and their tracking trajectories. The results show the detection of a person and tracking of a detected person. Counting entering and exiting people can be done in an accurate way.

2.4 Traffic visualization

This subsection illustrates some possible ways to visualize people counting and lift traffic overviews based on data acquired from technologies embedded in lift sensors.

Figure 14 Heatmap of the utilisation of a 20-storey lift over a 24-hour period

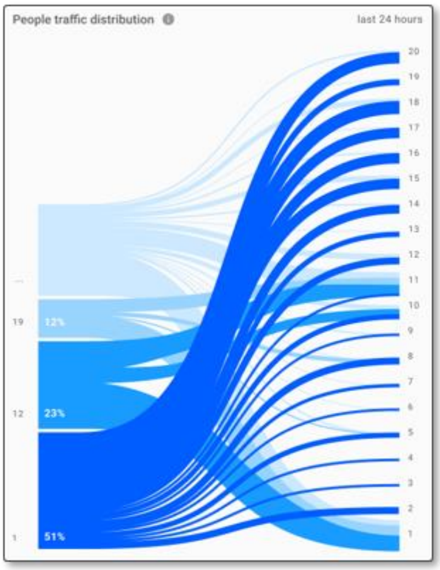


Figure 15 Distribution of passenger traffic in a 20-storey lift; on the left the departure floor, on the right the arrival floor

3 DATA VALUE FOR THE END USER

3.1 Data value in the lift business

People flow analysis has a significant impact on lift design. Peters, Smith and Evans point out that the design process is all too often based on historical data and assumptions, despite a visible change in traffic patterns in modern office buildings [1]. Real-time traffic data contributes to increasing dispatch algorithm efficiency and lift performance. This applies not only to new lift installations but also to lift modernization projects. People flow analysis helps to make informed decisions on the scope of modernization, such as replacing a conventional control system with a destination control system (DCS) to avoid long waiting times during peak times [2].

Ultimately, the main benefit lies in improving the individual experience of each lift passenger. In today's fast-moving world, sacrificing many minutes of a half-hour lunch break just to wait for a lift becomes a real nuisance, especially when it turns out to be overcrowded after it has finally arrived. Smart, data-driven lift traffic management increases end-user satisfaction by helping them save their most precious resource – time.

Moreover, the people counting function can serve to increase passenger safety where the number of passengers using the lift simultaneously needs to be controlled, for instance, to prevent lift overload. Another interesting potential use case came about during the COVID-19 pandemic, when, following the rules of social distancing, only one person at a time was allowed to use the lift. More importantly, a smart lift system knows that passengers are trapped inside a blocked lift before the passengers themselves do anything about it. Process improvements lead to faster rescue and might even save lives [3].

3.2 Data value in smart buildings

The potential of traffic data collected by lift sensors goes beyond the lift itself. Combined with data from other sources and visualised in reports and dashboards, this data turns into useful information for facility managers and building owners, improving the people flow and energy management in the building. The collected information becomes a piece of the smart building puzzle, contributing to a more complete picture of people flow.

Figure 16 Various sensors applied in a building (Source: CEDES [4])

Understanding modern building usage trends is crucial for optimization. Most recently, the COVID-19 pandemic has changed the way we work, shop, or eat out, and how much time we spend at home and in the office. According to a report published by Microsoft in 2021 [5], flexible working models such as remote or hybrid work are in high demand from the workforce. Consequently, building management needs to be adapted to this new reality, ensuring optimal use of resources such as energy and space. Rather than relying on past assumptions, building managers can base their decisions on near real-time people flow data.

Reducing building energy consumption while maintaining the comfort level of visitors and tenants remains a major challenge, especially since it depends on individual behaviour to a large extent. Data transparency on energy usage can lead to a change in behaviour towards conscious energy saving. In addition, many building-wide processes can be automated through occupancy-based control, i.e., determining the indoor environment settings based on the number of people in the room. Depending on the current number of occupants, the heating, ventilation, air conditioning (HVAC) and lighting systems can be regulated. This approach requires an efficient people-counting method. Zhang et al. (2022) compare various types of sensing technologies for this application [6].

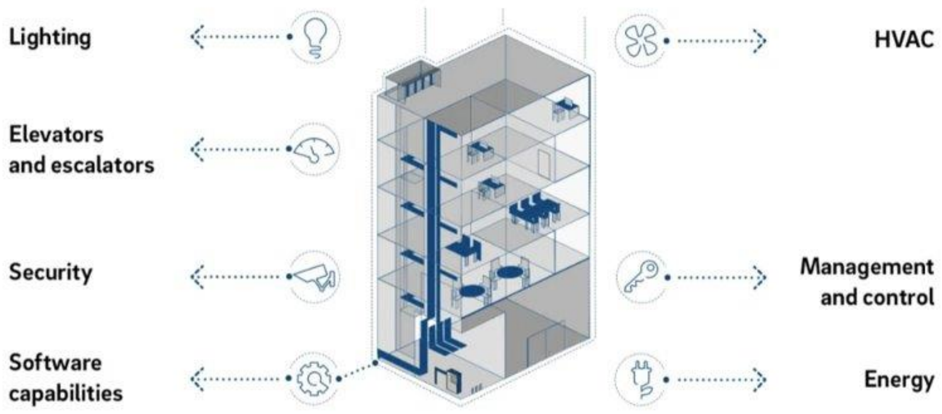


Figure 17 Key sectors in building automation (Source: Roland Berger, July 2020 [7])

Of course, precise occupancy information is relevant not only for comfort but also for safety. Similarly to the lift overload situation, maximum occupancy limits need to be observed in buildings, e.g. under fire safety regulations or social distancing rules [8]. Optimizing people flow with regard to safety is also of utmost importance in large event venues, during concerts, sporting events, etc.

Finally, people flow analysis is a basis for business decisions and can serve to prove the commercial value of real estate, justifying the rent or sales price of a particular property or a space within a property, such as store space in a shopping mall, in an area with particularly high traffic. Another good example is a convention centre, where organisers can share traffic data with exhibitors, for them to calculate their return on investment of a specific trade show booth.

4 CONCLUSION

Data is at the heart of any digital transformation. The more data sources on people flow that become available, the more applications for sustainable, safe, and life-enhancing buildings and cities can be discovered in the future. Vertical transportation is also an important part of this smart ecosystem. Lift sensors such as light curtains and 3D time-of-flight sensors already collect valuable data – feeding them into an IoT platform along with information obtained from other smart building systems provides a complete and transparent picture of how we use our buildings, as well as insights on how to optimise this usage.

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BIOGRAPHICAL DETAILS

Michele Guidotti – a graduate of ETH Zürich and the MIT Sloan School of Management, an IoT expert with extensive experience in the lift industry (Schindler Group), currently Senior Product Manager at CEDES working on an IoT business case.